Circularity Assessment Protocol
Athens, Georgia, USA

University of Georgia
Circularity Informatics Lab
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New Materials Institute
UNIVERSITY OF GEORGIA

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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Location:
New Materials Institute
University of Georgia
Athens, GA
US 30602
www.circularityinformatics.org

Contact:
Dr. Jenna Jambeck
jjambeck@uga.edu

Authors:
Amy Brooks (CIL), Taylor Maddalene (CIL), Lindsay Coats (CIL), Rachel Johnson (CIL), Kaylee Tam (CIL), Kathryn Youngblood (CIL), Jenna Jambeck (CIL)

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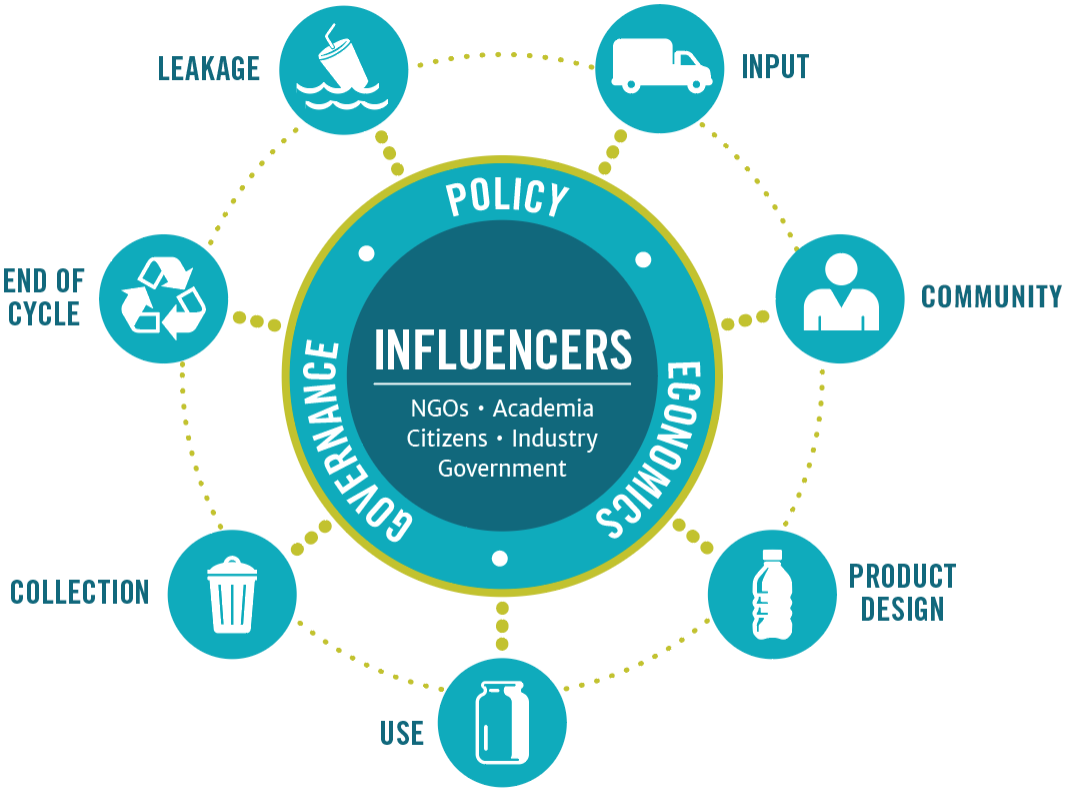
Executive Summary

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 April and May 2022 (litter transects) and stores and restaurants during the summer (2022) store products a team from the Circularity Informatics Lab conducted fieldwork in the city of Athens, Georgia with support from the city's local government. This report was made possible through funding by the Walmart Foundation. Fieldwork included product and packaging assessments in stores across the city; key stakeholder interviews with government, industry, and non-profit organizations; material type characterizations for consumer plastic items; cost analysis of reusable products and alternatives to plastic available in the city; visual audits of recycling contamination; identification of public waste and recycling

collection bins; and litter transects in three categories of population. Key findings from each spoke are summarized in the table below.

Key Findings

INPUT

Findings: Georgia ranks 10th nationally in plastics industry employment, with nearly 1.2 million people employed in plastic-dependent industries and about 33,000 directly employed in the plastics sector. Athens specifically hosts several plastics-based organizations, including plastic producers, manufacturers, distributors, and wholesalers such as the Athens Coca-Cola Bottling Company. Although there is a heavy presence of the plastic industry, there is no local Extended Producer Responsibility (EPR) legislation in Athens or statewide. The product survey revealed that many of the products sold in Athens may have domestic sources, with several producers based in Athens, other Georgia localities, as well as neighboring states. Those goods that are internationally sourced were primarily candy, while beverages and chips tended to be sourced from domestic suppliers and producers.

Opportunities:

- Given the domestic producers and manufacturers of consumer goods sold in Athens, there may be opportunities for partnerships in potential EPR initiatives, as well as local EPR initiatives that take advantage of local industries such as sports and entertainment as well as restaurants and retail.
- Athens should leverage its proximity to several producers in Georgia and neighboring states to foster partnerships for more sustainable practices.
- The city should explore potential business incentives or support for local producers and manufacturing companies like Echo Base that are working on more sustainable alternatives to traditional plastics.

COMMUNITY

Findings: Semi-structured interviews with key stakeholders, including representatives from local recycling centers, city government, and academic institutions, provided insights into local perceptions and behaviors. Findings indicate a core group of engaged residents practicing proper waste management, counterbalanced by widespread confusion about recycling practices. This confusion is exacerbated by conflicting information sources and unclear product labeling, contributing to high contamination rates in collected recyclables. Socioeconomic disparities in sustainable waste practices were observed, with higher participation rates among upper-middle-class residents. Post-COVID issues, including labor shortages and supply chain disruptions, have compounded existing challenges such

as budget constraints and public reluctance to fund waste management services. Regional attitudes in the Southeast present additional barriers to progressive waste management policies. Despite these obstacles, the waste management system demonstrates adaptability, with ongoing efforts to improve community engagement and education.

Opportunities:

- While Athens has successfully generated targeted interventions and public communications, the city could enhance public education campaigns by focusing on accessibility of sustainable practices across socioeconomic groups.
- The city has also proactively investigated effectiveness of existing waste management efforts but might benefit from further investigation into the effectiveness of existing programs.

PRODUCT DESIGN

Findings: Multilayer film and PET dominated packaging materials found in the Athens product surveys among convenience and grocery stores. Beverage packaging primarily utilizes PET (98%), while chip packaging predominantly employs multilayer film (97%). Candy packaging exhibits the highest material diversity. Additionally, plastic dominated food packaging associated with restaurants and food vendors, with the material constituting 68% of takeaway items such as to-go containers, cups, utensils, and straws. Given the prevalence of restaurants and bars in Athens, the prevalence of difficult-to-recycle plastics, particularly in takeaway food containers and convenience items, presents a substantial challenge for municipal waste management systems.

Opportunities:

- The city may not have robust leverage with major manufacturers regarding product design, however, ACC solid waste representatives could work with local manufacturers to identify redesign opportunities that use more recyclable or compostable materials.
- The city should continue emphasizing consumer education on different types of packaging materials and their proper disposal.

USE

Findings: Athens generates an estimated 6.92 lb (3.12 kg) of waste per capita daily, substantially exceeding the U.S. national average of 4.9 lb (2.21 kg) and the global average of 1.6 lb (0.74 kg). Notably, plastics constitute 18-19% of ACC's waste stream, compared to 12% nationally and globally. This disproportionate plastic waste generation in Athens emphasizes the need for targeted reduction strategies. Product surveys indicated some availability of reusable and alternative options for plastics, particularly in food service and retail sectors. However, coupled with the high plastic waste generation, there is critical need for initiatives promoting reuse and refill practices among local businesses. The research also identified a lack of Extended Producer Responsibility (EPR) legislation at the state level, which could potentially drive product design improvements and end-of-life management.

Opportunities:

- The city could partner with large consumer groups in the area (e.g., UGA or the ACC public school system, etc.) to select product alternatives that have viable waste management routes, especially for takeaway food packaging.

COLLECTION

Findings: There is an extensive waste collection program in Athens encompassing curbside pickup for landfill, recyclable, and compostable waste, as well as strategically located drop-off centers. Notably, ACC's Recovered Materials Processing Facility (RMPF) and Center for Hard to Recycle Materials (CHaRM) collectively divert an estimated 19,100 tons annually from landfills. A distinguishing feature of ACC's recycling program is its acceptance of all seven plastic types, surpassing many municipalities in scope. However, data indicates significant contamination issues, with 27% of received waste at the RMPF showing contamination levels of 11% or higher in November 2022.

Opportunities:

- While a wide range of materials are collected through single stream recycling in Athens, the city has historically experienced high rates of contamination. The city should continue examining outlets for improving contamination rates, including limiting or simplifying which materials are accepted at the facility.
- There are some disparities in waste collection services between urban and rural areas of the county, with Athens' Urban Service District seeing more comprehensive public collection services. While the more rural General Service District can opt to hire private waste haulers or pay-as-you-throw schemes, the lack of consistent collection infrastructure may contribute to

illegal dumping. Well-monitored drop off centers in more rural areas of the community, as well as targeted events in under-serviced areas may help to encourage waste collection in those areas if comprehensive collection remains unfeasible.

- The city should continue a robust examination of food waste collection and invest in developing a system to continue meeting landfill diversion rates while also generating useful composted products.

END OF CYCLE

Findings: Most waste in Athens is treated locally via landfilling, with around 23,000 tons deposited in the ACC Landfill annually. Another 18,000 tons of waste is processed at the city's Recovered Materials Processing Facility, which sorts over 30 different materials. Additionally, the ACC CHaRM processes difficult to recycle goods, particularly scrap metal, film plastic, and electronics. The city is a leader in Georgia advancing industrial composting capabilities and hosts a facility that converts food waste and leaf & limb debris to various applications.

Opportunities:

- Landfilling is a significant component of Athens' waste management capabilities, but the city has a track record of meeting ambitious diversion rates. Athens should continue aiming for high diversion rates, but also consider how the complexity of waste reduction and segregation can contribute to contamination in other waste treatment streams.
- Continue advancing the composting capabilities of the city, including education efforts for both individual consumers as well as businesses and retailers that are electing to use and/or provide alternatives to plastics.

LEAKAGE

Findings: Nearly 4,200 litter items were documented across 27 transects, with plastic comprising 71% of all litter. Cigarettes and plastic foam fragments were the most common items, making up 35% of the total count. Litter composition and density varied across population density areas, with an average litter density of 1.2 items per square meter citywide. While Athens has a lower average litter density compared to larger U.S. cities, illegal dumping remains a significant issue, costing the city nearly $860,000 in 2017 for prevention, cleanup, and enforcement efforts. Evidence of microplastics has been documented in wastewater treatment discharge outlets in the community as well.

Opportunities:

- Collecting data and monitoring trends over time can provide invaluable insight into waste patterns, community needs, and effectiveness of waste

management programs. With continued litter monitoring, the city may be able to identify innovative ways to prevent and abate litter in the community.
- Cigarettes were the most common item, which lends an advantage in being able to identify intervention points such as education campaigns, litter violation enforcement, and investment in cigarette collection receptacles in the city.
- Continuing to host recurring clean up and drop off events may help to encourage legal deposition of hard to recycle items that are often illegally abandoned.

Strengths

- Athens has a well-developed plastic manufacturing and production industry that is situated in a state that contributes substantially to plastic production. There are opportunities for high levels of engagement with local businesses, creating an outlet for improved business partnerships and collaboration with respect to product sourcing as well as material selection and design.
- There may be growing local support for a regulatory action targeting plastic goods, as demonstrated by several local examples throughout Georgia and Athens' progressive environmental activities.
- There are several local initiatives targeting waste reduction and improved disposal practices, which presents an opportunity for coupled approaches that advance education efforts.
- Athens has demonstrated a strong commitment to crafting meaningful education campaigns ranging from waste reduction, disposal behavior, and litter prevention while also dedicating efforts to developing robust waste collection and treatment infrastructure.
- There is strong waste collection coverage across various waste streams and demonstrates partnership between public and private entities involved in the community's waste collection and treatment infrastructure.
- The advanced recycling and composting systems in Athens provides the foundation for managing alternative materials to traditional plastics as more are introduced to the market and various businesses adopt them.
- Although cigarettes are the main litter offender in Athens, they provide a clear target for reducing and preventing plastic pollution through education and enforcement efforts including tobacco use behaviors, tobacco-specific waste receptacles, and targeted clean ups as cigarettes are relatively easy to identify. Further, as rates of tobacco usage decrease nationally, cigarette losses may reduce in the future.

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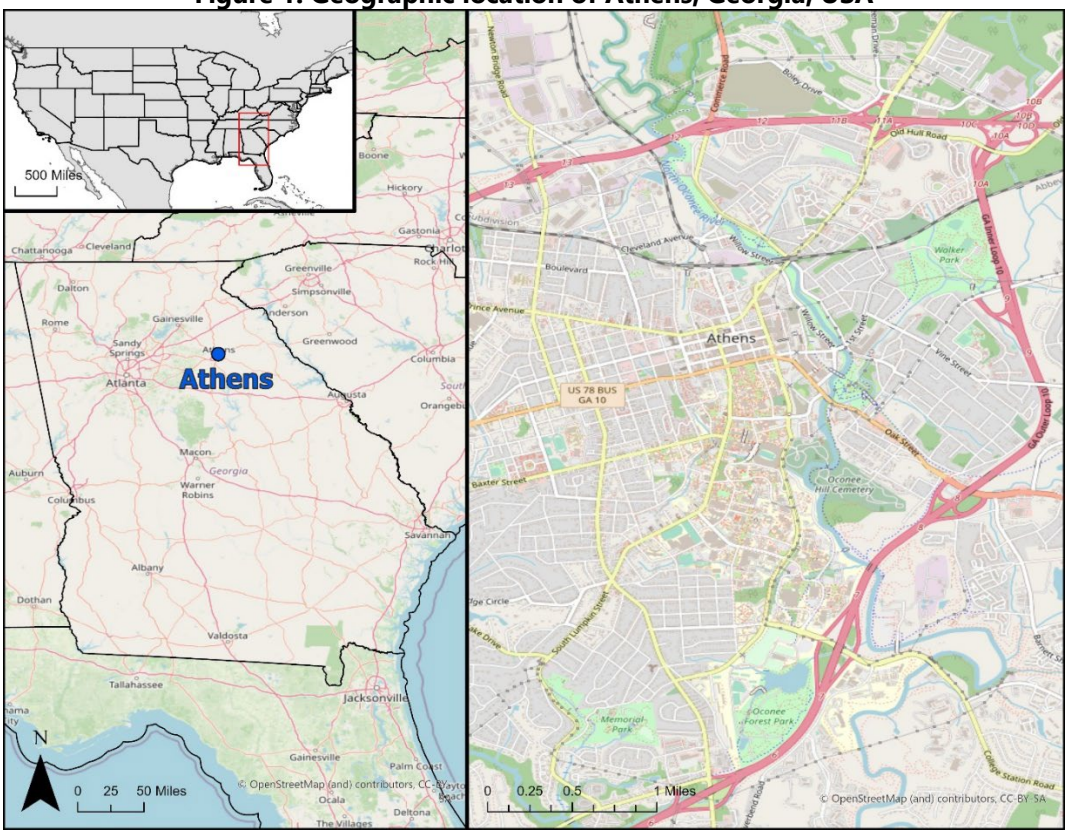
Introduction

Athens, Georgia is a vibrant city located in northeastern Georgia, about 70 miles east of Atlanta. Because of efforts in the 1980s to reduce challenges with financing local government activities and workload, the city consolidated with the surrounding Clarke County in 1991 to become a unified government Athens-Clarke County (ACC) [1]. Founded in 1801 as the site of the University of Georgia (UGA), the city now is home to almost 130,000 residents as of 2024 [2], making Athens the sixth most populous city in the state of Georgia after Atlanta, Augusta, Columbus, Macon, and Savannah.

At 122 square miles, ACC is the smallest county in the state in terms of area. The landscape in Athens is relatively hilly and has a wide range of land uses from residential, commercial, industrial, and agricultural uses. The city lies at the confluence of the Middle and North Oconee Rivers, which ultimately feed into the Altamaha watershed, one of the largest river basins in the eastern US. With 425 miles of streams and river systems within the county, it is imperative that solid waste is disposed of correctly by citizens and businesses, collected and managed properly by the MSW system and that litter prevention is in place via education, advocacy groups, and volunteers.

Athens is where the composting pilot took place for this larger body of work and so this pilot was informed by results from this CAP and working with other CAP cities, namely, Minneapolis, to mentor Athens and provide advice for the pilot program.

Figure 1: Geographic location of Athens, Georgia, USA



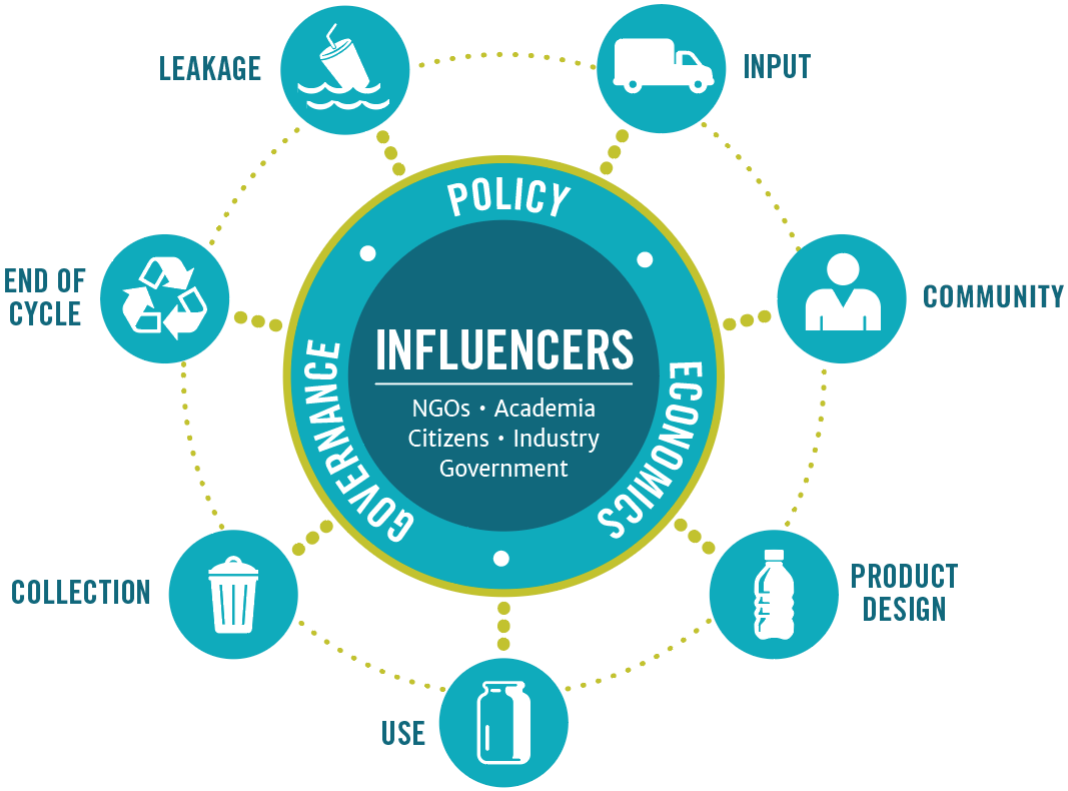
Athens has grown into a dynamic cultural hub due to its diverse local economy housing major industries including education, healthcare, and manufacturing, as well as tourism, particularly for events related to UGA and the city's thriving music and arts scene. Athens is known for its vibrant downtown area, which features art galleries, shops, and acclaimed restaurants. The presence of UGA, the state's flagship institution, contributes significantly to the city's intellectual and cultural atmosphere as well as its economy and infrastructure demands. Despite great economic activity across these local sectors, income disparity is an ongoing challenge, with 27% of the population living in poverty. Additionally, the median household income is $47,800, compared to $77,700 in the nearby state capital, Atlanta.

While there is evidence that income is correlated with waste generation rates [3], Athens has a somewhat high per capita waste generation rate. Based on estimates from 2003, Athens residents are estimated to produce 5.98 lbs (2.71 kg), which is higher than the nationwide waste generation rate 2.24 kilograms of waste per person per day and more than twice that of the global per capita rate of 0.74 kg per day [2, 4]. To process this waste, the city has a robust residential and commercial waste collection system for non-recyclable, recyclable, and organic waste. To meet the waste treatment needs, the city operates a landfill, municipal recycling facility, Center for Hard to Recycle Materials (ChaRM), and a commercial composting facility. Despite effective solid waste management in the community, litter and illegal dumping remain a challenge.

The Circularity Informatics Lab (CIL) at the University of Georgia (UGA) developed the Circularity Assessment Protocol (CAP) in 2018, which is a standardized assessment protocol used to collect community-level data to inform decision-makers (Figure 2). 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 2: Circularity Assessment Protocol (CAP) hub-and-spoke model.

