What Baltimore's Waste Management System is Missing: A Case for Measuring Idle Resources

At a Glance

The efficiency of municipal solid waste (MSW) systems is evaluated with regards to disposal, diversion, and recycling rates. These metrics capture end-of-life outcomes for waste, but overlook a significant portion of materials in MSW systems that retain functional value but remain unused, delayed, or stranded structurally before disposal.

Utilizing results from a case study we conducted in Baltimore city, we introduce and define **“idle resources”** as materials with remaining utility that lose their value due to inactivity, bottlenecks, or other inefficiencies in modern MSW systems. We argue that this phenomenon is non-existent in measures of MSW efficiency, as idle resources never formally enter the disposal streams in which measurements are taken. Without accounting for idle resources, cities like Baltimore systematically underestimate the true inefficiency of their waste management systems, missing actionable opportunities to recover value before it is permanently lost.

The concept of idle resources reframes opportunities for infrastructure interventions that can help reduce waste. We propose the conceptual and measurement effects of incorporating idle resources into current sustainability assessment frameworks. This includes identifying key design, governance, and infrastructural interventions capable of reducing inactivity and enhancing sustainability of current MSW systems.

Problem

Lack of Circular Economy

Globally, over 2 billion tons of MSW are produced each year, yet only 19% is composted or recycled. In the United States, half of MSW is landfilled (Chertow et al). Global MSW generation shows no signs of slowing. Projected to grow from 2.1B tons in 2023 to 3.8B tons by 2050, this 81% increase is more than double the rate of projected population growth over the same period. Currently, food and green waste make up the largest share of 44% of global MSW, followed by recyclable materials at 38% (Kaza et al). The significant portion of recyclable materials present in global MSW statistics highlights a global mismanagement issue within waste management systems.

The concept of a circular economy has emerged in response to the current system of MSW management. Instead of the linear extract-produce-discard model of the past, the circular economy model advocates for keeping materials in use, recovering valuable resources, and disconnecting economic growth from rampant resource consumption (Ferronato et al., 2019). However, existing circular economy frameworks heavily weigh end-of-life interventions, monitoring metrics like recycling rates, landfill diversion, and waste-to-energy conversion. These mechanisms fail to accurately consider or track what happens to materials before entering the final stages of current MSW pipelines. Furthermore, little MSW research examines the period during which materials retain functional value but remain unused due to systemic delays or coordination failures.

Baltimore offers an instructive case to examine these dynamics, managing over 200,000 tons of waste annually (Baltimore City Department of Public Works). Its waste management infrastructure situation is lacking on multiple fronts, with the only solid waste landfill within city limits rapidly reaching its permitted capacity.

Baltimore's Waste Management Problem

Across Maryland, 12.53M tons of waste was produced in 2023, achieving a 40.3% diversion rate of waste kept out of landfills through recycling and other programs (Maryland Department of the Environment, 2025). Baltimore's recycling rates remain among the lowest in Maryland, not meeting the state's mandated threshold of a 35% recycling rate for cities of its size. These metrics indicate Maryland's continued reliance on disposal infrastructure as opposed to closed-loop systems for material recovery. While diversion programs exist, a significant portion of the waste stream still follows the linear disposal pathways of yesterday, highlighting opportunities for intervention in major urban generators of MSW.

In Baltimore, these categories are reflected in the city's reliance on large-scale waste processing infrastructure, particularly conversion of waste to energy via incineration. The Wheelabrator Baltimore facility represents a current technical and logistical approach to managing MSW by reducing landfill demand and simultaneously generating electricity, improving disposal efficiency (Alamu et al., 2021). However, analyses of the facility show that incineration produces significant environmental impacts like greenhouse gas emissions and nitrogen oxide pollution. Additionally, the volume of DPW-hauled waste brought to BRESCO incinerator increased by about 80,000 tons from 2017 to 2024, showcasing only the measured inefficiencies of the Baltimore MSW system ("Baltimore City's").

Still, these values reflect only the portion of the waste stream that reached formal processing; resources that never arrived are not reflected. Current technical infrastructure and governance frameworks promote marginal improvements in MSW systems, but significant inefficiencies remain due to a lack of accurate metrics.

Idle Resources

To address this gap, we define "idle resources" as:

> Materials that retain functional or recoverable value but remain unused, unprocessed, or inaccessible due to systemic delays that lose their value due to inactivity, bottlenecks, or other inefficiencies in modern MSW systems.