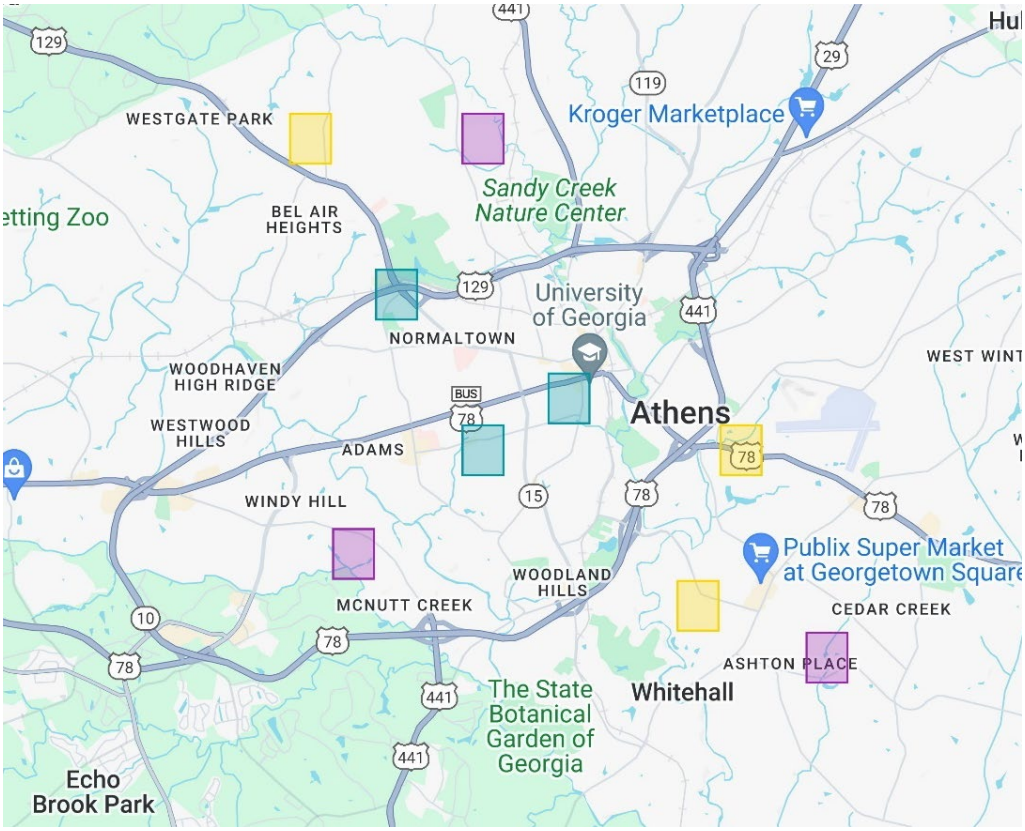


In August - September of 2022, a team from the Circularity Informatics Lab conducted fieldwork in Athens, Georgia. This CAP was conducted with funding support from the Walmart Foundation. The CAP report is split into the following sections, which include results and discussion of each: Input, Community, 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 Athens, Georgia.

Sampling Strategy

To randomly sample various locations in a city, the CAP typically identifies a 10 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 3). Ambient population count can be described as "where people go" and "societal activity" — it is not population density of where people live. These three areas often provide 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, nine sites were surveyed, three in each of the high, mid and low population count tertiles.

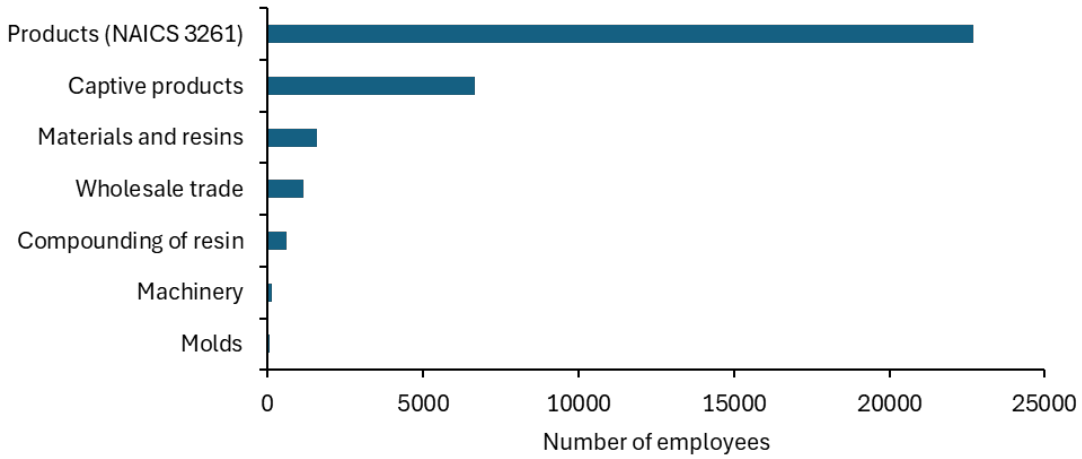
Figure 3: Population tertiles and survey sites in Athens. (Blue = high population; Yellow = middle population; Purple = low population)



Input

The US and its partner countries in the North American Free Trade Agreement (NAFTA) contributed to 19% of the world's plastic production, having produced about 70 million metric tons of plastic products in 2020. According to the Plastics Industry Association [5], nearly 1.2 million people in the state of Georgia are employed are employed in plastic-dependent industries, leading to ranking as 10th in plastics industry employment nationally. Almost 33,000 Georgians are directly employed in the plastics industry, with 70% in industry segments dedicated to plastic products (NAICS 3261), followed by captive plastic products (i.e., components of products; 20%), and materials and resins (4.8%; see Figure 4).

Figure 4: Employment by plastic industry segment in the state of Georgia (Source: Plastics Industry Association [5])



Additionally, employment of plastic-dependent industries in Georgia is primarily concentrated in sub-industries of healthcare, food service, and construction [5]. According to the ACC Chamber of Commerce, there are several plastics-based businesses in the city, particularly plastic producers, manufacturers, distributors, and wholesalers of beverage packaging, miscellaneous goods and décor, packaging production, and textiles as described in the examples below.

- **Athens Coca-Cola Bottling Company:** This company is part of Coca-Cola UNITED, which engages in production, marketing, and sales and distribution of several Coca-Cola brand beverages. While little information is publicly available, this operation likely plays a role in production and distribution of beverage bottles or cans, which likely comprise aluminum, glass, or combinations of polyethylene terephthalate (PET), polypropylene (PP), or high-density polyethylene (HDPE), as well as adhesive plastic labels. Notably, PET bottles and caps are considered relatively high value plastics because of their recyclability, which can lead to effective collection. (https://cocacolaunited.com/locations/athens/)
- **Burton + BURTON:** Wholesale supplier of gift products and decorative accessories based in the City of Bogart, on the west side of Athens-Clarke County. They supply over 13,00 products including balloons and balloon supplies, gifts, plush toys, containers and seasonal decorations. In

2022, the company held a charity event in ACC showcasing over 400,000 balloons from various producers and designers, with another similar event planned for 2027. While it is unknown if and how the company's balloons enter the waste stream or are lost to the local environment, they are typically made of natural or synthetic latex or foil-coated polyethylene or nylon [6]. Such formats of plastic are difficult to recycle [7], and when released (whether intentionally or unintentionally—to the environment they can pose significant risk to wildlife [8]. (https://www.burtonandburton.com/about/default.aspx)

- **Echo Base:** Echo Base is a company that revolutionizes the vinyl industry by connecting creators with reliable and transparent vinyl manufacturers. Their platform is designed to streamline the process of vinyl record production, making it faster and more cost-effective compared to traditional brokers. Echo Base meticulously selects top-tier manufacturers to ensure unparalleled quality in every project. They offer complete visibility into all vendors, step-by-step project tracking, and clear, upfront pricing throughout the vinyl production run. They offer vinyl record pressing using an alternative called Ecovinyl, a bio-based plastic. (https://evolution-music.co.uk/evovinyl/)
- **Evergreen Resources:** Procurement company specializing in glass, metal, and plastic packaging, with a focus on markets including food and beverage, home care, industrial chemicals, personal care, and pharmaceuticals. Their plastic products include containers (e.g., bottles, jars, pouches, tubes), caps and enclosures (including sprayers and pumps), various cartridges, and cosmetic packaging. Additionally, the company offers packaging 'solutions' using post-consumer resin made of PET, PP, PE, HDPE, ABS, and even ocean plastics for bottles, jars, sticks,, tubes, pumps, and sprayers, bottles, cartridges, cosmetics, recycled resins, caps, jars, pouches consisting of 25-100% post-consumer resin. Similarly, the company offers refillable packaging options including jars, airless bottles, sticks, and pencils made of paper, polypropylene, post-consumer polymers, PETG, and ABS. (https://evergreenresources.com/)
- **Indorama Ventures Hygiene Athens, Inc.:** Manufactures synthetic fibers for a range of products. Specifically, the organization manufactures polypropylene and polyethylene staple fibers and as bicomponent fibers containing polyethylene combined with PP or PET for widespread applications across sectors including building and construction, automotive, apparel and textiles, diapers and personal care products, and paper products. (https://www.indoramaventures.com/en/worldwide/792/indorama-ventures-hygiene-athens-inc)

Product and manufacturing data is typically proprietary and challenging to access. To generate a snapshot of the composition, scope, and sources of common plastic packaged items that are entering Athens, 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-km^2 survey areas in Athens — three within each tertile of the population count (Figure 3). Per the CAP guidelines, the team samples at least three convenience or grocery shops to sample within each 1 km2 transect area. In Athens, CIL surveyed 16 retailers, half of which were major grocery stores, followed by three small grocery stores, two gas stations, two pharmacies, and one mini-mart on the university campus. In total, 149 convenience and grocery products were collected and sampled, including 66 candy, 30 chips, and 53 beverage products. Samples of identical brands were not collected multiple times, even when present in multiple stores. 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 was able to determine the manufacturing location, which was determined 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).

Table 1: Distances between surveyed stores in Athens and their respective parent companies and manufacturers for convenience items

Product category	Distance from store to parent company (km)*				Distance from store to manufacturer (km)*			
	Min.	***Max.***	***Mean***	***Median***	***Min.***	***Max.***	***Mean***	***Median***
Candy	98	7383	1580	939	79	7325	1571	973
Beverage	784	9207	3018	1159	268	7981	1253	1120
Chips	324	3207	1233	1159	324	3585	1345	1243

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

A handful of states in the US have implemented Extended Producer Responsibility (EPR) policy legislation that encourages producers of products to bear some responsibility for their end-of-life management. At current, Georgia does not have any EPR legislation, which generally requires packaging producers to join a producer responsibility organization, or stakeholder organization, to develop a plan and manage the program [9]. 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 [10]. The plastics industry in the US tends to oppose EPR schemes arguing that waste management relies on consumer practices and behaviors [11], and that the schemes can lead to increased costs, food waste, and life cycle impacts [12]. EPR schemes are typically supported by state-level governance, suggesting that Athens' state-level representatives could advocate for legislation targeting EPR efforts or engagement with packaging producers. The product survey identified one producer (Pepsi Bottling Group) based locally in Athens, five in other cities in Georgia, and seven in neighboring states. These proximal producers signify opportunity for partnership with companies such as those based in Athens or nearby states as shown in Table 2. EPR can be a requirement of the companies doing business in a state no matter where products are manufactured, or companies are located. A full list of parent companies and manufacturers documented across the Athens product surveys is available in the Appendix.

Figure 5: World map displaying manufacturing locations for top convenience items in Athens

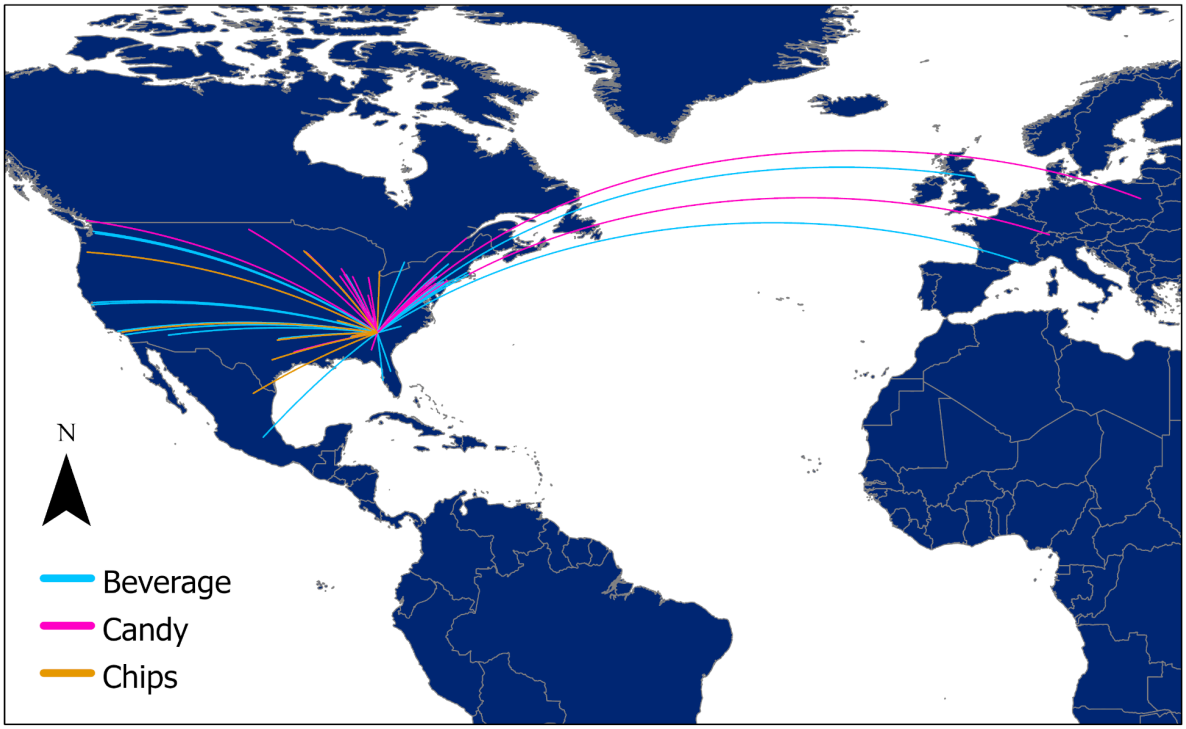


Figure 6: World map displaying parent company locations for top convenience items in Athens

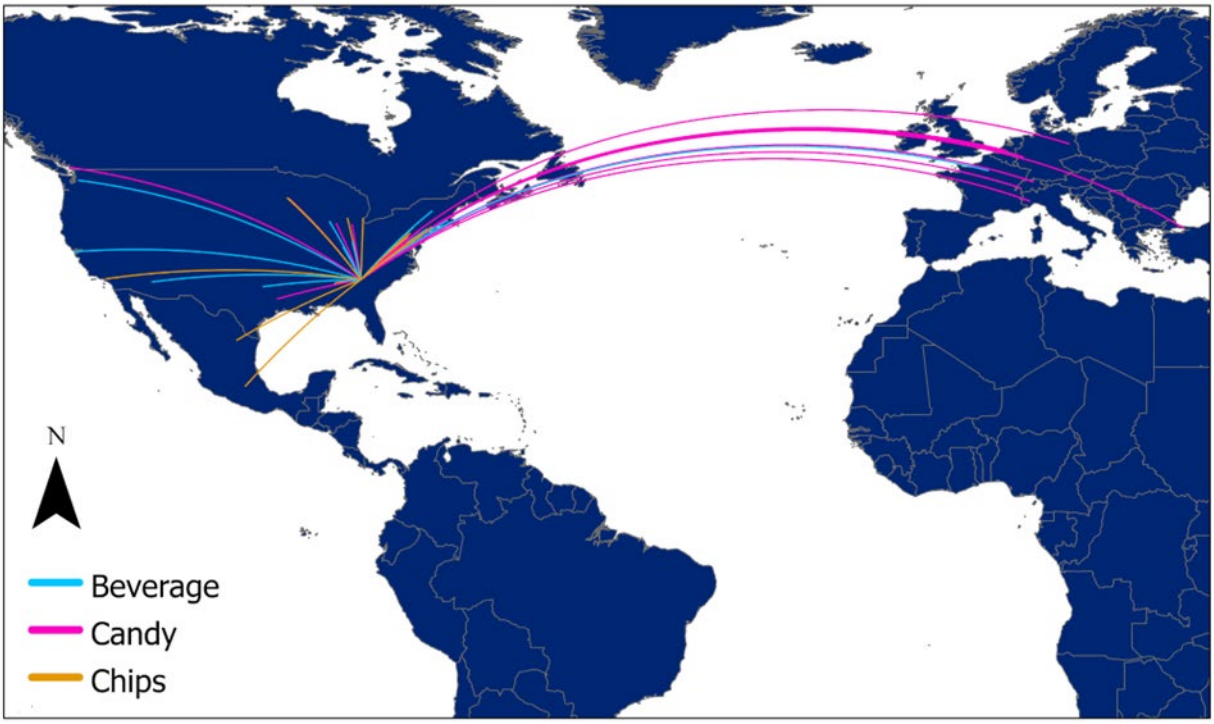


Table 2: Domestic products and materials produced or manufactured in Athens, throughout Georgia, and in neighboring states

Location **Company name**	**Product category**	**Identified packaging types**
Local to Athens		
Pepsi Bottling Group	Beverage, Chips	PET bottle; plastic film label; PP cap; HDPE cap; multilayer film
Georgia-based		
The Coca-Cola Company (Atlanta & Marrietta)	Beverage	PET bottle; plastic film label; plastic cap
Glaceau (Atlanta)	Beverage	PET
Keurig Dr. Pepper (Norcross)	Beverage	PET
Mars, Inc. (Albany)	Candy	Multilayer film
Tum-e Yummies (Atlanta)	Beverage	PET bottle; plastic film label; plastic cap; plastic sippy top
Neighboring states		
Alabama		
Golden Flake Snack Foods	Chips	Multilayer film
Milo's Tea Company Inc.	Beverage	HDPE bottle; plastic film label; plastic cap
Florida		
Minutemaid	Beverage	PET bottle; plastic film label; plastic cap
Tropicana Manufacturing Company	Beverage	PET bottle; plastic film label; plastic cap
South Carolina		
Deer Park	Beverage	PET
Tennessee		
Pepsico	Beverage	PET bottle; plastic film label; plastic cap
Pringles	Chips	Cardboard, metal, plastic lid

Producers and manufacturers of packaged products can play an important role in improving waste reduction, lowering cost burdens on public waste infrastructure, and innovating in product design, which altogether can result in better collection and prevention of losses to the environment. One growing policy-based strategy is Extended Producer Responsibility (EPR), which is a form of product stewardship that holds producers responsible for better end-of-life management of their goods, typically through innovative design approaches to maximize post-consumer product recovery and internalizing costs associated with local waste management systems. Several states have implemented statewide EPR legislation targeting electronics, batteries, and paint as well as landfill bans on specific materials. As of 2024, five states (California, Colorado, Maine, Minnesota, and Oregon) have passed EPR legislation specifically targeting plastic packaging. These laws generally have defined targets for waste reduction and recycling, generated collection lists that clarify waste collection systems, and created Producer Responsibility Organizations (PROs), which comprise producers that pay an agreed upon fee based on the products introduced locally [13, 14].

While there are almost 140 EPR laws across 33 states [15], Georgia currently has no EPR policy targeting any product categories. However, the state hosts Ascend Elements, a lithium-ion battery recycler which

may play a role in supporting the expanding state EPR legislation for batteries and in turn, the growing demand for electrical vehicles throughout the state and country. While statewide legislation in the US is in its relative infancy, cities can play an important role in developing and operationalizing local EPR strategies. For example, as part of the development of their modern Solid Waste Master Plan, the city of Ottawa, Canada has been exploring ways to integrate EPR locally into their existing city-wide programs targeting household hazardous waste, batteries, and electronics in support of the statewide EPR model in Ontario [16]. At present, Athens does not have its own EPR policy, but has a robust waste infrastructure system combined with an active product and manufacturing business community that may provide the foundation for eventually adapting such a strategy locally.

Community

The CIL team conducted semi-structured interviews with five key stakeholders in person in Athens Clarke County (ACC). Among the interviewees, two participants represented a local recycling center, two worked in the city government, and one was involved in sustainability at a local academic institution. Thematic analysis uncovered some trends related to local perceptions and awareness of personal waste management, infrastructure and economic barriers to waste management, and potential strategies for intervention as summarized in the remainder of this section.

The most common industry-related problems mentioned by interviewees included current challenges surrounding inflation and supply chain setbacks in a post-COVID world, as well as the general cost of having an effective and reliable waste management system. When discussing perceptions of waste management, interviewees described how "waste" tends to be valued by people, as well as where waste management is positioned as a priority in relation to other environmental issues. When discussing community awareness and participation in waste management and recycling, all interviewees noted that there is some degree of confusion brought on by conflicting information, unclear or nonexistent labeling, etc. Potential opportunities to bolster waste management and recycling in Athens includes extended producer responsibility (EPR) in education, labeling, and packaging, "marrying" mutually beneficial initiatives already going on in Athens, providing clear and accessible information about best practices via CAP or other partner organizations, instituting furniture waste initiatives that align with cyclical move-out dates, and inflating regional landfilling fees to encourage recycling.

Interviewees mentioned challenges related to post-COVID labor shortages, supply chain issues, inflation, and the general costs of maintaining a waste management system. However, most of the interviewees who mentioned these issues noted that although these are current challenges, they will not last forever due to the cyclical market nature of the waste management and recycling fields. Examples of interviewees who mentioned inflation or supply chain setbacks related to cost and/or manpower:

> *"One of the crazy things about the supply chain challenge is that we actually can't get the vehicles for [our new beautification] crews yet. So we've got the money in the budget and we are ready to hire the people, but it's going to take a while for the vehicles to arrive. So I anticipate that we will be seeing some litter remediation and beautification activity coming as soon as stuff shows up." (Government Official)*

"The last couple of years have been challenging all around. Coming out of COVID is a challenge. And a piece of that has been labor shortage. So right now local governments are just kind of keeping their head above water [laughs] in terms of day-to-day functionality. It would have been the case in 2018 or 2019 if you looked at our job listing and you went to our website and you just printed them off as a pdf file, you would have gotten a page of job listings. If you do that same exercise today, you would get 4 or 5 pages of job listings. So everybody is just struggling to keep their head above water." (Government Official)

"The most expensive part of waste is the humans in trucks -- paying the humans and paying for the maintenance of those trucks." (Government Official)

"It is just that some of this is gonna be legislative activity, budget activity, and staff capacity. I identify those three buckets that are challenges. And it's a time that we are doing lots and lots of legislative work in a variety of areas, so there's sort of a human capacity there. You've got to pay for these things, and then you've got to have human beings to carry them out. So those are the big challenges." (Government Official)

Perceptions of waste management that were frequently brought up by interviewees included how people view waste, as well as how waste management tends to be prioritized within broader environmental and climate concerns. Examples of these sentiments are shown below:

"People don't want to pay for trash in general. It's valueless if you think about it. It's valueless to you as a person or you wouldn't be getting rid of it. Nobody wants to pay for garbage regardless of what the fee is." (Government Official)

"Recycling was the champion of the environmental sector back in the '70s and it is not anymore and people don't think about it as much. They're starting to think about it again but there's lots of things to take all of our attention when it comes to climate change, and waste is just one…Recycling isn't sexy anymore. And we are competing with sexier things like electrical vehicles and solar panels -- all these topics that are in the environmental realm." (Government Official)

Interviewees also mentioned how waste management efforts in the United States, and particularly the South, tend to be slowed or even hampered due to various political and cultural factors. Examples of how interviewees related waste management to geography are shown below:

"We are starting to see more investment from sponsors, companies, entrepreneurs, and even upper administration on sustainable practices on campus. Generally, as the community and the culture pushes for this stuff more, it just kind of falls into place. Politically it is easier to make changes like this if everyone around you, and our donors and supporters, are on the same page. It's been kind of a slow change, but that is pretty typical for our region." (Academic)

"Georgia's recycling rate sucks…With a 20% recycling rate around the state and the U.S. recycling rates are declining." (Government Official)

"We have no vision as a state as far as waste reduction, which means all of the local governments are just doing what they can to keep things rolling in the recycling realm." We do have one for the region now, but our surrounding counties don't put a priority on waste reduction because they don't have the political or financial ability to do so or their citizens haven't asked." (Government Official)

"A carrot doesn't always work, you have to have that stick as well on solid waste ordinances…In the Southeast in particular as well, using the stick is not looked at favorably. " (Government Official)

"In the U.S., people are very short sighted. Even people with kids, they don't look past themselves. They don't look into their children's generation and see how their inaction in certain realms will affect their children. They are too caught up in their lives at that moment, and if it is not convenient then a lot of folks will not want to do it. In the US we are not as much about community, it's about individuals. It is frustrating here sometimes, especially in the Southeast, we don't have that same mindset which hurts as well." (Government Official)

"It just is the case regionally in the Southeast, and certainly that we see locally, that there's a great deal more litter than I would prefer -- plastics and other materials." (Government Official)

Interviewees' perceptions of the extent to which people are involved in and aware of waste management and recycling practices in Athens were mixed. Some interviewees noted how awareness and involvement could be dependent on getting the information out to different groups of people. Others mentioned how those who participate in recycling tend to have more time, availability, and resources to participate:

"I think we have a core group of people in Athens that do a great job. They use the [recycling center], they compost, and they recycle well. And then we have folks that will do it if it's convenient. And then we have folks that really don't want to do it at all." (Government Official)

"In January we had 3,000 visits after Christmas. And we aren't open every day of the week." (Recycling Representative)

"There are huge gaps. There's probably ten people a week that come in here that are first timers, who have lived here for forever and didn't know we had a recycling facility. And I don't know if that's an age thing, maybe because they are technology challenged like me and they don't do social media and things like that. We do that here…we are very much involved in social media. And if it's not in the paper, you know, when they go in the Athens Banner Herald, maybe they don't know about it." (Recycling Representative)

"I see new electric and hybrid vehicles out here before I hear about them anywhere else. I only say that because it is a disproportionate number that is actually driving on the streets. And so that is

representative of who is coming in here for the most part. It does seem to be mostly upper-middle class. You see customers, but in terms of racial makeup of who comes to the [recycling center] versus who lives in Athens, it's not representative. I mean you have to pay money to come here and you have to have time. And you have to learn when the hours are and come down here during those hours. I mean there are all kinds of people that come to bring their stuff here and are passionate about it. But the car thing is a good [indicator] -- and you have to have a car [laughs]. There are a couple of people that come in here that don't drive cars, but for the most part the do." (Recycling Representative)

When discussing community awareness and participation in waste management, a theme frequently brought up by interviewees is general confusion surrounding information around best waste management and recycling practices:

"There is so much miscommunication and misinformation…Someone will read a national article about how glass is not recyclable and then they will stop recycling it in their local communities where they could recycle glass. There is some deception -- if you are a corporation and you want your product to still be out there. Then there's people reporting what they know in their region and making it sound like that's the way it is in every part of the U.S., and recycling is very local and people don't treat it that way often." (Government Official)

"They don't have time, it's confusing, they read articles outside of Athens-Clarke County that make them more confused" (Government Official)

"Companies are quick to want to identify their product as something that is recyclable, and some things are conditionally recyclable. A lot of times people will bring something in and sure enough they have that recycling symbol on it, but it's not recyclable." (Recycling Representative)

"We get the weird stuff all the time that says 'put in your curbside bin' and it is not recyclable. We don't want that." (Recycling Representative)

"There are disposable electric recreational devices -- like those hoverboard things -- things like that -- they don't really carry a designation on the battery itself. The issue is that when the batteries were manufactured for that product, it met the specifications for that device. But as far as letting us know what type of battery it is, it's a mystery. We have to do a lot of research to figure out exactly what type of battery it is before we can say how we should ship it. It's very important. You wouldn't want to ship a lithium battery like you would a rechargeable battery. It's really important to know just what type of battery that is…batteries are the most involved material we take." (Recycling Representative)

"Vapes have been coming in for over a year now. But sometimes they do not tell you what kind of battery it is, although we know it's lithium. Those little recharging banks for cell phones -- again, they

will not tell you what type of battery is in that device. So we have to do a lot of research to figure out what type of battery it is before we ship it." (Recycling Representative)

"It really isn't the customers. It really isn't. It's more the items that they bring in that are -- we hate to say "no" -- but sometimes you just have to say "no" because there are no outlets for it." (Recycling Representative)

"Reiterate the importance for better identification of those materials when they come here so we don't have to waste so much time trying to figure out what they are. When it comes to chemicals, I would much rather take a person's best guess written on a bottle as opposed to dealing with it as an unknown. You just have to be so careful around here, you know? You got all these different materials, and they can all live together happily as long as you keep them separated. And when you've got an unknown, it is a real challenge to keep them separated because you just don't know what that unknown is." (Recycling Representative)

"There are obviously lots of things that individuals use in their home or show up on their doorsteps these days from high density Styrofoam to film plastic that we don't collect at the curbside, that are difficult to collect at the curbside, if not functionally impossible." (Government Official)

Although current industry-related issues include manpower, inflation, and the general cost of running a comprehensive waste management system, many interviewees felt these issues were temporary setbacks. More broadly, interviewees cited geographically-specific attitudes toward waste management as something that complicates progress, and they also noted that individuals tend to be confused about recycling information and how to act accordingly. Regardless of complications and barriers, interviewees remained optimistic, which can be best summed up by the following quote:

"We adjust here. We have rules and regulations and we follow them...We do realize that we are operating on the goodwill of people who are trying to do the right thing. For some of those people, it doesn't take much for that goodwill to go away. So while we are still generating more revenue than we ever have before, we are still able to strike a balance where we don't kill everybody's pocketbook that comes in here if we don't have to." (Recycling Representative)

Product Design

To characterize material types used in common consumer products, samples of common convenience products were obtained as described in the Input section. The CIL team sampled stores and vendors in each of the nine 1km^2 transect areas, as well as within 1km of the surrounding area if none were present inside the sample site. The team purchased a total 119 common products across three food packaging categories including beverage, candy, and chips at eight retailers including three small grocery stores, two gas stations, one large grocery chain, and one mini-mart on the UGA campus. The team measured the mass of each product item and their respective packaging components, which allowed us to calculate the ratio of packaging to product, where a larger ratio means that more packaging is used to deliver less

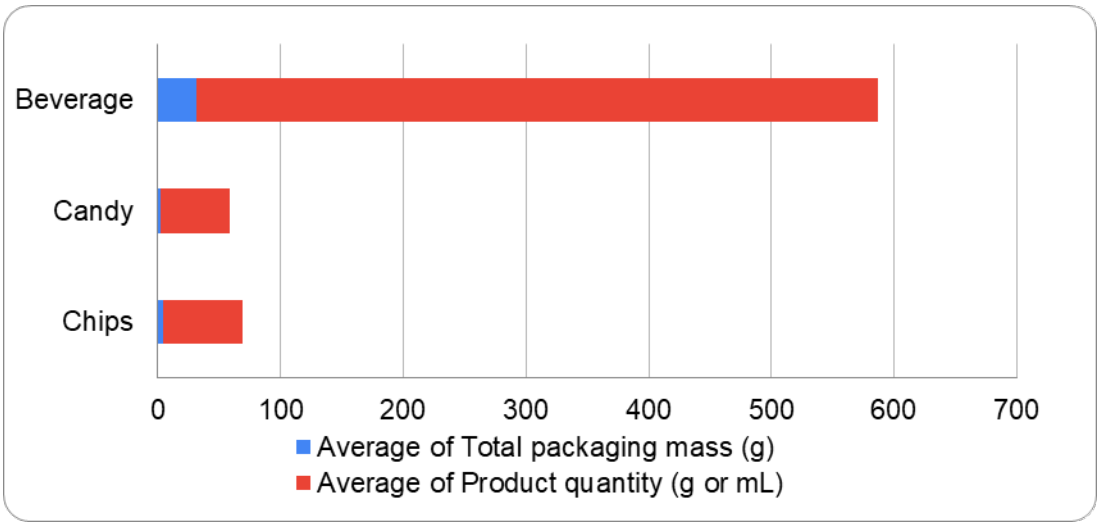
product. Table 3 summarizes the samples, mass, and product quantities documented by the CIL team in the convenience product surveys.

Table 3: Average weight of products and their plastic packaging for common convenience items

Product Type	Number of samples	Mean plastic packaging mass (g)	Mean product quantity (g or mL)
Beverages	53	31	555
Candy	66	2.6	55.6
Chips	31	4.4	64.2

Beverage packaging comprised the largest mean mass across the three product categories—weighing almost seven and twelve times as much as chips and candy packaging, respectively. This high packaging mass corresponded with product quantities as well, with beverage products having the greatest mass in packaging mass, likely due to the higher density of liquid beverages compared to dry candy and chip goods. The proportion of packaging across all three category types was similar with plastic packaging ranging between 4 and 6%. However, despite beverages having the greatest overall, the plastic packaging content was largest among the chip products, of which, packaging made up an average 6.4% of the total product mass, followed by beverages (5.3%) and candy (4.5%). of packaging to product weight (visualized in Figure 7).

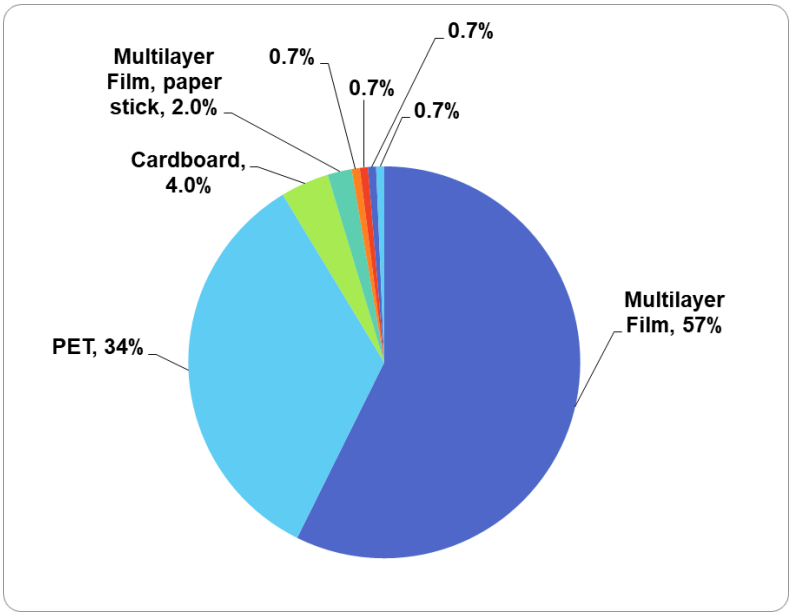
Figure 7: Convenience store plastic to product ratios, shown in grams (not including unknown products or tobacco as there is no weight data for tobacco)



Of all the products sampled, multilayer film comprised the largest proportion of products by packaging type, followed by PET (Figure 8). Multilayer film is particularly difficult to recycle due to the nature of comprising multiple materials that makes it expensive and less practical for management (cite). In contrast, PET, often used in beverage containers or rigid plastic packaging applications, is considered a

more valuable polymer of plastic for recycling due to its ease of collection, mono-material characteristics, and market outlets carpet and textiles [7]. Beyond these two main packaging materials, the remaining products were delivered in cardboard, HDPE, or multiple packaging materials, and made up 4% or less of the products sampled. Across the three product categories, beverages had the most homogenous packaging, with 98% of samples packaged in PET and 2% of samples packaged in HDPE. However, more than half (55%) of the beverage products contained multiple packaging materials, such as PET, hard plastic, and film. In contrast, candy products had the most diverse packaging types, although 91% of products still contained some multilayer film plastic. The remaining 9% of products were packaged in cardboard. For chip products, 97% of products were packaged in multilayer film, which is considered a low value plastic due to difficulty separating materials in recycling processes [7].

Figure 8: Material breakdown of top convenience items in Athens; include pie charts or bar graphs for each item category (beverages, chips, candy) based on averages of visual surveys.



In addition to surveying convenience and grocery stores, the CIL team surveyed 177 food vendors and restaurants throughout Athens, including quick service (i.e., fast food), fast casual, midscale and casual, chain, and independent restaurants to explore what businesses used for takeaway containers and packaging. Through visual assessments and discussions with restaurant owners, we assessed the material type for to-go food items like containers (including their lids), cups, utensils, and straws. Across these vendors, 1,007 individual packaging items and components were collected such as cups, straws, utensils, bags, etc. across 24 general categories. The most common items acquired were food containers (21%) and cups (18%), both of which varied by material type. Plastic accounted for most (68%) items (Table 4), followed by paper (16%), coated paper (6.1%), and cardboard (3.8%). Among the 683 plastic items, most were made of polypropylene (36%), followed by unspecified plastic (23%), polystyrene (including extended PS; 18%), PET (10%), and HDPE (9.4%).

Table 4: Products and material types of common items surveyed in restaurants and food vendors

Product	Material Type	Number of Observations
To-Go Containers (including lids if applicable)	Plastic	92
	Coated paper	36
	Paper	34
	Cardboard	28
	Aluminum	11
	Plastic	92
Cups	Plastic	112
	Paper	46
	Coated paper	15
	Bioplastic	3
	Composite	2
	Compostable	1
Utensils	Plastic	123
	Wood	5
	Paper	1
Straws	Plastic	101
	Paper	11
	Bioplastic	5
	Compostable	1

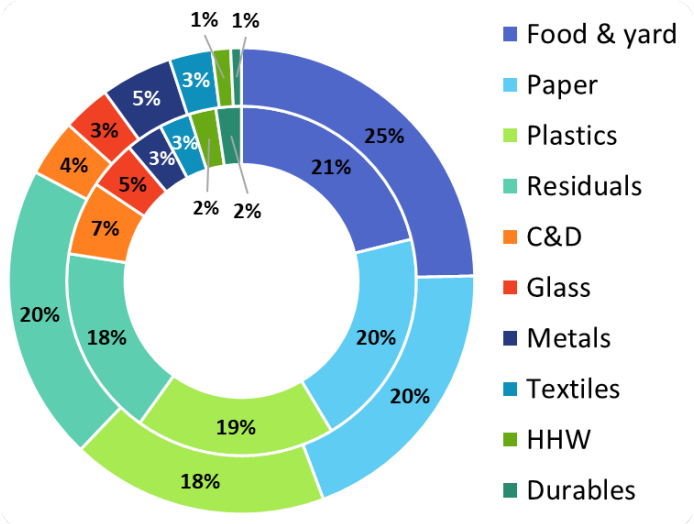
Use

Waste generation & composition

In 2020, Athens-Clarke County generated an estimated 162,000 tons (147,000 metric tons), of which MSW made up the proportion (64%). Based on the 2020 population of over 128,000 people, an estimated 6.92 lb (3.12 kg) of waste is generated per person per day in ACC. Notably, this waste generation rate is above the national waste generation rate of 2.21 kilograms of waste per person per day and more than four times that of the global per capita rate of 0.74 kg [4]. However, the estimate may be slightly elevated due to the increase in waste generation in the early stages of the COVID-19 pandemic. With a growing population in ACC as well as neighboring counties, waste generation is expected to grow by almost 14% between 2020 and 2031, which highlights the importance of continued efforts in waste reduction.

By material type, a 2015 waste audit conducted by researchers at the University of Florida for ACC found that organic waste accounted for the largest proportion of materials, making up a fifth of all commercial waste and a quarter of all residential waste. While organics represent a significant waste stream in Athens, it is a smaller fraction compared to the nationwide estimate of 34% [17] and the global estimate for organic waste composition of 44% [4]. This difference may be explained by the larger proportion of plastic waste generated in ACC, with approximately 18-19% of waste in ACC comprising plastics (Figure 9), equivalent to approximately 1.28 lb (0.58 kg) of plastic waste generated daily per capita [18]. Comparatively, plastics account for an estimated 12% of the waste generated nationally [17] and globally [4] in 2018. Waste reduction strategies will likely continue to be a key component of ACC's strategy for moving toward a local circular economy. Finally, compositions of residential and commercial waste generated in Athens are relatively similar. Construction & demolition debris and durable goods account for slightly more waste in the commercial stream than residential, while food & yard debris, residuals, and metals have slightly larger proportions in the residential stream.

Figure 9: Material proportions by mass of commercial (inner circle) and residential (outer circle) waste in ACC in 2015 (C&D = Construction & demolition; HHW = Household hazardous waste; Adapted from Townsend [18])



Policies targeting plastic waste reduction

Policies and regulations can be an effective lever to reduce waste generation, improve collection, and prevent leakage of harmful materials to the environment. There are several formats of plastics that are currently targeted by regulations across various scales in the United States and beyond. Nationally, the US has been a leader in regulation targeting microbeads, but has yet to establish other nationwide legislation related to plastics. Under the nationwide Microbead-Free Waters Act of 2015, all states, including, Georgia, are prevented from enacting or enforcing laws restricting the manufacturer of microbead-containing rinse-off cosmetics or introducing such products into interstate commerce unless the restrictions match the federal law which prohibits the manufacturing, packaging, and distribution of rinse-off cosmetics containing plastic microbeads. As defined by the federal law, such microbeads are considered 5 millimeters or less in size and are intended to exfoliate or cleanse the body [19].

Similarly, bottle deposit schemes, which are a form of EPR policy, have demonstrated effectiveness in ten US states (California, Connecticut, Hawaii, Iowa, Maine, Massachusetts, Michigan, New York, Oregon, and Vermont), with redemption rates ranging from 38% in Massachusetts to 86% in Oregon. These schemes work by consumers paying a deposit, typically 5-10¢, for certain beverages such as soft drinks, water, and alcoholic beverages (though state limitations vary). Consumers can collect their empty, post-consumer containers and return them to the state programs to get their deposit back, minus a handling fee (around 2.5-4¢ depending on the state and handling agent) [20]. In 2011, Georgia state senators sponsored House Bill 51 (11 HB 51), which aimed to create a statewide bottle deposit scheme such that Georgia customers would pay a 5 deposit and a 3.5 handling fees at retail or redemption centers. Most of the unclaimed deposits would be paid to the state, while 20% would remain as the property of distributors and manufacturers. Further, the bill would enlist a specific barcode system to support the scheme. Unfortunately, the bill stagnated and did not pass, and there is no evidence that another version is forthcoming.

Similarly, across the US, twelve states (California, Colorado, Connecticut, Delaware, Hawaii, Maine, New Jersey, New York, Oregon, Rhode Island, Vermont, and Washington) have enacted statewide bans on plastic bags, while several states throughout the country have developed preemptive legislation restricting plastic bag bans [10]. Georgia currently remains free of statewide legislation on plastic bags, neither banning their purchase and sale, or banning regulations curtailing their use. However, Georgia Senate Bill 49 was released in January of 2023 and is aiming to prohibit distribution of plastic bags and polystyrene foam at certain retail establishments. While there is momentum for passing such a statewide law, one recent study ranked the state as 28th most likely to pass a plastic bag ban [21], suggesting there may be difficulty in successfully passing it. Until there is a statewide ban enacted, Georgia localities throughout the state are able to independently develop their own regulatory tools to target certain plastic materials.

Without statewide legislation targeting waste reduction and circular materials management, such efforts fall under the purview of local city and county governments. In Georgia, waste management regulation is relegated to local jurisdictions under the 2011 Georgia Comprehensive Solid Waste Management Act, which was enacted to address concerns related to solid waste management in the state of Georgia and aims to enhance the efficiency and effectiveness of waste management practices across the state by promoting recycling, waste reduction, and proper disposal methods. The Act mandates the development of comprehensive solid waste management plans by local governments, ensuring that they incorporate strategies for waste reduction, recycling, and the safe disposal of hazardous materials. Additionally, the

Act emphasizes the importance of public education and awareness programs to encourage responsible waste management behaviors among residents and businesses. There is growing momentum throughout the state as some jurisdictions in Georgia have enacted their own plastic bag regulations in recent years. For example, in2019, the City of Clarkston passed a resolution banning the purchase and sale of single-use plastics and polystyrene at businesses citywide, promoting unspecified compostable food packaging and locally recyclable products as alternatives. That same year, South Fulton similarly enacted an ordinance prohibiting single-use plastic grocery bags, cups, straws, and containers, mandating certified compostable, 100% recyclable, or recycled material alternatives [22]. More recently, in 2021, the City of Savannah adopted a resolution to phase out single-use plastics and expanded polystyrene foam containers, offering paper or reusable bags for a fee as alternatives [23]. Other communities such as Tybee Island, which was the first Georgia municipality to attempt to ban plastic bags, have continued to try to pass local ordinances without success.

Despite interest in the county for several years, ACC has yet to enact such legislation targeting plastic products as of 2024, however, In Nov. 2023, CAP data along with other litter data collected by community members and Keep ACC Beautiful and Rivers Alive with UGA's app Debris Tracker was presented to the solid waste commission. The CAP data mostly included the store and restaurant data, along with the leakage (litter) data. The mayor had asked for this information to begin to think about a plastic bag and expanded polystyrene (EPS) ban in ACC. There is now a draft ordinance that is recommended by the commission which would eliminate plastic bags and EPS containers at points of purchase in ACC. This ordinance would be implemented in a phased approach. In addition, the city has implemented a glass bottle reduction program targeting commercial glass waste generated by restaurants in bars. In 2017, glass bottles were identified as a significant hazard in Athens and by 2020, the community implemented a program for beer-selling businesses to participate in glass waste reduction efforts. County ordinance SW-023 works as an incentive to businesses to adapt their top five selling beer brands to draft or aluminum containers, and in return, the county reduces their beer license renewal fee by 25-50% depending on the amount of reduction businesses undertake [24]. The program highlights the role that businesses can play in effective waste reduction strategies.