This shifts the analytical attention of MSW system assessors away from where materials end up. The question becomes: how long does a resource spend losing value before reaching disposal systems, and could they have been salvaged before? We argue that this phenomenon is uncounted in measures of MSW efficiency, as idle resources never formally enter the disposal streams in which measurements are taken.

Exploring Baltimore's Waste Management Weaknesses: an Interview Project

Mapping the System

Interviews were conducted as a part of the Kindling pre-accelator program at the Johns Hopkins University Pava Center for Entrepreneurship. The goal of our interviews was to identify pain points within Baltimore’s waste management system in the industry professionals, independent sectors, and general public.

We defined these customer personas by their roles as such:

- *Waste industry professionals:* people who directly control the waste management system, such as waste service providers or municipal agencies.
- *Community members:* people who help mitigate waste locally, such as business owners and staff at non-profits.
- *The public:* average citizens who may or may not be conscious about their role in waste management.

Interview findings were compared across phases to surface recurring bottlenecks, inefficiencies, and points where material consistently went unused or underutilized. In Figure 1, we used these findings to outline the system of waste management in Baltimore by tracing the flow of solid waste from household to processing and back to household.

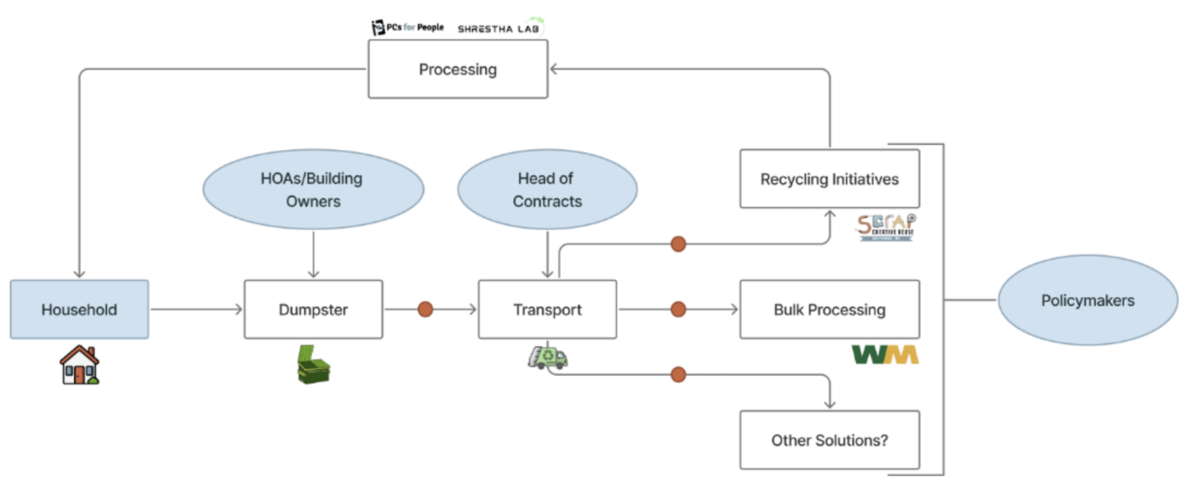

Figure 1: Waste Management Pipeline

The system is segmented into different phases– dumpster, transport, bulk processing, etc.– and important stakeholders in each phase of the flow are highlighted as interview targets. We highlight key areas of opportunity in red, or places where new companies and technologies can innovate to make the process more systematically efficient. These areas include collection-stage efficiency, bulk processing logistics, independent transport pathways, and emergent/experimental interventions.

Interviews

Interviews with waste management industry professionals focused on how their role in the waste management pipeline impacts waste reduction and challenges they face in doing so. Interviews with community members/organizations focused on the impact their work has made on the community, their mission, and challenges. Interviews with public participants focused on everyday waste behaviors, perceptions of recycling and reuse, and personal definitions of "waste."

After comparing the different pain points from our three stakeholder groups, we discovered the common pattern of idle resources. Interviews afterwards included questions tailored more to defining and identifying idle resources as a phenomenon in the Baltimore waste management system.