In terms of plastic waste reduction, local businesses could similarly lead the implementation of product bans or fees could through exploring cost-effective alternatives to bags or simply ask their customers to bring their own for a small discount on their purchase. One low-hanging option is plastic carrier bags distributed by food and retailers. Throughout the transects, the CIL team surveyed what types of bags business provided at check-out across eight grocery and convenience retailers and 109 food vendors, all at no additional cost to consumers. All eight grocery retailers offered plastic bags (LDPE free) and none offered plastic-free alternatives. Only two locations offered alternative bags one pharmacy/convenience shop and a large grocery retailer, offered reusable options made of pressed polypropylene fabric that costed $1.29 and $0.99, respectively. The large grocery retailer also offered a foldable and reusable bag made of thin, unspecified plastic for small items that customers could purchase for $2.99. Half of the food vendors and restaurants offered only plastic carrier bags, while another 35% offered only paper carrier bags. Seventeen restaurants offered both plastic and paper bags, and only one vendor offered coated paper bags. Half of the plastic bags offered by restaurants were labeled as HDPE, while the material for the remainder was not specified. comprised most (48%) of the plastic bags offered, however, about 4% of them were labeled as recycled or recyclable. Among the paper bags, 9% were labeled as recyclable, and only one bag indicated that it was comprised of 40% post-consumer material.

Alternatives to plastic

The CIL team documented several material alternatives in Athens for common plastic items, many associated with takeout food, including baggies, bowls, cups, plates, straws, trash bags, and utensils (Table 5). Typical plastics used in these products included LDPE, PE, EPS, and PP, while material alternatives included recyclable paper, compostable fibers, wood, and bio-based plastics including potato starch-derived trash bags and polylactic acid (PLA), and reusable silicone, aluminum, and stainless-steel items. These reusable bags, cups, and utensils tended to have higher per-unit costs compared to their single-use plastic alternative. Compostable items were available for most product categories, often at a higher rate, while recyclable items, including recyclable plastics, were sometimes competitively priced with their single-use alternatives. The cheapest products found were single-use extended polystyrene bowl, which cost only $1.00, and are difficult to recycle. Comparatively, silicone plastic bags were most expensive at $12.99, but their long-term value and reduced environmental impact may offset the initial investment required.

While it is promising that there are compostable, recyclable, and reusable alternatives are widely available in Athens, it is worth noting that misleading nomenclature, packaging labels, and public information can cause confusion, particularly when it comes to 'compostable' items. Based on the CAP survey, plastic items labeled as compostable were typically designated as made of paper, wood, potato starch, and fiber which can be natural or organic plant material, as well as bioplastics. 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. Further, bio-based plastics can be chemically identical to fossil-fuel-based plastics but can be confused for compostable or biodegradable, and potentially be mistaken by consumers as recyclable [7], which can end up contaminating the recycling stream and ultimately the distribution of cost burdens to the public. 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 [25].

Outlets for product reuse

Reuse, repair, and refurbishment are key facets of the circular economy. While there are limited outlets for reuse of single use packaging, such as those listed in Table 5, there are some existing models of reuse in the community that serve as examples (Table 6). For example the Teacher Reuse Store, which accepts office and school supplies helped to divert an estimated 3,100 lbs (1400 kg) of waste from the landfill in 2020, all while supporting local educators by providing goods at no cost to those employed in ACC and surrounding counties [26]. Similarly, the UGA Swap Shop, which accepts goods such as school supplies and household goods on campus, diverted an estimated 536 lbs (243 kg) of waste from the ACC Landfill in 2021 [27]. While policy approaches can effectively encourage reduced waste generation and encourage public awareness, private efforts can be impactful as well. One reuse system implemented recently in Atlanta emerged from a partnership between LiveNation and the TURN Reusable Cup Systems in 2023. The system encompasses reusable cups, collection bins, and washing systems that together incentivize fans at various music and sporting event venues to return TURN cups for rewards [28]. As host to several live entertainment and sports, Athens could particularly benefit from exploring such a system, which might dramatically reduce waste generation of single use cups and reduce losses to the environment during concerts and shows at venues like the Georgia Theatre and the Classic Center, as well as sporting events throughout the UGA campus.

Table 5: Price per count of items sold in stores by product, material type, and disposal designation on packaging (EPS = expanded polystyrene; LDPE = low density polyethylene; PE = polyethylene; PLA = polylactic acid; PP = polypropylene; PCR = post-consumer recycled)

Item type Material	Compostable	Recyclable	Reusable	Single-use
Baggies				
LDPE		$4.99		
Paper	$5.49	$3.79		
PE		$2.99		
Plastic			$5.49	
Silicone			$12.99	
Bowls				
EPS				$1.00
Fiber	$3.50			
Lined paper		$4.25		
Cups				
Aluminum			$9.52	
Lined paper	$7.79	$7.99		
Paper	$5.49			
PLA	$4.99			
PP		$5.29		
Cups & Lids				
Fiber	$6.99			
Paper	$5.99			
Plates				
EPS				$2.25
Fiber	$6.27	$3.99		
Lined paper		$5.16		
Paper		$4.49		
PP		$3.54		
Straws				
Paper	$2.98	$4.99		
Stainless steel			$5.79	
Trash Bags				
Plastic w/ PCR content		$5.99		
Potato starch	$7.79			
Utensils				
PLA	$3.49			
PP		$8.59		
Wood	$4.64			

Table 6: Established reuse programs in ACC

Program	Location	Accepted items
Athens Repair Café	745 Hancock Industrial Way (Co-located with the Solid Waste Dept.)	Bicycles Electrical appliances Toys Clothing Furniture Computers Others
Teacher Reuse Store	1005 College Ave (Co-located with the CHaRM)	Office and school supplies (paper, pencils, pens, tape, scissors, etc.) Science equipment Furniture (shelving, desks, chairs, etc.) Working electronics (computers, printers, etc.) Unusual items for creative reuse projects (e.g., bottle caps, gift cards, pieces of plastic, containers)
Tool Shed Program	1005 College Ave (Co-located with the CHaRM)	Tools (e.g., hammers, power tools, paint supplies) Equipment (e.g., safety gear, first aid kits) Garden and lawn supplies
UGA Swap Shop	University of Georgia Miller Learning Center	School and craft supplies Small kitchen wares Small household appliances Working electronics Games/entertainment Cleaning supplies Household goods and decorations Umbrellas Clothing

Collection

Non-recyclable solid waste

In the US, nearly 100% of waste is collected with many cities mandating the provision of household waste collection [4]. Typically, waste is collected via curbside bins, dumpsters, or drop off points. Trucks then transport waste to their final disposal site or to transfer stations or sorting facilities that temporarily store waste for further transport over longer distances. Effective plastic waste management at the city level requires not just efforts toward waste reduction, but also consistent collection services. At present, successful collection of plastic waste relies heavily on behaviors at the household and individual level. As such, efforts toward education and incentivization strategies can help encourage behavior that helps waste infrastructure run smoothly.

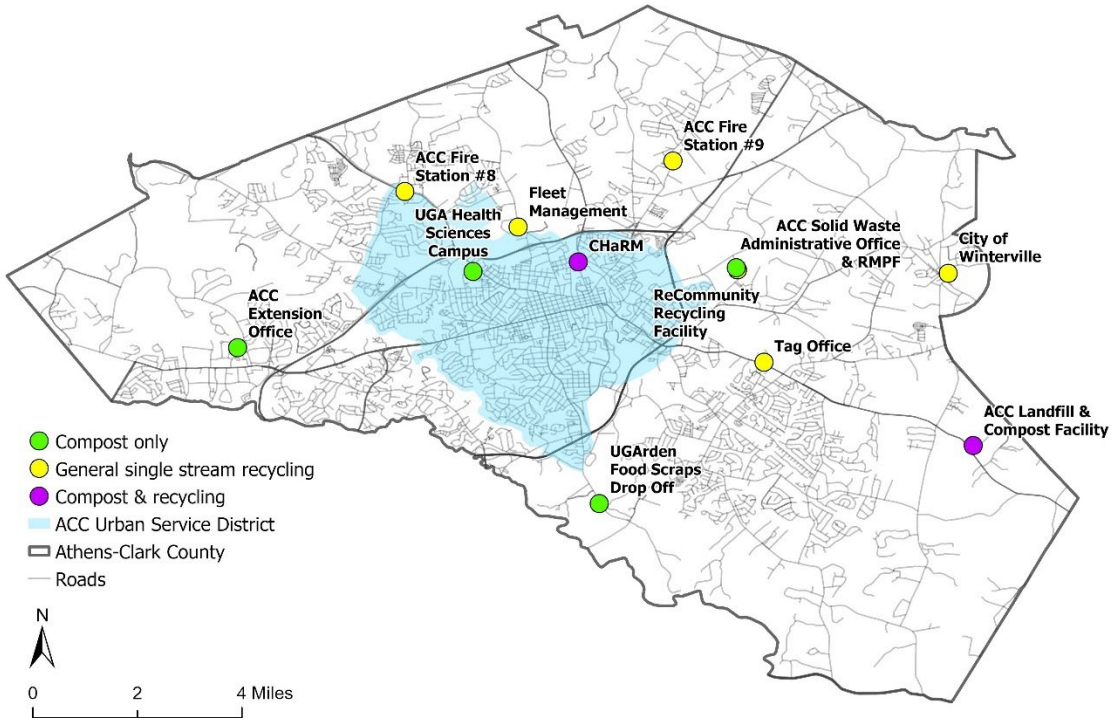
In Athens, waste collection is divided into two districts based on urbanization: Urban Service District and General Service District (Figure 10). As of 2020, the Urban Service District accounted for 10,200 households and businesses and receives public collection provided by the ACC Solid Waste Department. Urban residential waste is collected once a week, while commercial waste is collected via curbside service 1-2 times daily, along with dumpster service. The General Service District, which comprised twice the number of households and businesses in 2020, must contract waste collection services through private

providers. Here, residents can select their preferred service provider, which must offer recycling and a pay-as-you-throw rate structure to customers based on the permitted agreements with ACC [26].

Recyclable items

ACC operates a comprehensive recycling program that includes curbside pickup for residents and several strategically located drop-off centers throughout the county. This infrastructure is designed to maximize convenience and participation among residents, thereby increasing recycling rates and reducing landfill waste. In addition to curbside pickup, there are also several recycling drop off locations throughout the community, including ACC Fire Stations #8 and #9, a location in the City of Winterville, the ACC Tag Office, and the ACC Fleet Management property, and the ACC Landfill (Figure 10). Two additional recycling facilities serve ACC: a Recovered Materials Processing Facility (RMPF) and the Center for Hard to Recycle Materials (CHaRM), which together divert an estimated 19,100 tons (17,300 metric tons) from the landfill annually.

Figure 10: Compost and recycling drop off points in ACC



Unlike many municipalities, ACC collects plastic items across all seven plastic types, including hard plastics #1-7 including cups, trays, bottles, and containers with lids on, bulky hard plastics #1-7 including buckets, crates, and totes, and food and beverage cartons [29]. The Recycling Division also offers digestible rules of thumb to residents to aid in their recycling behaviors of mixed items which must be: Clean, empty, and free of residue, Not mixed materials, Bigger than a Post-It Note, Hard, and Not bagged. Additionally, the Recycling Division clarifies items that are not accepted in their single stream recycling system such as

plastic bags/wraps, Styrofoam, plastic cutlery, plastic hangers, or wax coated cardboard. However, some of these items are accepted at the city's CHaRM facility (Figure 11).

Figure 11: ACC recyclable items flyer (Source: ACC Recycling Division [30])

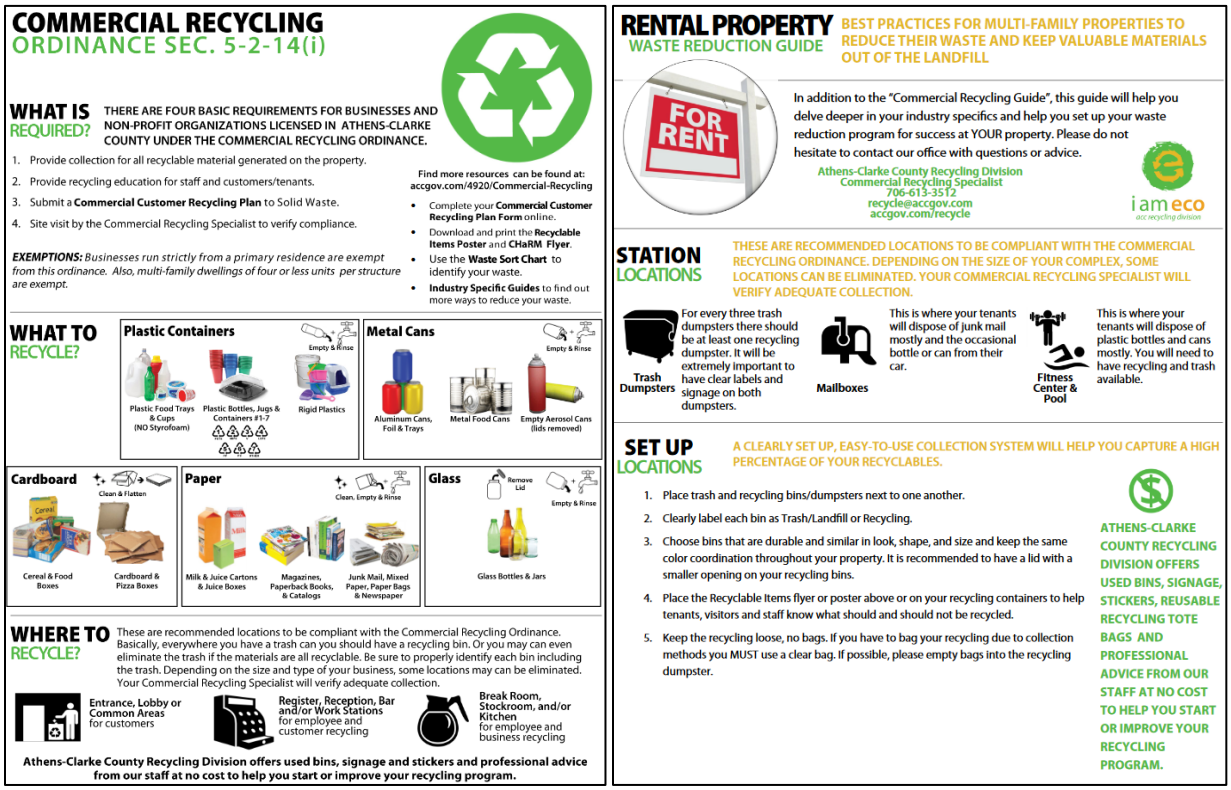
In addition to the residential recycling program, the county adopted a mandatory commercial recycling ordinance in 2012 (Sec. 5-2-14 (i)), which requires the following of all ACC businesses and non-profit organizations:

1) Collection and separation of targeted materials for recycling (i.e., items in Figure 11) in designated containers
2) Promotion and education related to recycling (e.g., commercial entities must educate their employees and/or tenants of recycling information and guidelines)
3) Completion and approval of a Commercial Recycling Plan by the ACC Recycling Division [31]
4) Compliance led by the entities' local manager of operation or owner

Commercial customers must complete a Commercial Recycling Plan, which clarifies the business type (i.e., multi-family residence, institutional organization, commercial business), business name, ownership information, and contact information, number of employees or tenants, name of recycling service provider, type of collection containers ((i.e., Roll-carts, Roll-off containers, dumpsters, compactors, others,

etc.), description of education plan for customers, employees, and/or tenants (e.g., web-based, written, other), and destination (processor) of recyclables [31]. The ACC Recycling Division has created a plethora of materials and information for commercial customers including 'quick start' guides for commercial businesses and rental properties (Figure 12), answers to Frequently Asked Questions regarding the commercial recycling ordinance [32], access to a commercial recycling specialist, list of approved private service providers for collection and processing [33], and provision of presentations and/or tours of the ACC Recycling Processing Facility.

Figure 12. Flyers for quick start guides for commercial businesses and rental properties.



The Recycling Division provides some industry-specific information for businesses that commonly utilize plastic goods and packaging such as retailers, restaurants, and bars. For each of these business types, the Recycling Division describes suggestions for waste collection station locations within the business, itemized list of targeted items, reminders of non-recyclable items, and tips to reduce waste.

Table 7: Summary of recommendations for plastic waste collection by business type (Adapted from ACC Recycling Division [34, 35])

	Business type	
Recommendations	**Retailers**	**Restaurants/bars**
Collection station locations for recyclables	Customer entrance/exit; By the register for receipts and beverage bottles;	In or by the bar for collecting bottles and cans and separating food, straws, and napkins;

	Break and/or shipping area for waste from staff meals and shipping materials	Kitchen and shipping area where most waste is created to collect empty and cleaned recyclables and separation of plastic wrapping; Break room for waste from staff meals
Targeted plastic items	Rinsed cleaning supply bottles; Plastic containers #1-7 (including milk jugs, soda, and water bottles)	Clean plastic food containers (e.g., butter, sour cream, condiments); Milk and juice cartons; Clean 5-gallon buckets; Rinsed plastic food trays and cups; Empty cleaning supply bottles
Important non-recyclable plastic items	Plastic bags, shrink wrap and bubble wrap; Styrofoam	Plastic bags, shrink wrap and bubble wrap; Styrofoam
Outlets for hard to recycle plastic items	CHaRM: Plastic packaging wrap and bags, broken electronics, Styrofoam, ink cartridges, and paint. Teacher Reuse Store/Thrift stores: Broken/unsellable merchandise, clothing, and shoes, old marketing signage, old product displays, hangers	CHaRM: Plastic packaging wrap and bags, broken electronics, Styrofoam, ink cartridges, and paint. Teacher Reuse Store/Thrift stores: Furniture/decorations, old marketing signage, old product displays, old uniforms, old pots, pans, or dishes
Plastic waste reduction tips	Purchase products with recycled content; Identify sources of excess waste; Adopting reusable utensils, plastes, and cups for staff use; Using special programs (e.g., TerraCycle.com) for hard-to-recycle items not accepted by the CHaRM such as make-up, toys, guitar strings, candy wrappers, etc.; Ditch plastic shopping bags or asking customers if they would like a bag; Working with suppliers or vendors to reduce packaging in shipments or for back-hauling shipment material; Develop a Sustainable Purchasing protocol for assessing suppliers and materials; Share efforts with customers, business partners, and community.	Purchase products with recycled content; Identify sources of excess waste; Adopting reusable utensils, plastes, and cups for staff and/or customer use; Using special programs (e.g., TerraCycle.com) for hard-to-recycle items not accepted by the CHaRM such as make-up, toys, guitar strings, candy wrappers, etc.; Ditch plastic shopping bags or asking customers if they would like a bag; Working with suppliers or vendors to reduce packaging in shipments; Serve beverages by fountain or draft in recyclable cups or reusable glasses; Develop a Sustainable Purchasing protocol for assessing suppliers and materials; Share efforts with customers, business partners, and community.

Hard to recycle items

Funding for the ACC CHaRM was procured in 2011 through a special-purpose local-option sales tax (SPLOST) fund, which are a financing mechanism used in capital improvement projects throughout Georgia that operate by letting jurisdictions, like ACC, use sales tax proceeds to fund such work rather than burden residents with additional income tax. Through the 2011 SPLOST, funding was provided to

improve Solid Waste Department facilities and equipment upgrades. The CHarM opened in 2015 and replaced the county's previous system of using scheduled drop off events for hard to recycle and hazardous waste, ultimately allowing both residents and non-residents, as well as commercial businesses, to bring such materials for disposal throughout the year. ACC customers can drop off mixed recyclables, scrap metal, and food scraps at no cost. Other items can be dropped off for small fee: $3 for businesses and residents of ACC or $8 for businesses or residents outside of ACC. Finally, several items require an additional fee for processing (Table A6). The facility receives approximately 800 customers per month [26] and serves as a 'one stop drop' for items that are challenging to collect and/or process due to their chemical composition, hazardous components, size, shapes, etc. [36].

Table 8: Film bags and wraps accepted at the CHaRM and store drop-off locations

Category	Film uses
Food-related goods	Bread bags (empty) Cereal box liners (empty) Case wrapping (e.g., snacks, bottles, etc.) Grocery/carry out bags Produce bags (empty) Food storage bags (e.g., hard components at top removed)
Personal care products	Diaper wrapping (packaging only) Toilet paper, napkin, and paper towel overwrapping
Household goods	Dry cleaning bags Electronic wrap Furniture wrap Retail bags (hard plastic and/or string handles removed)
Shipping material	Bubble wrap/air pillows Newspaper bags Shipping envelopes (labels removed)
General	All clean, dry bags labeled #2 (HDPE) or #4 (LDPE) Plastic bags Tyvek (no glue, labels, or other material)

Organic waste collection

Collection infrastructure for organic waste, such as food scraps and yard waste, is provided by the city as well as private organizations and the University of Georgia. There are several drop-off locations for food scraps and other materials throughout the ACC community, which includes the ACC Landfill, ACC Extension Office, CHaRM, Solid Waste Administrative Office, UGArden, and UGA Health Sciences Campus (Figure 10). Materials can be dropped off at no cost as part of an effort to divert waste from the landfill. Items accepted for compost are summarized in Table 9. Commercial businesses and organizations in ACC can sign up for curbside pickup for food scraps by the city, which provides a 32-gallon roll cart, with additional carts available for a fee of $6.60 per cart per month but does not include bags. Businesses can select their preferred frequency for pickup ranging from $35.10 per month for weekly collection to $72.60 per month for collection five days per week. In addition to the drop off system, there are both public and private curbside collectors serving the residents and commercial organizations throughout the community (Table A4). Two haulers, ACC Solid Waste Department and Closed Loops Organics provide curbside pickup only for commercial businesses and organizations. Quantities and pickup frequency vary and are specified

by the customer. Most residential pickup services offer at least one 2-4 gallon bins for pickup, while commercial pickup can range from several small bins, large 32 to 65 gallon carts, or even roll-off dumpsters. Frequency of pickup also ranges from weekly to several days a week. In addition to the dropoff and curbside pickup systems, ACC also hosts some one-off events as part of educational campaigns and special promotions for reducing waste from seasonal events.

Table 9. Summary of accepted compost items by material category (Source: ACC Solid Waste Department [37])

Material category	Item
Food waste	Meat (including spoiled meat)
	Dairy (e.g., cheese and yogurt)
	Bones
	Coffee grounds
	Egg shells
	Beverages
	Rotten fruit/vegetables
Paper & cardboard	Dirty paper (including pizza boxes, plates, and napkins)
	Sandwich wrapping paper
	Wax-coated cardboard
	Shredded paper
	Paper teabags
Yard waste	Leaves
	Limbs
	Flowers
Other	Cork
	Wooden toothpicks
	Wooden chopsticks
	Sawdust
	Hair
	Vacuumed debris
	Laundry lint
BPI-Certified products	Cups
	Plates
	Bags
	Cutlery
	Others

UGA has also played a key role in the organic waste reduction and local composting system. The Campus Kitchen at UGA, for example, recovered almost 20,000 lbs (9 Mt) of food in 2021 and donated 9,800 lbs (4.4 Mt) to local agencies to provide meals to ACC residents [27]. Similarly, since 2014, the Dining Services on campus has been partnering with the UGA Facilities Management Division and the Office of Sustainability to collect food scraps on campus to be managed at the University's Bioconversion Research and Education Center for composting [27]. Additionally, research on campus has been playing an active role in advancing the community-wide composting infrastructure through a pilot research program funded by the Walmart Foundation. The program aims to test a Residential Compost Pilot Program which is collecting food scrap and yard waste from 400 households throughout the Normaltown and Boulevard neighborhoods between January and May of 2024 (Figure 10; [38]). Through the provision of 32-gallon metal compost bins, the existing truck fleet aimed to collect waste from the test households weekly and at no cost for the duration of the study. The system has already seen some success, with 6.26 tons collected between February and March, equivalent to about 1.42 kg per household per week [38]. Results will

inform models to advance a community-wide compost program aimed at integrating curbside pickup to increase collection of compostable materials and reduce landfill quantities [39].

End of Cycle

Landfilling

While most (61%) waste generated in ACC is disposed of locally, the remainder is sent out of the county for treatment in other landfills. Most of the remaining waste comprises C&D debris (23%), which is disposed of in C&D-specific landfills in Oglethorpe, Walton, and Hall Counties [26]. Another 13% comprises industrial waste that is disposed of in Barrow County. Athens currently owns and operates one Subtitle D landfill located in the City of Winterville located in the eastern portion of the county. These landfills are regulated under Subtitle D of the US Resources Conservation and Recycling Act which is codified in Title 40, which offers minimum national standards for managing non-hazardous solid waste including MSW, as well as commercial solid waste, non-hazardous sludge, and industrial solid waste, to protect human health and the environment (see for example [40]). Specifically, Subtitle D landfills are required to meet minimum design criteria, location restrictions, financial assurances, corrective cleanup actions, and closure requirements that are under the purview of the states, however, while the federal regulations offer guidance to states, they are not obligated to adopt the requirements [41].

Relative to the rest of the state, the ACC Landfill disposed of the 32nd most waste in 2022 out of 48 operating MSW landfills, at 91,300 tons (82,800 metric tons) [42]. Despite the transient nature of the community's population, the landfill experiences somewhat consistent waste generation and landfill disposal throughout the year, with quarterly tonnage amounts ranging from 21,300 to 25,000 tons [26, 42]. Further, the landfill accepts an estimated 95% of MSW generated in ACC as well as waste from Oglethorpe County as part of an agreement between the counties that trades disposal of construction & demolition waste in Oglethorpe's C&D landfill in exchange for Oglethorpe disposal of MSW in the ACC Landfill. In addition to landfilling, the community is making strides toward dedicated diversion efforts with a goal to divert 75% of waste from landfill by 2030 and 90% by 2050. To accomplish these diversion goals, the community is building momentum in developing their composting and material recovery systems described in the next sections.

The ACC Landfill has 444 acres of disposal capacity, with 193 acres permitted for disposal as of 2023 [26]. Located at the boundary of the county, the landfill was expanded by 79 acres into neighboring Oglethorpe County in 2020 as part of a multi-phase effort to increase capacity. With 6.7% of the landfill covered as of 2020, the Georgia EPD estimates that the ACC Landfill has a net remaining 5.9 million cubic yards (4.5 million m^3) of disposal capacity remaining, equivalent to about 40 more years of operation at current waste generation and disposal rates [43]. As landfill capacity decreases over time, tipping fees tend to increase. Per the ACC Solid Waste Department, tipping fees are $55.00 per ton for both commercial and residential disposers [44]. These fees align with the national tipping fees. In 2018, the average landfill tipping fee was $55.11 per ton in the US, however, tipping fees in states with more available landfill space are typically lower than states that are more densely developed [17].

Recycling

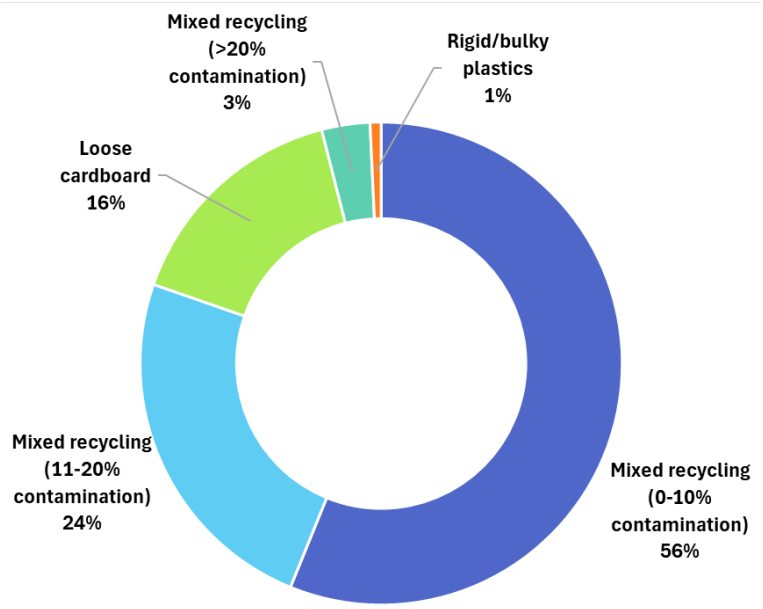
Nationally, only about 24% of all waste is recycled, and only 4.5% of plastic is recycled [17]. In ACC, an estimated 2.96 tons of recycled material are collected daily [45]. The ACC Recovered Materials Processing Facility (RMPF), located on the central-east side of the county at 725 Hancock Industrial Way address

(shown in Figure 10) was opened in 1995 via a public-private partnership under a shared revenue contract with a company known as ReCommunity. While ReCommunity operates the facility, ACC owns the property and oversees the agreement with ReCommunity, allowing ACC to pay a fee for every ton of recycled waste processed while receiving an 80% share of revenue when the recycled material is sold. Prior to 2011, residential single-stream waste was sent to nearby Gwinnett County to be processed. The RMPF converted to single-stream recycling capability in 2011, allowing comingled recycling to enter the facility for processing. Recycled waste from ACC, UGA, as well as Oconee, Oglethorpe, and Madison Counties, and many nearby communities is delivered to the ACC facility for processing either through public collection or private haulers as described previously.

The RMPF is a 22,000-square foot facility that processes 70-80 tons per day on average, or a total of 1,500 tons monthly. However, the facility has the capacity to sort up to 120 tons per day. Over thirty different materials are able to be sorted and processed via manual and automated sorting including aluminum, certain plastic items, metals, glass containers, cardboard, and paper products. Once commingled waste is processed and sorted, materials are baled and sent to various facilities located primarily in Georgia and the Southeast. Mixed paper and corrugated containers are converted to cardboard boxes and other paper products, while office paper is converted to tissue and toilet paper. Glass bottles and jars are converted to new bottles and jars as well as reflective road paint and other products. Aluminum cans are sent to scrap metal brokers and converted to aluminum cans, automotive components, and other metal products, while steel and tin cans are converted to products used in automotive and building sectors as well as new cans. For plastics, only PET (#1 plastic) and HDPE (#2 plastic) are converted into specific products, while end markets for plastics #3-7 are varied and depend on market conditions. Specifically, PET is used for carpet materials and HDPE is converted to milk or juice bottles or detergent bottles.

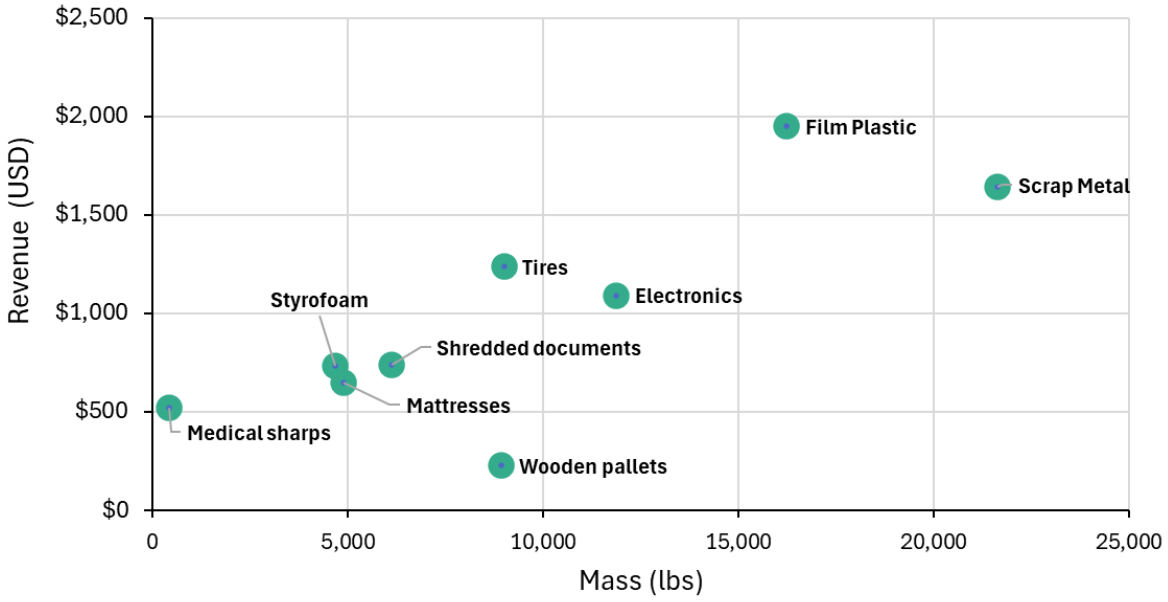
Unfortunately, the facility has historically struggled with high levels of contamination despite widespread efforts to raise awareness and educate the public on good recycling practices and behaviors. For example, in November of 2022, mixed recyclables with contamination of 11% or greater accounted for 27% of the facility's received waste that month [46] (Figure 13).

Figure 13: Composition of RMPF waste in November 2022 (Source: Solid Waste Advisory Commission [46])



Contributing to the community's well developed recycling infrastructure, the ACC CHaRM is a specialized facility designed to accept and process items that are not suitable for curbside recycling or standard drop-off sites (See Table A6 for a full list of accepted items). These materials are typically processed for reuse, recycling, and in rare cases, safe disposal. By mass, scrap metal, film plastic, and electronics comprise the largest fraction of waste processed by the CHaRM, according to a Division Report from March of 2023 [45]. Importantly, the CHaRM accepts a wide range of film plastics (Table 8), which are notoriously difficult to recycle via commercial recycling facilities like the RMPF due to its lightweight and flexible characteristics that can tangle in sorting equipment and machinery. In a recent Division Report, film plastics generated the highest revenue for the facility, representing a lucrative outlet for operation costs, followed by scrap metal, and tires (Figure 14). While information on end markets specific to plastic film collected in ACC is not available, there are some well-known uses for recycled plastic film materials. In a 2015 report on national plastic film recycling commissioned by the American Chemistry Council, composite lumber, film and sheet, and other various uses such as marine and agricultural products, buckets, crates, and pallets. comprised the main end markets for processed film [47].

Figure 14: Mass versus revenue of various CHaRM materials from December 2022 -January 2023 (Source: Solid Waste Advisory Commission [45])



Composting

Food waste can be converted into several applications including animal feed, compost, land application, or meal donations, as well as disposed via landfill and controlled combustion. In the US, most food waste is managed via anaerobic digestion, followed by conversion to animal feed, and land applications. Composting, on the other hand, accounts for only 1.5% of the quantity of food waste managed nationally [48]. Despite its low adoption rate across the US, composting has become a major service provided by the county and is expected to continue growing. Athens is one of only two municipalities in Georgia that operates a public composting system. hosts the ACC Commercial Composting Facility (CCF), which is a

paved 4.5-acre facility that opened in 2011 on the east side of ACC (Figure 10). Onsite leaf & limb storage comprises another 4.5 acres, resulting in a total facility footprint of 9 acres. The CCF originally cost $800,000 to construct and comprises $750,000 worth of equipment paid for by the ACC Public Utilities department. Compost can be created through various approaches, and the CCF relies on a common approach, the windrow system, which is aerated manually by turning equipment and is useful for processing large volumes with diverse materials. More recently the facility has begun to integrate aerated static piles (ASP), a system that passes air beneath piles, which helps to convert materials more quickly, with a smaller footprint, and less odor [37, 49]. The facility generates two types of compost: food waste compost and bio-solid compost.

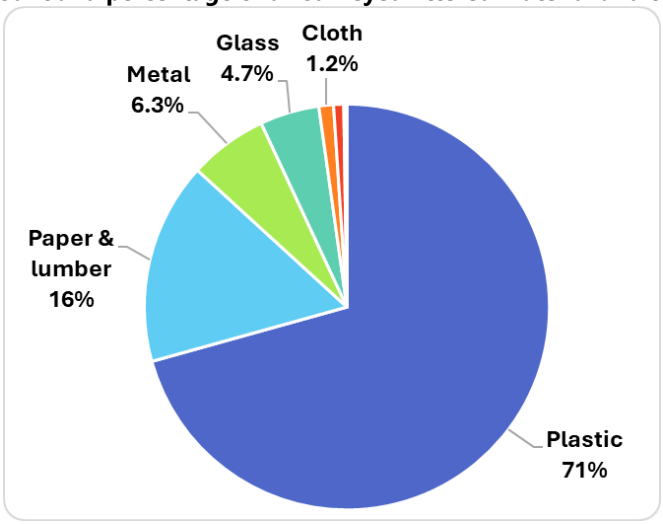
Food waste compost is derived from food waste and leaf & limb debris collected from residents and businesses by ACC, Closed Loop Organics, and CompostNow. Bio-solid compost, however, is comprised of digested solids processed by the ACC Public Utilities Wastewater Treatment Facilities and must meet specific criteria as defined by the US EPA Clean Water Act (40 CFR Part 503), which sets contamination limits for pollutants like arsenic, heavy metals, dioxins, as well as defining requirements for pathogens and weed seed controls, management, monitoring, recordkeeping, and reporting [49]. These bio-solids are the result of separating liquids and solids during wastewater treatment, which are then treated physically, biologically, or chemically treated to stabilize organic compounds, reduce pathogens, and reduce material volumes. Composting these separated and treated solids can provide an effective way for stabilizing materials for a range of applications [49]. For compliance with the federal regulations, compost must be tested and certified by the Seal of Testing Assurance Program of the United States Composting Council, which is performed regularly in ACC [37].

The resulting compost product can be used in a variety of applications for both households and business use alike. ACC recommends compost be used for plant bed embellishment, landscape mulch, turf establishment, growing media, and vegetable gardens [37]. Residents of ACC and commercial businesses and organizations can purchase compost directly from the facility for $20 per cubic yard, or in smaller amounts for $2 per 5-gallon bucket [37]. Buyers can either pick up purchased compost directly from the CCF or work with several private haulers depending on the quantity (Table A4). Additionally, there are some promising applications of compost material uses in packaging formats. For example, Compostia, who operates a curbside collection system in ACC, advertises research activities associated with creating new materials from composted waste including the following bioleather, soap bottles, and specific applications for potato skins and orange peels [50].

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 population count (upper, middle, lower) across Athens. These population counts were based on the Oak Ridge National Laboratory's LandScan global ambient population data for 2021 [51] (shown previously in Figure 3). Litter items were recorded using the open-source Debris Tracker mobile application ('app') [52]. 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, 4,185 litter items were recorded across twenty-seven 100 m^2 transects in nine different square kilometer areas sampled in August - September 2022. Across all surveyed transects, plastic made of the largest proportion by material category (71%) followed by paper & lumber and metal items (Figure 15). The remaining categories represented 5% or less of all litter items.

Figure 15: Count and percentage of all surveyed littered material and top ten items



Together, the top 10 items comprised over almost three quarters of the total sample of littered debris. By individual product types, cigarettes and plastic foam fragments were the most recorded items, together making up 35% count (Table 10). Abundance of cigarette litter in Athens varies in previous studies, but remains a problematic litter item that will benefit from continued prevention activities. Keisling [53], for example, found that cigarettes made up over a third of items recorded in stormwater traps, litter surveys, and drainage infrastructure in ACC, while ACC's Keep Athens-Clarke County Beautiful (KACCB) found that cigarettes comprised only 5.3% of surveys conducted in each commission districts in the county. Nevertheless, cigarettes are the most documented litter item in the USA and in Georgia according to the Ocean Conservancy's International Coastal Cleanup Report for 2023 [54], signifying the continued challenge with preventing their losses to the environment. Like other surveys, plastic food packaging and goods comprised a substantial number of littered items. Common food packaging, like candy wrappers and chip packets, have low packaging-to-product ratios (Figure 7), which are generally less valuable for recycling compared to plastic bottles made of PET, which only comprised 4% of the litter recorded in Athens, suggesting that there may be slightly more effective collection of plastic beverage bottles for disposal or recycling currently in the community.

Table 10: Top ten items by count and proportion of surveyed litter items

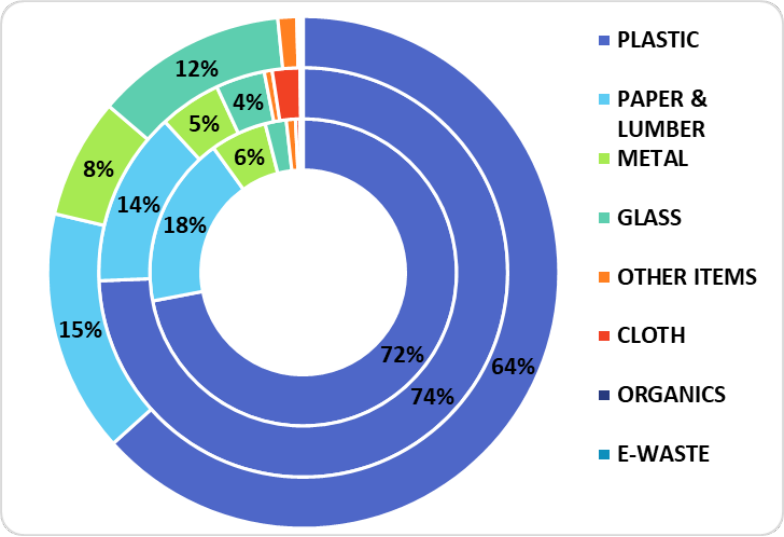
Rank	Item Type	Count	Percent of total
1	Cigarettes/Cigars	1063	25%
2	Plastic or Foam Fragments	438	10%
3	Plastic Food Wrappers	415	9.9%
4	Paper and Cardboard	315	7.5%
5	Plastic Film	212	5.1%
6	Plastic Bottle	167	4.0%
7	Glass Fragments	164	3.9%
8	Other Paper	135	3.2%
9	Aluminum or Tin Cans	121	2.9%

10	Foam Fragment	118	2.8%

Leakage across population tertiles

When examining the litter characterization based on the population count, some similarities and distinctions can be seen between the three groups. In terms of litter composition, findings from the leakage surveys in the high, mid, and low population areas were mostly consistent with the overall sample. For example, cigarettes were consistently the highest ranked item by count across all three tertiles (Table 11). However, plastic food wrappers, which were the third most recorded item in the full sample and 2nd and 3rd in the mid and low-density tertiles, were not among the top five items in the high density areas, which may be attributed to higher density of full service restaurants that are more likely to utilize reusable food items (e.g., silverware, drinking glasses, etc.) and fewer single-use packaged items, as well as adopt a systematic waste collection process, consistent with the commercial recycling compliance programs described previously in the Collection section and the restaurant-specific recommendations made by the city (Table 7). The proportion of glass in the high-density population areas were more than three times the proportions recorded in the mid- and lower density areas, which may similarly be attributable to the presence of glass use at the bars and restaurants in these areas. The variation in proportions of litter types across the three population count groups can provide insight into material use and disposal patterns that differ across the areas. Similarly, the large proportion of plastic fragments in all three areas is notable given the challenges related to collecting, managing, sorting, and disposing or recycling those items given their size.

Figure 18. Composition of surveyed litter items across the high (outer), middle, and lower (inner) population areas in Athens



When aggregated across all surveys, Athens has an average litter density of 1.2 items per square meter, which is similar to other CAP cities in the US [55, 56]. However, like the variation seen in litter composition, litter density also differed between the three population count areas. The mid-density population areas have the highest total item count and mean litter density and saw the largest range of densities across transects from 0.2-5.93 items per square meter, suggesting more variation in litter abundance in these areas. In contrast, high-density areas had the lowest litter density. By material composition, the proportion

of plastic was highest in mid-density areas (74%), followed closely by high-density areas (72%), with low-density areas having the lowest plastic composition (63%). Further, the types of litter items had little variation across the three population areas. For example, cigarettes/cigars were consistently the top litter item across all population densities, and plastic and paper items dominate the top five litter categories in all areas. Athens had the highest average litter density across the six cities with CAPs completed for this work, it is 1.2 items/m^2, just higher than Atlanta (1.14 items/m^2) and Vicksburg (1.1 items/m^2).

Table 11: Top litter items, total item count, total plastic composition, and litter densities for population tertiles in Athens

Population tertile	Top five litter items by product type	Total item count (n)	Total plastic composition (%)	Mean litter density (count/m^2)
High	1. Cigarettes/cigars 2. Paper and cardboard 3. Glass fragments 4. Plastic or foam fragments 5. Plastic film	1126	72	0.56
Mid	1. Cigarettes/cigars 2. Plastic or foam fragments 3. Plastic food wrappers 4. Plastic film 5. Paper and cardboard	1598	74	1.78
Low	1. Cigarettes/cigars 2. Plastic food wrappers 3. Plastic or foam fragments 4. Paper and cardboard 5. Other paper	502	63	1.25

While the CIL team did not target tracking of illegal dumping, there are many efforts in Athens to address this issue, which is ubiquitous in the US and globally. Despite widespread access to waste and recycling collection throughout the USA, it is estimated that 0.14-0.41 million metric tons of plastic waste are illegally dumped throughout the country annually [57]. Compounding the environmental and aesthetic impacts illegal dumping contributes, it can also be a costly endeavor for municipalities to clean up and prevent [4]. For example, the cities of Sacramento, California, Austin, Texas, and Fort Worth, Texas budget $40,000, $70,000, and $90,000, respectively, to raise awareness about illegal dumping [58]. Reporting from 2018 indicated that ACC spent almost $860,000 on efforts to tackle both litter and illegal dumping issues in 2017, which included code enforcement, landscape management, financing for the solid waste department city, volunteer and cleanup event expenses, and department of transportation costs [59]. Comparatively, a report commissioned by Keep Pennsylvania Beautiful estimated that prevention, education, abatement, and enforcement activities targeting litter and illegal dumping cost the city of Pittsburgh, which has almost twice the population as Athens, $6.3 million annually [60]. Cities can address the issue through investment in bulk waste collection infrastructure (e.g., bulk waste dumpsters), improved upkeep of abandoned and vacant properties, and the continuation of programs (e.g., education

campaigns, free dump coupons, and neighborhood drop-off events) which may help to directly address problems in the community associated with the harmful practice.

Sources and pathways of plastics in ACC's natural environment

There is little published research on plastic losses or microplastics in the surrounding natural environments in ACC. However, two graduate theses by UGA students offer a glimpse of pollution sources and fates that may play a role in holistically addressing plastic waste management. Keisling [53] estimated that 0.7-1.3 metric tons of plastic litter may enter terrestrial and aquatic environments each day. Additionally, they conducted field sampling throughout low, middle, and high population locations, drainage ditches, and stormwater traps throughout Athens. They found that plastic items comprised 67-80% of the sampled litter items by count and 26-36% by mass depending on sampling method, with the most common items being cigarettes, plastic film fragments, hard plastic fragments, foam fragments, and paper, which was similar to the sampling conducted by the CIL for this report. Keisling [53] also found a weak, but correlative relationship between population density and litter rates (kg/ha/yr), with higher population density associated with lower litter loading, which is similarly mirrors the findings of this report as the high population areas were associated with a lower mean litter density (Table 11). Based on their findings, the author recommended several routes for preventing and abating leakage of litter in ACC summarized in Table 12.

Table 12: Summary of leakage recommendations adapted from Keisling [53]

Solution approach	
Water resources management	**Solid waste management**
• Monitoring effluents and biosolid microplastic concentrations at wastewater treatment plants • Increasing green infrastructure and stormwater best management practices, particularly around impervious surface reduction • Improving public education campaigns related to water management	• Improving existing public education campaigns on waste reduction, anti-littering, and dumping • Holding more cleanup events • Improving law enforcement and monitoring of littering • Implementing bans or fees on certain plastic items • Optimizing street sweeping to correlate heavy rainfall events • Improve access to waste collection, particularly in low income and rural areas

Complementing the work by Keisling [53], Monroe [61] conducted a study on wastewater-derived microplastics in ACC. Through sampling water effluent from three water reclamation facilities in Athens, they estimated that 1.6 billion microplastics enter the Oconee River through wastewater effluent in ACC, equivalent to 600 billion microplastics annually, with the highest rates observed in the North Oconee River section. By type, fibers made up 90% of captured microplastics, followed by fragments (7.2%), film (2.1%), foam (0.3%), and fiber bundles (0.2%). The smallest size classification in the study was the most common, with 46% of sampled microplastics measuring between 250 µm and 25 µm, while 1mm – 250 µm made up 28% and 4.75 – 1 mm made up 25%. The authors concluded that abundance patterns were influenced by sampling date, morphologies, and size class, and there was no evidence that water reclamation facilities influenced concentrations. In particular, the authors surmised that higher concentrations of microplastics recorded in October may have been correlated with a UGA home football game that happened before one of the sampling events. The high incidence of fibers was connected to less effective treatment for

fibers compared to other morphologies combined with residential inputs, particularly related to discharge from residential washing machines.

Table 13: Mean microplastic concentration and riverine loads in the Oconee River by sampling location. (Adapted from Monroe [61]; sd = standard deviation).

Water reclamation facility	Mean particles per liter	Microplastic load (billion per year)
Cedar Creek	38.0 (sd = 9.6)	92 (sd = 23)
Middle Oconee	36.6 (sd = 9.2)	183 (sd = 47)
North Oconee	35.6 (sd = 10.0)	326 (sd = 91)

Opportunities

CIL found the following opportunities to expand and enhance circularity in Athens 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 large percentage of domestic parent companies and manufacturers for top convenience items lend themselves to engaging companies on end-of-life management, product design, alternative materials and alternative product delivery systems. Athens could build upon existing partnerships and engaged businesses that are members of the Chamber of Commerce to develop community initiatives toward working with top local brands and producers that operate locations proximal to the community and Georgia, with a particular focus on beverage packaging.
- Explore resources and potential local industry partnerships that may be available for effective development, implementation, and enforcement of EPR Guidelines and rules that result from those guidelines. In addition, ACC should be involved to the extent possible in crafting EPR Guidelines at the local, regional, and national levels to ensure that they can be effectively implemented at the local level.
- While several businesses connected to plastic product manufacturing and distribution are members of the Chamber of Commerce, many were absent from the list. Incentives for participation, targeting plastic manufacturers could encourage other organizations to join and engage on issues related to innovative design, policies around waste collection and management, and local supply chain opportunities.

Community

- ACC has exceptional education and awareness campaigns around waste reduction, segregation, and litter prevention for residential and commercial customers alike. The city should continue expanding education and volunteer programs. For example, creating a youth council like that of neighboring counties could provide education and leadership opportunities for local kids.
- ACC has similarly demonstrated collaborations with neighboring counties including the landfill agreements with Oglethorpe County as well as provision of some services and events that include residents from nearby communities. The Northeast Georgia Regional Commission is an excellent outlet for doing so, and, as a major generator and manager of waste, Athens should continue engaging in regional advancements particularly in relation to infrastructure expansion and public education.

- Athens has well established, and award winning, education and awareness efforts targeting waste reduction and sustainable consumption. The community might examine ways to streamline information for residential and commercial customers to more easily navigate to information.
- Encourage local schools and businesses to sign up and participate as collection points for recycling programs such as TerraCycle, which rewards schools with cash for collecting some hard to recycle items.

Product Design

- Engage local manufacturers by bringing together producers, academics, and waste management practitioners throughout Athens and Georgia to discuss tangible, actionable solutions in the area.
- Plastic alternatives in the form of bio-based, biodegradable, and compostable plastics are likely to continue gaining momentum in Athens and beyond. By investing in education around identifying product materials and appropriate disposal options early, the city may mitigate challenges with managing these complex products over time.

Use

- ACC has crafted effective reduction program incentivizing businesses to reduce their glass waste generation. ACC should examine levers for similarly incentivizing retail and food establishments that might help limit distribution of plastic carrier bags to customers.
- There are no policies in place in ACC banning or limiting the use of plastic bags or other SUPs. Plastic film fragments and plastic bags together comprise 6.5% of the litter recorded in Athens, demonstrating the potential for reducing their impact through targeted policy. ACC should continue gathering data, exploring public sentiment, and advocating for a community-wide ban or similar ordinance. Until then, continuing to encourage local businesses to implement policies that curtail plastic bag use through incentivizing customers to reuse or avoid bags at checkout.
- Several states have plastic bottle deposit schemes which have been found to greatly encourage collection of plastic bottles, diverting them from landfill and reducing their potential to reach the environment. Athen should consider

Collection

- Waste generation rate and plastic composition is high in ACC, highlighting the important role that waste reduction strategies may play. In particular, there were lacking reusable and

alternative options for plastics found during the product design and use surveys, highlighting the opportunity for businesses to lead initiatives in reuse or refill.

- Waste collection is currently uneven throughout the county, as ACC has understandably prioritized urban collection. Given ACC's collection targets, implementing rural collection service could help to improve collection rates.
- Wastewater discharge was identified as a source of microplastic losses to the river systems in Athens. Continued monitoring of microplastic capture at the wastewater treatment facilities may help reduce …
- Waste sorting generally falls to individuals and households, and while there is abundant information available to the public regarding what types of materials are accepted by the various waste management facilities, there may be opportunity to strengthen education around what constitutes compostable packaging, utensils, and other goods and what items do not. There may also be a need for developing education around differentiating compostable materials versus recyclable materials to help reduce contamination in either waste streams.
- 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. Potential local partners such as Vicksburg Solid Waste Department, the Department of Commerce, or the Vicksburg Beautification Committee could partner with local organizations to collaborate on maximizing efficient data collection and monitoring capabilities.

End of Cycle

- Landfilling is a significant component of Athens' waste management capabilities, but the city has a track record of meeting ambitious diversion rates. Athens should continue aiming for high diversion rates, but also consider how the complexity of waste reduction and segregation can contribute to contamination in other waste treatment streams.
- While a wide range of materials are collected through single stream recycling in Athens, the city has historically experienced high rates of contamination. The city should continue examining outlets for improving contamination rates, including limiting or simplifying which materials are accepted at the facility.
- Continue advancing the composting capabilities of the city, including education efforts for both individual consumers as well as businesses and retailers that are electing to use and/or provide alternatives to plastics.

Leakage

- The city and local partners could revisit the CAP litter transects and/or areas that have different waste collection schemes to generate comparable data to identify patterns and gaps and inform best practices.

- Given the collection of captured debris from stormwater drains and street sweeping, there may be opportunities to initiate monitoring of litter quantities, types, and characteristics ending up in the built environment.
- Collecting data at cleanup events can help to elicit an understanding of what is cleaned up as well as provide tangible outcomes that encourage and validate volunteer participation. The county could partner with academics to produce robust datasets and models that help strengthen understanding of the complex waste management system.
- Plastic fragments are a significant challenge in terms of leakage, but upstream efforts that prevent items from reaching the environment where they have the opportunity to fragment may be effective.
- Cigarettes are the most commonly littered item documented in the community, suggesting that some targeted programming toward improving education around waste reduction and collection may help prevent losses to the environment. Given the prevalence of tobacco-related litter, educational schemes combined with increased infrastructure targeted toward tobacco waste disposal may be beneficial in reducing the prevalence of those items in the environment.
- Additionally, TerraCycle offers a municipality-based program specifically targeting cigarette recycling. Through their program, municipalities can purchase cigarette waste receptacles ($746 for a set of six) to place in high traffic areas (e.g., bus stops, parks, etc.). These containers can be used to collect ash, cigarette filters, extinguished cigarettes, inner foil packaging, loose tobacco pouches, outer plastic packing, and rolling paper.
- To target capture of wastewater-derived losses of microplastics, educate and encourage residents to consider collection options such as Cora Ball and Lint LUV-R.

Abbreviations

ACC	Athens-Clarke County
ASP	Aerated static piles
C&D	Construction & demolition
CAP	Circularity Assessment Protocol
CCF	Commercial Composting Facility
CHaRM	Center for Hard to Recycle Materials
CIL	Circularity Informatics Lab
EPR	Extended Producer Responsibility
EPS	Expanded polystyrene
FMCG	Fast moving consumer goods
HDPE	High density polyethylene
HHW	Household hazardous waste
LDPE	Low-density polyethylene
MSW	Municipal solid waste
PCR	Post-consumer recycled
PET	Polyethylene terephthalate
PLA	Polylactic acid
PP	Polypropylene
RMPF	Recovered Materials Processing Facility
SPLOST	Special-purpose local-option sales tax
SUP	Single-use plastic
UGA	University of Georgia

References

1. Douglas Smith, *A History of the Unification of the Athens-Clarke County Government*. 1997.
2. US Census Bureau. *U.S. and World Population Clock*. 2024 June 3, 2024]; Available from: https://www.census.gov/popclock/.
3. Jambeck, J.R., R. Geyer, C. Wilcox, T.R. Siegler, M. Perryman, and A. Andrady, *Plastic waste inputs from land into the ocean.* Science, 2015. **347**.
4. Kaza, S., L. Yao, P. Bhada-Tata, and F. Van Woerden, *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050.*, in *Urban Development Series*. 2018, World Bank: Washington, DC.
5. Plastics Industry Association, *Facts & Figures of Georgia*, in *State & Congressional Data*. 2023.
6. NOAA Marine Debris Program. *Why does the datasheet have Balloons listed under both Plastic and Rubber items?* . 2021 [cited 2024 June 8]; Available from: https://marinedebris.noaa.gov/why-does-datasheet-have-balloons-listed-under-both-plastic-and-rubber-items.
7. Moss, E., Eidson, A., and Jambeck J., *Sea of Opportunity: Supply Chain Investment Opportunities to Address Marine Plastic Pollution*. 2017, Encourage Capital on behalf of Vulcan, Inc.: New York, New York.
8. Wilcox, C., N.J. Mallos, G.H. Leonard, A. Rodriguez, and B.D. Hardesty, *Using expert elicitation to estimate the impacts of plastic pollution on marine wildlife.* Marine Policy, 2016. **65**: p. 107-114.
9. Sustainable Packaging Coalition. *Introduction to the Guide for EPR Proposals*. 2022; Available from: https://epr.sustainablepackaging.org/.
10. UNEP, *Legal Limits on Single-Use Plastics and Microplastics: A Global Review of National Laws and Regulations.* 2018.
11. Nash, J. and C. Bosso, *Extended Producer Responsibility in the United States.* Journal of Industrial Ecology, 2013. **17**(2): p. 175-185.
12. ACC, *Plastic Makers Support Fair, Feasible Policy Approaches To Improve Packaging Recycling*. 2021.
13. Eureka Recycling. *Minnesota Passes Extended Producer Responsibility for Packaging*. 2024; Available from: https://eurekarecycling.org/mn-passes-extended-producer-responsibility-for-packaging/.
14. NCSL, *Extended Producer Responsibility.* 2023.
15. Product Stewardship Institute. *EPR Laws in the United States*. 2024; Available from: https://productstewardship.us/epr-laws-map/.
16. City of Ottawa, *The Circular Economy and Extended Producer Responsibility*.
17. US EPA, *Advancing Sustainable Materials Management: 2018 Fact Sheet Assessing Trends in Material Generation, Recycling, Composting, Combustion with Energy Recovery and Landfilling in the United States*. 2020: Washington, DC.
18. Townsend, T., Chickering, G., Krause, M., *2015 Waste Composition Study March 3-6, 2015*. 2015.
19. US Food and Drug Administration. *The Microbead-Free Waters Act: FAQs*. 2022; Available from: https://www.fda.gov/cosmetics/cosmetics-laws-regulations/microbead-free-waters-act-faqs.
20. Container Recycling Institute, *Redemption Rates and Other Features of 10 U.S. State Deposit Programs*. 2024.
21. Li, Z. and F. Zhao, *An analytical hierarchy process-based study on the factors affecting legislation on plastic bags in the USA.* Waste Management & Research, 2017. **35**(8): p. 795-809.
22. City of South Fulton, *An Ordinance by the City of South Fulton, Georgia, Encouraging Protection of the Environment, Amending Title 14, Environment, of the City Code of Ordinances, Reducing the Use of Single-Use Plastic Products Within the City and for Other Lawful Purposes*. 2019: County of Fulton.
23. City of Savannah, *A Resolution to Commit the City of Savannah to Protect Its Nature, Waterways, and Neighborhood Streets Through Management of Acceptable Single Use Packaing and Products*. 2021.

24. ACC Solid Waste Department, *Policy and/or Procedure Statement: Glass Bottle REduction Program Reporting Requirement*, S.W. Department, Editor. 2020: Athens, Georgia.
25. Stasiškienė, Ž., J. Barbir, L. Draudvilienė, Z.K. Chong, K. Kuchta, V. Voronova, and W. Leal Filho, *Challenges and Strategies for Bio-Based and Biodegradable Plastic Waste Management in Europe.* Sustainability, 2022. **14**(24): p. 16476.
26. NEGRC Solid Waste Management Authority, *Regional Solid Waste Management Plan*. 2022.
27. UGA Office of Sustainability, *University of Georgia Sustainable Development Goals Report | 2021*. 2021, University of Georgia: Athens, GA.
28. LiveNation Entertainment. *Atlanta Becomes First U.S. City to Implement TURN Reusable Cup Systems Across All Live Nation Venues*. 2023; Available from: https://www.livenationentertainment.com/2023/06/atlanta-becomes-first-u-s-city-to-implement-turn-reusable-cup-systems-across-all-live-nation-venues/.
29. ACC Recycling Division. *Mixed Recycling*. Available from: https://www.accgov.com/1329/Recycling.
30. ACC Recycling Division, *Recyclable Items Flyer*, S.W. Department, Editor. 2022.
31. ACC REcycling Division. *Athens-Clarke County Solid Waste Department Commercial Recycling Plan Form*. Available from: https://www.accgov.com/FormCenter/Solid-Waste-4/Athens-Clarke-County-Solid-Waste-Departm-201.
32. ACC Recycling Division. *Commercial Recycling FAQs*. Available from: https://www.accgov.com/5354/Frequently-Asked-Questions.
33. ACC Recycling Division. *Private Haulers*. Available from: https://www.accgov.com/1318/Private-Haulers.
34. ACC Recycling Division, *ACC Guide to Commercial Recycling - Restuarants*, S.W. Department, Editor.
35. ACC Recycling Division, *ACC Guide to Commercial Recycling - Retail*, S.W. Department, Editor.
36. ACC Recycling Division. *CHaRM (Center for Hard to Recycle Materials)* Available from: https://www.accgov.com/5894/Hard-to-Recycle-Materials-CHaRM.
37. ACC Solid Waste Department, *Athens-Clarke County Composting Facility*.
38. ACC Solid Waste Department. *Normaltown & Boulevard District Residential Compost Pilot Project* Available from: https://www.accgov.com/composttrial.
39. New Materials Institute, *Athens-Clarke County, University of Georgia seek 400 local residences for study on curbside pickup of food scraps* University of Georgia.
40. *CRITERIA FOR CLASSIFICATION OF SOLID WASTE DISPOSAL FACILITIES AND PRACTICES, 40 CFR pt. 257*. 2024.
41. *Hazardous and Solid Waste Management System: Disposal of Coal Combustion Residuals From Electric Utilities; Legacy CCR Surface Impoundments, 89 FR 38950*. 2024.
42. Environmental Protection Division, *2022 Tonnage_Totals_By_Quarter 2022 final.xlsx*, Georgia Department of Natural Resources, Editor. 2022.
43. Environmental Protection Division, *2020 Remaining Capacity.xlsx*, Georgia Department of Natural Resources, Editor. 2020.
44. ACC Solid Waste Department. *Fees, Materials & Other Services*. Available from: https://www.accgov.com/1310/Fees-Materials-Other-Services.
45. Solid Waste Advisory Commission, *Division Reports: March, 2023*, A.S.W. Department, Editor. 2023.
46. Solid Waste Advisory Commission, *Division Reports: December, 2022*, A.S.W. Department, Editor. 2022.
47. Moore Recycling Associates Inc., *2015 National Post-consumer Plastic Bag & Film Recycling Report*. 2017, American Chemistry Council.
48. US EPA, *2019 Wasted Food Report: Estimates of generation and management of wasted food in the United States in 2019*. 2023.

49. US EPA. *Approaches to Composting*. 2023; Available from: https://www.epa.gov/sustainable-management-food/approaches-composting.
50. Compostia. *Compostia: Food Scraps and Compostables Pick Up Service, Athens, GA*. Available from: https://www.compostia.com/.
51. Sims, K., A. Reith, E. Bright, J. McKee, and A. Rose, *LandScan Global 2021*. 2022, Oak Ridge National Laboratory: Oak Ridge, TN.
52. Jambeck, J.R. and K. Johnsen, *Citizen-Based Litter and Marine Debris Data Collection and Mapping.* Computing in Science & Engineering, 2015. **17**(4): p. 20-26.
53. Keisling, C., *The Characterization of the Abundance and Movement of Anthropogenic Litter via Stormwater Runoff with Proposed Reduction Options*. 2021, University of Georgia.
54. Ocean Conservancy, *#SeatheChange: 2023 Report*. 2023.
55. Circularity Informatics Lab, *Circularity Assesment: Vicksburg, Mississippi, USA*. 2023, University of Georgia: Athens, GA.
56. Circularity Informatics Lab, *Circularity Assesment: Miami, Florida*. 2021, University of Georgia: Athens, GA.
57. Law, K.L., Starr, N., Siegler, T., Jambeck, J., Mallos, N., Leonard, G., *The United States' contribution of plastic waste to land and ocean.* Science Advances, 2020. **6**(44).
58. Waste360, *Eunomia Sets New Measures to Tackle Cost of Illegal Dumping*, in *Waste360*. 2023.
59. Shearer, L., *Besides the ugliness, litter costs Athens some big bucks*, in *Athens Banner-Herald*. 2018.
60. Burns & McDonnell, *The Cost of Litter & Illegal Dumping in Pennsylvania: A Study of Nine Cities Across the Commonwealth*. 2020.
61. Monroe, E.M., *Spatial and Temporal Patterns of Microplastic Concentrations in Athens-Clarke County, Georgia Wastewater Treatment Systems*. 2021, University of Georgia.
62. ACC Solid Waste Department, *Compost Haulers*.
63. ACC Solid Waste Department. *Recycling Facility*. Available from: https://www.accgov.com/6281/Recycling-Facility.

Appendix

Table A1: 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

Table A2: Full table of manufacturers of top convenience products

Manufacturer	Manufacturing Location
Alani Nutrition	Louisville, Kentucky, USA
American Licorice Co	Laporte, Indiana, USA
Amplify Snack Brands	Austin, Texas, USA
Argo Teat	Chicago, Illinois, USA
Arizona	Woodbury, New York, USA
Atkinson Candy Company	Lufkin, Texas, USA
August Storck USA	Chicago, Illinois, USA
BA Sports Nutrition LLC	Queens, New York, USA
Bai Brands LLC	Plano, Texas, USA
Beanfields	Los Angles, California, USA
Better Made Special	Detroit, Michigan, USA
Boom Chika Pop	Osseo, Minnesota, USA
Canada Dry Mott's INC	Mississauga, Ontario, Canada
Cheetos	Plano, Texas, USA
Core Nutrition LLC	Plano, Texas, USA
CytoSport	Beicia, California, USA
Danone Waters of America Inc.	Pasadena, California, USA
Deer Park	Chesterfield County, South Carolina, USA
Deja Blue	Plano, Texas, USA
Dole Food Company	Thousand Oaks, California, USA
Dot's Pretzels	Velva, North Dakota, USA
Dr Pepper Snapple Group	Plano, Texas, USA
Dunkin Donuts	Canton, Massachussetts, USA
Essentia Water	Bothell, Washington, USA
Ferrara Candy Co.	Chicago, Illinois, USA Franklin Park, Illinois, USA Warsaw, Poland
Ferrero USA Inc	Parsippany, New Jersey, USA

Food Should Taste Good	Minneapolis, Minnesota, USA
Fox Ledge Inc.	Honesdale, Pennsylvania, USA
Frito-Lay	Plano, Texas, USA
Funyuns	Plano, Texas, USA
Gatorade	Chicago, Illinois, USA
General Mills	Minneapolis, Minnesota, USA
Glaceau	Atlanta, Georgia, USA Morpeth, Northumberland, UK
Godiva Chocolatier Inc.	Reading, Pennsylvania, USA
Goezte's Candy Co, Inc	Baltimore, Maryland, USA
Golden Flake Snack Foods	Birmingham, Alabama, USA
Grupo Bimbo	Coppell, Texas, USA
Haribo of America, Inc	Rosemont, Illinois, USA
Herr's	Nottingham, Pennsylvania, USA
Hint Inc.	San Francisco, California, USA
Independent bottlers for Alkaline88, LLC	Scottsdale, Arizona, USA
Just Born Inc.	Bethlehem, Pennsylvania, USA
Just Goods Inc.	Glens Falls, New York, USA
Kettle Brand	Salem, Oregon, USA
Keurig Dr. Pepper	Norcross, Georgia, USA
Kitchen Fresh Candies	Hunt Valley, Maryland, USA
La Joya Wraps and Snack Products	Montoray, Nueva Leon, Mexico
Lays	Plano, Texas, USA
Lindt & Sprungli	Kilchberg, Switzerland
Lipton	New York, New York, USA
Mars Inc.	Albany, Georgia, USA
Mars Wriggley Confectionary	Hackettstown, New Jersey, USA
Milo's Tea Company Inc.	Bessemer, Alabama, USA
Minute Maid	Apopka, Florida,USA
Mondelez Global LLC	East Hanover, New Jersey, USA

Motts LLP	Plano, Texas, USA
Naked Juice Co	Irvine, California, USA
NatuChips	Plano, Texas, USA
Nestle	Burlington, Wisconsin, USA
Ocean Spray Cranberries Inc	Lakeville-Middleborough, Massachussetts, USA
OWYN	Fairfield, New Jersey, USA
Pearson's Candy Co	St. Paul, Minnesota, USA
Pepsico	Knoxville, Tennessee, USA
Perfetti Van Melle USA	Erlanger, Kentucky, USA
Perrier	Vergèze, France
Pringles	Jackson, Tennessee, USA
Sabritones	Plano, Texas, USA
Sensible Portions	Lake Sucess, New York, USA
Smart Sweets Inc.	Vancouver, British Columbia, Canada
Smarties Candy Company	Union, New Jersey, USA
Snapple Beverage Corporation	Frisco, Texas, USA
Spangler Candy Company	Bryan, Ohio, USA
SPI Westport Incorporated	San Francisco, California, USA
Squirt	Tecámac - Ent. Atlatongo, San Pablo Tecalco, Méx., Mexico
Star Brands North America Inc.	White Plains, New York, USA
Sunchips	Plano, Texas, USA
Talking Rain Beverage Company	Preston, Washington, USA
The Coca-Cola Company	Atlanta, Georgia, USA Marietta, Georgia, USA
The Hershey Company	Hanover, Pennsylvania, USA Hershey, Pennsylvania, USA Quebec, Ontario, Canada
The Pepsi Bottling Group	Athens, Georgia, USA
The Wonderful Company	Los Angeles, California, USA
Tootsie Roll Industries, LLC	Chicago, Illinois, USA
Topps	Scranton, Pennsylvania, USA

Tropicana Manufacturing Company	Bradenton, Florida, USA
Tum-e Yummies	Atlanta, Georgia, USA
Vita Coco	New York, New York, USA
Vital Proteins LLC	Franklin Park, Illinois, USA
Wise	Berwick, Pennsylvania, USA
Wrigley Company	Yorkville, Illinois, USA
Zapps	Hanover, Pennsylvania, USA

Table A3: Full table of Parent Companies of top convenience products

Parent Company	Parent Company Location
Alani Nutrition	Louisville Kentucky, USA
All Market Inc	New York, New York, USA
American Licorice Co	Laporte, Indiana, USA
Angie's Artisan Treats	Osseo, Minnesota, USA
Atkinson Candy Company	Lufkin, Texas, USA
August Storck KG	Berlin, Germany
Better Made Snack Foods	Detroit, Michigan, USA
Bleu Triton	Stamford, Connecticut, USA
Campbell's Soup Company	Camden, New Jersey, USA
Core Nutrition LLC	Plano, Texas, USA
CVS	Woonsocket, Rhode Island, USA
Danone	Paris, France
Ferraro SpA	Alba, Italy
Frito-Lay	Plano, Texas, USA
General Mills	Minneapolis, Minnesota, USA
Goezte's Candy Co, Inc	Baltimore, Maryland, USA
Golden Enterprises Inc	Birmingham, Alabama, USA
Golden Fleece Bevarages Inc.	Chicago, Illinois, USA
Grupo Bimbo	Mexico City, Mexico

Halen Brands Inc	Fairfield, New Jersey, USA
Haribo	Bonn, Germany
Herr Foods Inc.	Nottingham, Pennsylvania, USA
Hershey Trust Company	Hershey, Pennsylvania, USA
Hint Inc.	San Francisco, California, USA
Hornell Brewing Co., Inc.	Cincinnati, Ohio, USA
Just Born Inc.	Bethlehem, Pennsylvania, USA
Just Goods Inc.	Glens Falls, New York, USA
Kellogg's	Battle Creek, Michigan, USA
Keurig Dr Pepper	Plano, Texas, USA
La Joya Wraps and Snack Products	Montoray, Nueva Leon, Mexico
Lindt & Sprungli	Kilchberg, Switzerland
Mars Inc	McLean, Virginia, USA
Milo's Tea Company Inc.	Bessemer, Alabama, USA
Mistic Beverage Inc.	New Rochelle, New York, USA
Mondelez International Group	Chicago, Illinois, USA
Nestle	Vevey, Switzerland
Ocean Spray Cranberries Inc	Lakeville-Middleborough, MA
Pearson's Candy Co	St. Paul, Minnesota, USA
Pepsico	Purchase, New York, USA
Perfetti Van Melle	Breda, Netherlands
PowerPlant Partners	Los Angles, California, USA
Small Planet Foods	Minneapolis, Minnesota, USA
Smart Sweets Inc.	Vancouver, British Columbia, Canada
Smarties Candy Company	Union, New Jersey, USA
Spangler Candy Company	Bryan, Ohio, USA
SPI Westport Incorporated	San Francisco, California, USA
Talking Rain Beverage Company	Preston, Washington, USA
The Alkaline Water Company Inc.	Scottsdale, Arizona, USA
The Coca-Cola Company	Atlanta, Georgia, USA

The Hain Celestial Group Inc	Lake Sucess, New York, USA
The Hershey Company	Hershey, Pennsylvania, USA Derry Township, Pennsylvania, USA
The Wonderful Company	Los Angeles, California, USA
Tootsie Roll Industries, LLC	Chicago, Illinois, USA
Topps	New York City, New York, USA
Utz Quality Foods	Hanover, Pennsylvania, USA
Wise	Berwick, Pennsylvania, USA
Yildiz Holding	Istanbul, Turkey

Table A4: Summary of organic waste and compost haulers in ACC by quantity (Source: ACC Solid Waste Department [62])

Quantity (cy)	Business name	Phone	Website (if available)
Food and yard waste pickup			
32-gallon cart minimum	ACC Solid Waste Department*	706-250-1007	https://www.compostia.com/
Residential: 4-gallon bin minimum Commercial: 1-5 4-gallon bins	Awesome Possum Composting	706-395-5042	https://www.awesomepossumcomposting.com/
Not specified	Closed Loop Organics*	678-643-7056	https://closedlooporganics.com/
2-gallon bin up to six 4-gallon bins	Compostia	706-250-1007	
Residential: 4-gallon bin Commercial: 10-65 gallon bin or roll off dumpster	CompostNow	919-526-0403	https://www.compostnow.org/
Not specified	LUC (formerly Let-Us-Compost)	404-805-0113	https://www.letuscompost.com/
Compost delivery			
1-3 cubic yards	Jimmy Johnson	706-546-0673	
4-9 cubic yards	Ogle Sanitation	706-742-2164	www.oglesanitation.com
10-20 cubic yards	Double A Hauling	706-742-5598	www.doubleahauling.com
	Gunter Transport	706-255-1158	
	Roll-Off Systems	770-725-7655	http://www.rolloffsystems.com/
	Shane Russell Tractor & Trucking	706-540-9701	
	Teri Harris Trucking	706-543-0062	http://www.teriharristrucking.com/

* Commercial pickup only

Table A5: Summary of end markets for Athens recyclables (Source: ACC Solid Waste Department [63]

Material	End market name	Location	Recycled product
Mixed paper	Pratt Industries	Conyers, GA	New cardboard boxes and other paper products
Old Corrugated Containers	International Paper	Pine Hill, AL	New cardboard boxes
Sorted Office Paper	Cascade Paper	Rockingham, NC	Tissue paper/toilet paper
Glass Bottles & Jars	Strategic Materials, Inc.	Atlanta, GA	New bottles & jars, reflective road paint, and more
PET (#1)	Mohawk Industries	Summerville, GA	Carpet
HDPE (#2)	Envision Plastics	Reidsville, NC	Milk, juice, and cleaner/detergent bottles, others
Plastics #4-6	Not specified	Not specified	Resin
Aluminum beverage cans	Anheuser-Busch Recycling	St. Louis, MO	Scrap metal broker
Aluminum beverage cans	Novelis Corporation	Greensboro, GA	Aluminum cans, automotive components, etc.
Steel/tin cans	Tube City	Glassport, PA	New still products for automotive, bridges, cans, and other sectors
Trash/residual	ACC Landfill	Athens, GA	Landfill material

Table A6: List of items accepted at the ACC CHaRM by material. Bolded items represent those which require additional processing fees (Source: ACC Recycling Division [36]).

Items made of, or potentially containing, plastic or plastic components	Other items
• Appliances and Tools (indoor and outdoor) • Balls (Golf balls, tennis balls and canisters) • Bicycles • Cell phones, tablets, gaming systems • **Computer monitors/screens ($5 each)** • Corks (synthetic or natural) • Electronics & cords/cables • Expired/used gift cards • Eyeglasses • **Hard drives for destruction ($10 each)** • Ink cartridges • **Mattresses & box springs ($10 each)** • **Media (CDs, DVDs, VHS, Tapes, etc.; $0.50 per pound)** • Mixed recyclables (bottles, cans, paper, cardboard, etc.) • Musical instruments • **Paint ($2/gallon container)** • Pallets (wooden or plastic, damaged or intact) • Plastic bags/wrap (plastic bags, stretch film, bubble wrap) • **Sharps/syringes ($5 per container; in a bleach or detergent bottle, residential only. Approximate cost/container is $5 per container, up to approx. 1 gallon capacity, at staff discretion.)** • Shoes (wearable only) • Styrofoam (Clean, No tape) • **Televisions (any size; $5 each)** • **Tires ($3.00/ tire; $10/oversize tire or on rim)**	• **Batteries (all types; $0.50/pound; car batteries $1 each)** • Books (hardcover and paperback) • **Dangerous chemicals requiring separate Lab Pack handling ($10 per gallon)** • **Documents for shredding – ($2/ banker's box-10" x 12" x 15")** • Donations for Teacher Reuse Store • Food Scraps (Residential Only- 24/7 drop-off outside the fence off Cleveland Ave) • Fire extinguishers • Glass (automotive, windows, glass doors, plates, beverage glass) • Glass dishes, plates, beverage glass • Grease (used cooking grease/oil) • Helium, HVAC, & Camping size propane tanks • **Propane tanks (20# or larger; $5 each, smaller; included with facility fee)** • **Light bulbs/tubs ($0.50 each)** • Mercury-containing devices • Motor oil filters • Scrap Metal • Shredded paper • U.S. flags for patriotic retirement at the Veterans of Foreign Wars (VFW)

Social Media Analysis

Education, infrastructure, and information transparency once again make an appearance in the community through our social media analysis. Through the data found in this analysis it is important to remark that information transparency plays a significant role in negative posts, those that usually include the criticism of a product, brand, or company. In this sense, people have negative feelings about the confusion around compostable and biodegradable items, the latter of which is sometimes used for greenwashing. Moreover, greenwashing creates a lot of distrust in potentially eco-friendly alternatives, making clearer labels and information transparency about the end-of-cycle of materials a crucial component of education. Education in the form of social media outreach has been present for a while, however, despite the clarifying bits of information in platforms, it's not always easy for users to refer to

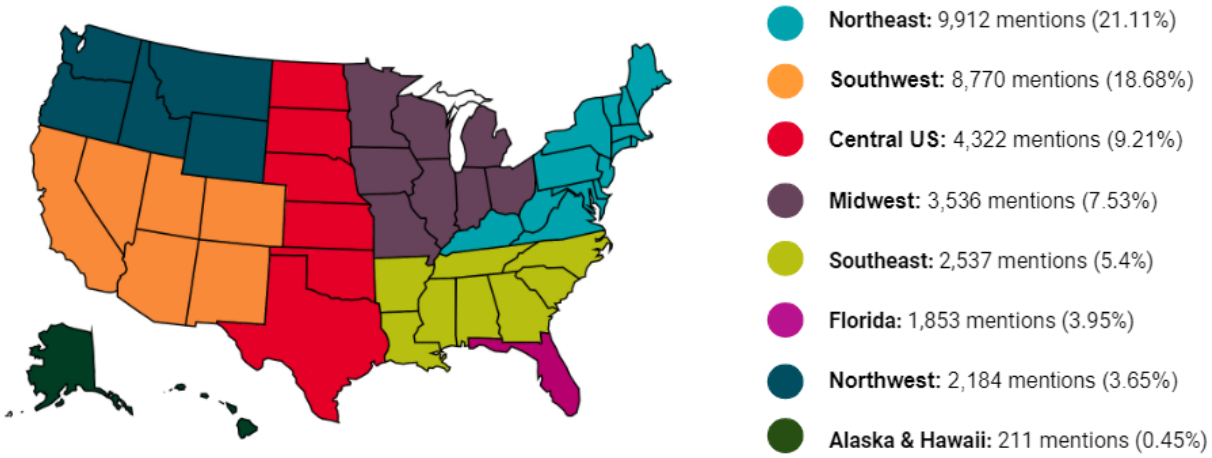
Twitter or Instagram to find information unless they already follow a specific educational account. These educational posts along with hopeful posts on infrastructure and composting count towards the positive or uplifting feelings demonstrated by the social media community. Some other posts give instructions on what to do with small and big contaminants of composting (from fruit stickers to sauce cups), or address the confusion about what is appropriate for what type of composting (home or industrial) and guide people on what what type of composting should be used for a certain product and what to do with it in the case of lack of infrastructure. In general, positive feelings posts highlight education initiatives or infrastructure/materials development while negative posts focus on the lack of information transparency that creates confusion and distrust, which is consistent with interviews and the general themes of stakeholders' concerns. Overall, between the lack of industrial composting facilities and citizens' confusion in how to dispose of plastic alternatives, the widespread introduction and use of compostables needs a responsible approach that includes addressing education, infrastructure, information transparency, and economics.

From July 1st, 2021, to August 31st, 2021, the Social Media Engagement and Evaluation (SEE Suite) group at University of Georgia's Grady College of Journalism and Mass Communication conducted a Compostable Plastics & Bioplastics Social Media Analysis using Bandwatch to aid in our understanding of consumer access and awareness of compostable and biodegradable plastics. SEE Suite sought to address three questions:

8. Are people aware of and purchasing biodegradable plastic alternatives?
9. Do people have access to compostable/biodegradable plastics in their community?
10. What types of composting systems would people like to see in their communities?

A geographic analysis of responses is shown below:

Figure A2: Geographic Analysis by Region



Twitter Conversations & Mentions

Conversations related to the awareness of and purchasing of biodegradable plastic alternatives that were analyzed on Twitter varied by region. 3.7% of the conversations related to biodegradable plastics were from the Southeast, while 7.5% of these conversations were from the Midwest. In contrast, 31% of biodegradable plastic conversations came from the Northeast and the Southwest, which indicates the regional awareness of plastic alternatives is higher in these areas than in the Southeast and Midwest. Tweets based on terms such as buy, own, purchase, use etc. captured 13.36% of the dataset, yet these conversations mostly discussed purchasing straws made from bioplastics, biodegradable/compostable straws, and reusable bags. Overall, purchasing patterns were difficult to gauge based on Twitter conversations.

Compostable/biodegradable plastics are widely available at grocery stores such as Walmart, Food Lion, Save A Lot, Kroger, Publix, etc., as well as at online retailers such as Amazon. However, compostable and biodegradable products are more expensive on average when compared to plastic, which can limit accessibility.

SEE Suite's search for specific methods of composting, ("warm composting," "hot composting," "vermicomposting,"etc.), only pulled ~6 mentions, which is very low compared to the almost 700 mentions from the total query. Data suggested that people are more focused on if composting is happening, as opposed to what type of composting. When using broader terms such as "composting infrastructure" and "composting systems," they found that industrial composting centers were desired among a niche group of people.

Industrial Composting

About half of those concerned with industrial composting came mostly from individuals with related professional experience, while the other half originated from nonprofits and professional/trade organizations such as Closed Loop Partners, Industrial Packaging, Nature Works, and the Plastics Industry Association. Most of these conversations revolved around the heat differences between home composting and industrial composting. Other conversations consisted of consumers purchasing biodegradable plastics with the intention of home composting, only to realize that the purchased items had to be sent to industrial composting, while other Tweets were from companies highlighting biodegradable plastics that can be home composted.

Home Composting

Home composting Twitter conversations tended to be broader, and had roughly equal representation from individuals, nonprofits, and companies. 25% of these conversations yielded no insights relating to how to live a more sustainable life or what activities to do to celebrate Earth Day. In contrast, insightful conversations tended to revolve around what items should and should not be added to home composts. A significant number of conversations were about how biodegradable plastics and stickers should not go into one's home compost. Overlapping conversations between Tweets about industrial composting and Tweets about home composting tended to share that industrial facilities are much hotter and that biodegradable plastic products must be sent to an industrial facility. Again, Tweets from companies highlighted products that can be home composted.

Greenwashing

About half of the Twitter conversations on greenwashing within the compostable/biodegradable plastics space came from individual users, while the other half came from media outlets, companies, nonprofits, and trade/professional organizations. Most of these Tweets focused on how biodegradable/compostable plastics/bioplastics are greenwashing, yet they rarely are explicit about sharing why. Conversations also focused on buzzwords that are typically used to convince consumers that a product is more environmentally friendly than it actually is, such as "plant-based," "biodegradable," "all natural," and "compostable." Although less common, conversations about how to avoid greenwashing typically bring up product labeling and certification, such as the USDA Certified Biobased label. Interestingly, there were a few instances where brands such as Exxon, Coca Cola Company, Unilever, and EcoTools were called out for explicit greenwashing.

Aside from the major themes related to industrial composting, home composting, and greenwashing, additional themes that emerged related to Packaging & Products, the Environment, Circular Economy, Purchasing Compostable/Biodegradable Plastics, and Research, Innovation, & Design.

- Packaging & Products: related to the materials used in packaging, as well as consumer products
    - Total Mentions: 9,997; 21.31% of all mentions
- The Environment: mentioned ecological systems from which bioplastics primarily benefit, such as oceans and plants
    - Total Mentions: 9,480; 20.19% of all mentions
- Circular Economy: primarily mentioned topics of recycling, composting, and reusing plastics
    - Total Mentions: 6,618; 14.11% of all mentions

- Purchasing Compostable/Biodegradable Plastics: related to the purchasing of biodegradable plastics instead of other plastic that is more environmentally harmful
    - Total Mentions: 6,266; 13.36% of all mentions
- Research, Innovation, & Design: focused mainly on research related to bioplastics and the market, as well as new forms of compostable and biodegradable technology
    - Total Mentions: 5,025; 11.1% of all mentions

Individual conversations related to these themes are shown on a timeline below:

Figure A3: Timeline of Conversations, July 1, 2021 - September 30, 2021

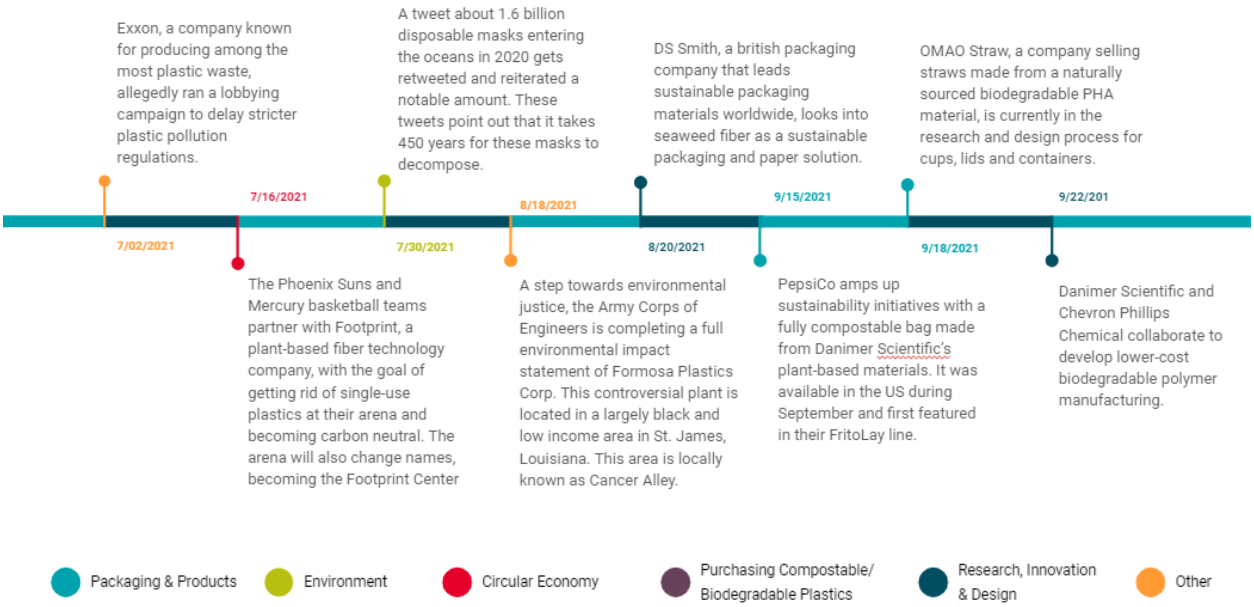


Figure A4: Timeline of Conversations, October 1, 2021 - December 31, 2021

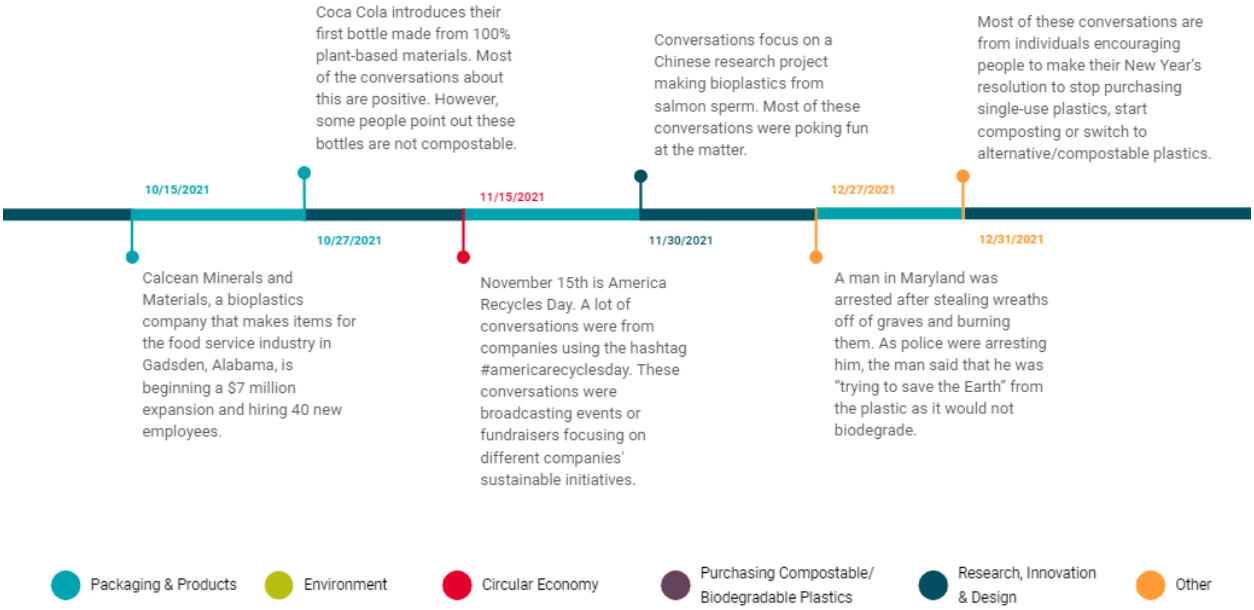


Figure A5: Timeline of Conversations, January 1, 2022 - March 31, 2022

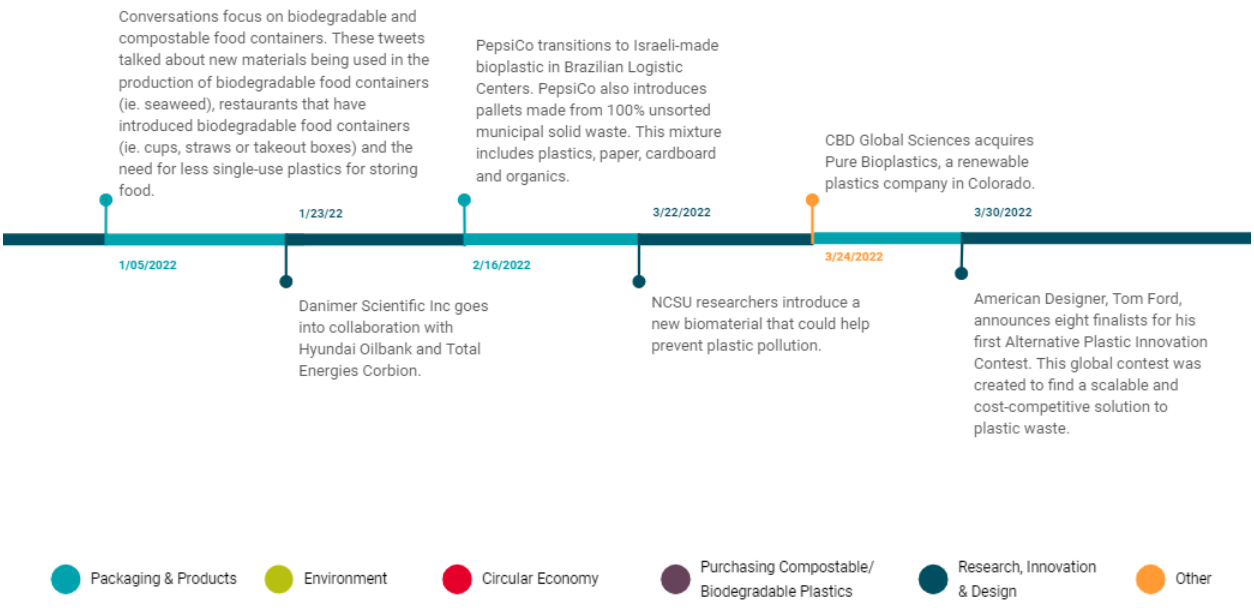


Figure A6: Timeline of Conversations, April 1, 2022 - June 30, 2022

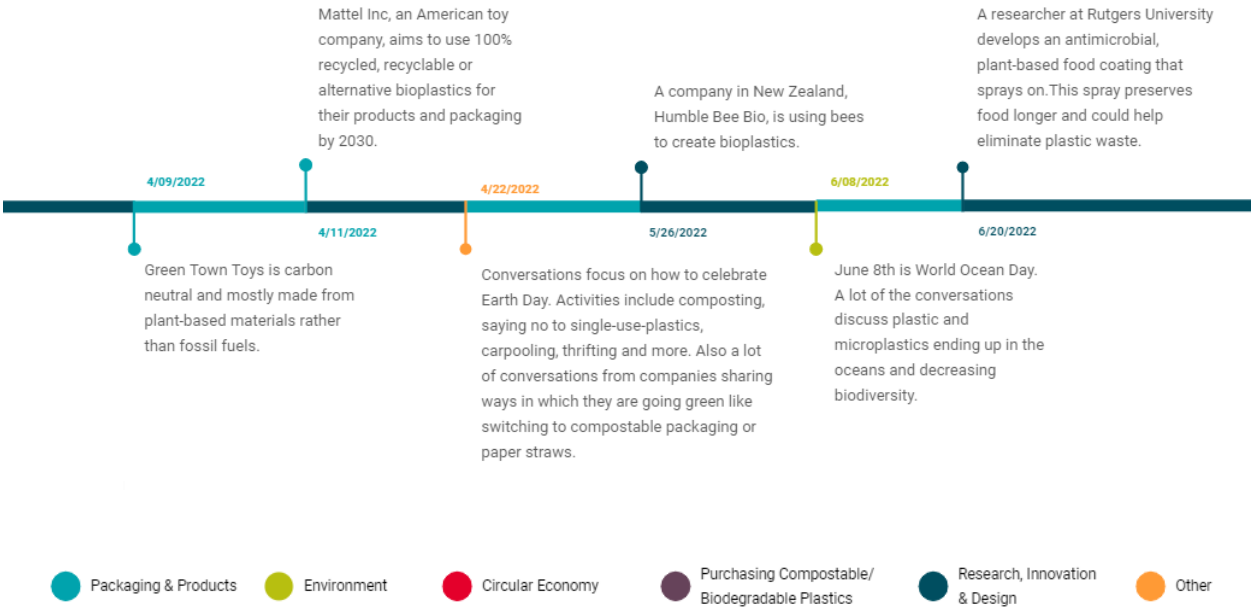
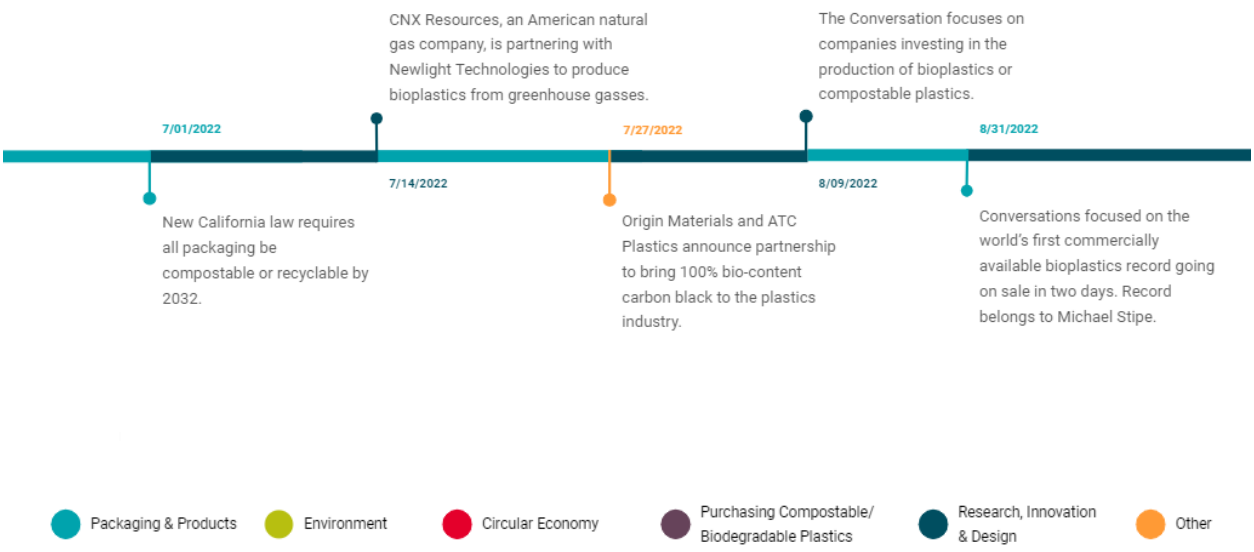


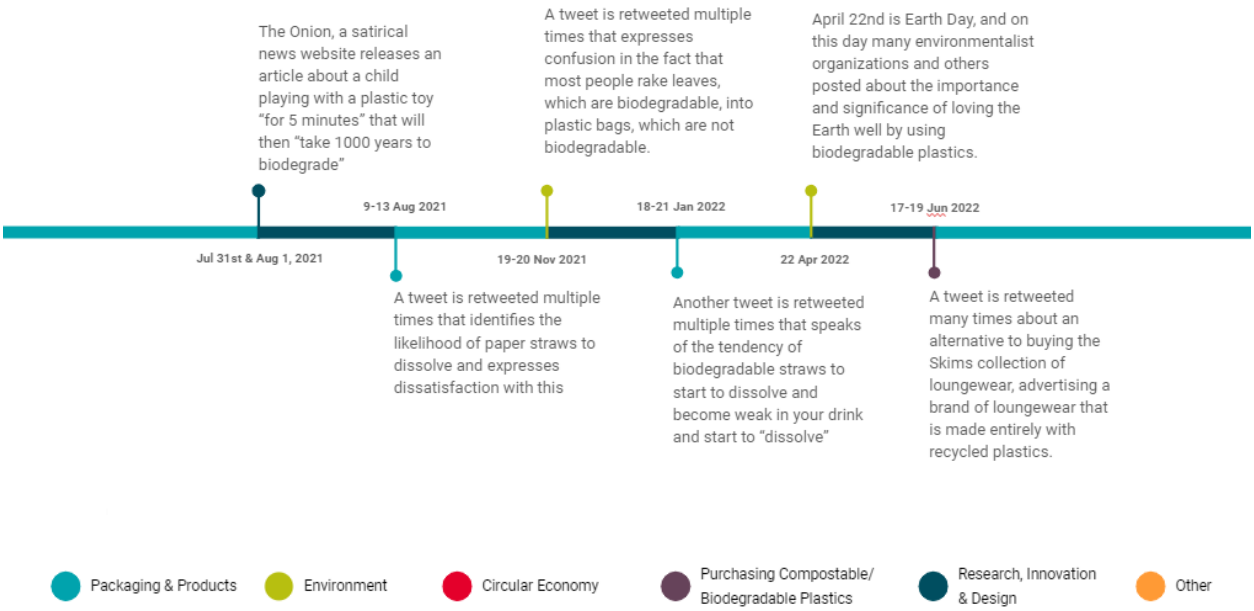
Figure A7: Timeline of Conversations, July 1, 2022 - August 31, 2022



Insights from the Southeast

Insights from the Southeast include both Tweets from the Southeast, and Tweets about the Southeast. Unique trending topics include "plastic pollution" (2,374 mentions) and "ban single use plastics" (104 mentions). "Plastic pollution" Tweets mostly described the environmental harm that plastics cause, as well as ways to combat this problem. Although a more narrow topic, "ban single-use plastics" examined the idea of single-use plastic bans in the South, which is increasingly gaining traction in the region.

Figure A8: Conversations from the Southeast; June, 2021 - July 31, 2022



Instagram Conversations & Mentions

While conversations about plastics, biodegradable and compostable materials, and related topics did happen on Instagram, Instagram's platform is mostly used as a way to sell alternative products. From Instagram, three main topics emerged, with total mentions of 140,753 and a total reach of 206,270,463. These topics are listed below:

- "Plastic Free July": @plasticfreejuly creates most of the posts mentioning this topic. Plastic Free July encourages people to stop consuming single-use plastics as part of their larger goal of ending plastic pollution globally. The nonprofit Let's Be Plastic Free mentioned the Plastic Free July Campaign in their popular yearly campaigns, while other nonprofits mentioned it when talking about actions to curb plastic pollution, such as composting. Companies mention Plastic Free July when promoting products that are packaged in compostable or biodegradable materials.
    - 6,657 mentions; 9,888,269 reach
- "Plastic Pollution": most of the mentions of plastic pollution come from nonprofits and companies. Nonprofits primarily mention plastic pollution when talking about community events such as beach cleanups, as well as other actions that curb plastic pollution. Companies tend to mention plastic pollution when discussing sustainability initiatives that resulted in less plastic pollution (such as turning waste into a bioplastic) or when discussing biodegradable packaging. Other posts related to environmental degradation, primarily in aquatic ecosystems. About 25% of these posts also mention Plastic Free July.
    - 4,629 mentions; 29,817,854 reach
- "Plant Based": here, "plant based" was used in multiple contexts, as this is the broadest topic. Food and restaurants described as being organic or plant forward consisted of the most common usage for the phrase; these conversations tended to mention biodegradable or compostable

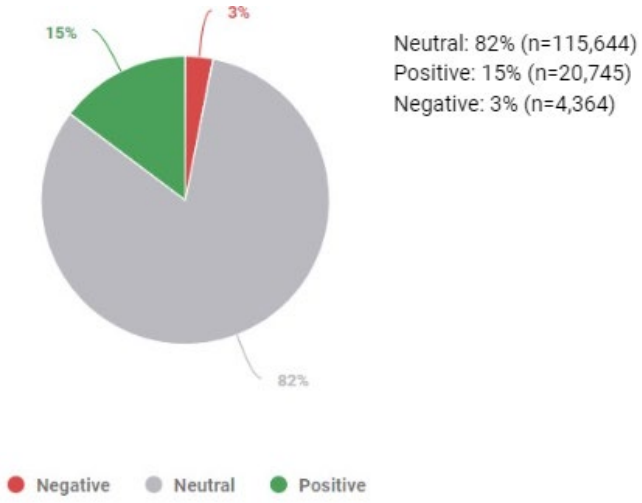
packaging. There were also many cleaning products and beauty products that were plant based. Posts from the two topics above -- "Plastic Free July" and "Plastic Pollution" -- tended to be evenly split between companies and nonprofits, with a few individuals chiming in. However, this topic mostly consisted of companies displaying and promoting different products.

- 13,585 mentions; 19,868,364 reach

Beauty and household products were a theme that was more specific to Instagram, consisting of 15.8% of the conversation, with 22,181 mentions and a total reach of 21,746,642. The eco-friendliness of everyday household and beauty products has been a prevalent topic of discussion in recent years. Conversations within this theme tend to be brands advertising their eco-friendly products on Instagram, due to Instagram's large marketplace and advertising platform. Other discussions urged consumers to not choose the "wrong products" by describing how those products are resulting in environmental harm.

Although posts sometimes had to mention the negative to promote positives, sentiment in Instagram posts tended to be neutral (82%), while positive posts (15%) outweighed the negative posts (3%).

Figure A9: Overview of Sentiment



While positive conversations were broad, they tended to come from companies and nonprofits. Companies had positive conversations when promoting new products, new partnerships, or anniversaries of important innovation milestones. Nonprofits were a part of many positive conversations when highlighting increasingly sustainable companies or successful events. Other posts from nonprofits and influencers relate to the impact that composting has on health and the environment. The top positive post in this dataset combined innovation and plastic is 4ocean's plastic guitar, shown below.

Figure A10: Top Positive Post - 4ocean Plastic Guitar

4ocean A guitar made from recovered ocean plastic 🎸

Last year, our good friend @Burlsart joined us for a day on the water cleaning up trash in Boca Raton, FL. The goal? Collect ocean plastic that Burls can turn into an epic guitar!

Due to its durability, Burls chose to use recovered HDPE and polypropylene plastic for the body of the guitar. And if you take a close look at the neck, you'll notice it's made up of plastic straws 👀

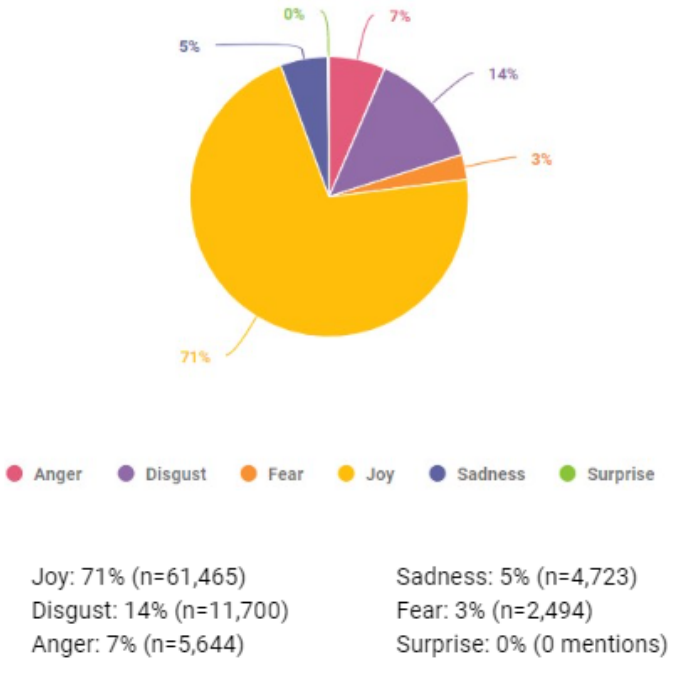
To check out a YouTube video on how Burls made this rad guitar, visit the link in our bio!

Negative conversations were also broad, but tended to bring up topics related to environmental harm, plastic pollution, and waste, as well as how these topics related to environmental justice issues and human health outcome. Some posts mention a lack of industrial composting facilities or people not sorting items correctly in waste or recycling bins. The top negative post was @get.waste.ed's post where they used a picture of Colgate's biodegradable packaging wrapped in plastic to promote their own line of bamboo toothbrushes.

Figure A11: Top Negative Post - Get.waste.ed and Colgate

While Brandwatch only categorized 61.12% of our dataset based on emotion, the emotions shown in Instagram posts tended to be overwhelmingly positive.

Figure A12: Overview of Emotions



Joy: 71% (n=61,465)
Disgust: 14% (n=11,700)
Anger: 7% (n=5,644)
Sadness: 5% (n=4,723)
Fear: 3% (n=2,494)
Surprise: 0% (0 mentions)

Conversations portraying joy were mostly from nonprofits expressing excitement about upcoming events and celebrations. Other conversations from individuals, companies, and nonprofits invoked discussions on

the beauty of nature while homing in on the importance of limiting plastic waste by purchasing products in compostable packaging or by composting. Other companies shared excitement about new compostable packaging or bioplastic products. Conversations portraying disgust tend to focus on fossil fuel, petroleum, and fishing industries, as well as pollution and plastic waste. Conversations that portray anger tend to be from individuals who express their irritation with a lack of global environmental policies, detailing how arduous legal and legislative processes are and how big companies should take more accountability by participating in sustainability initiatives, changing their packaging, etc.

Overall, interest in biodegradable and compostable materials, concern over plastics, and other related materials seems to be growing on platforms like Twitter and Instagram. While individuals do participate in these interrelated conversations on both Twitter and Instagram, nonprofits, companies, and even some professionals in this space seem to be leading the discourse. While Twitter conversations tended to be more closely related to discourse about these topics, Instagram's visual nature provided more of an opportunity to promote alternative products.