Interview Findings

Professionals

Interviews with Waste Management professionals highlighted the inefficiencies in the waste system that are driven by logistical constraints and economic incentives, rather than individual behavior. Collection and coordination were mentioned as major pain points. For example, it is difficult for e-waste to make it to a reputable recycler, and though these recyclers exist, they are underutilized due to lack of prioritization. Additionally, economic factors play a role in how successful waste management facilities are in reducing waste. While Waste Management professionals believe that recycling is economically beneficial due to getting more usage out of the same material, any sustainability programs must align with financial incentives before being approved.

Community Organizations

Community organizations believed that public lack of awareness and behavioral issues surrounding the production of waste was less significant. The Station North Tool Library noted that the issue is likely structurally driven by corporations and poor policy. Therefore, it would be ineffective and unfair to place the burden wholly on the community, as the current reuse, recycle, landfill pipeline is systematically ineffective. These non-profits shared the challenge of having capacity constraints, urging for the need for a more collaborative solution. The emergence of tool libraries (and other reuse organizations) arose due to the realization that fragmented resources are hard to find and/or not centralized. They added that certain public grants and policies helped keep their doors open. Lastly, organizations mentioned the existence of idle resources within their own organizations, due to limited awareness.

Public Awareness

Across several interviews, the problem of waste was labelled as a "people's problem" and caused by a lack of education or proactivity in the public's hands. Stakeholders consistently mentioned that people care about waste reduction and sustainability but the system is often confusing (for example, the Hopkins waste management system, Baltimore's lack of recycling etc.). This confusion results from people not being aware of alternatives to throwing items away or belief that their waste is not reused anyway. However, a few students mentioned that people are not particularly concerned with their impact on their environment and continue engaging in sustainable habits. A common pain point with the public was concern over convenience being prioritized over sustainability and reuse. To summarize public opinion, most people framed idle resources as a behavioral problem, while few also acknowledged systemic failures.

Stakeholder Type	# of Interviews	Pain Points
Waste industry professionals/policymakers	4	• Recycling takes many steps before material reuse • Recyclables sorted incorrectly in single-stream systems • Value of recycled materials changes often
Non-profits/community organizations	8	• Red tape and slow processes • Lots of hoops to jump through for compliance • Grant access/funding
Public participants	7	• Individuals do not (or do not know how to) build more sustainable waste habits • Underfunded public services • Limited impact perception

Table 1. Summary of common pain points for interviewed stakeholder types

Idle Resources in Reference to Our Interviews

Now, with the context of these interviews, the concept of idle resources can be exemplified in many sectors. Professionals highlighted how materials fail to move efficiently through collection and processing systems. Community organizations pointed to capacity limits and lack of awareness that prevent redistribution. Meanwhile, individuals described behaviors and system confusion that result in usable items being stored, ignored, or discarded. For example, e-waste, in the form of old and unusable electronics, becomes idle. Fast fashion is a currently relevant sector that produces a lot of idle resources. In terms of research, technologies are being utilized to decrease the amount of waste that could be used for something else, which was idle up until that point. Idle resources are value waiting to be lost.

Integrating "Idle Resources" into Baltimore's Waste Management System: A Research Proposal

To make idle resources legible to policymakers, we propose a structured tool for visualizing where in the system value is being lost and how urgently. First, we must quantify idle resources to gauge how large of a problem it is in Baltimore. However, the sample size and qualitative nature of our study limits generalizability; our findings are exploratory as opposed to statistically representative. Quantitative data is needed to establish the scale of idle resources in Baltimore and identify where intervention will have the highest impact.

We propose a research study to track and quantify idle resources across the organic waste, clothing waste, and construction waste sectors through accurate measurements of wait times for samples. Pilot implementation would likely require partnerships with waste haulers and community organizations already operating in these sectors. This can be done with unique methods for each sector:

Sector	**Methods to Track**
Organic Waste	Weigh and date waste after production and once it reaches the end destination.
Clothing Waste	Apply invisible chemical markers to waste at each stage of the process. One sample unit gets tracked so time difference can be estimated at each stage.
Construction/Larger Waste	Use a small sensor for location and time tracking.

Table 2. Proposed methods to track idle waste in different sectors of waste

This data can then be normalized and augmented into a 3-dimensional matrix to accurately pinpoint areas of concern within the system. The dimensions of the matrix are:

- category of waste (organic, clothing, construction)
- point in waste management pipeline (collection, transport, sorting, processing)
- point in production pipeline (new material, manufacturing, retail, distribution, retail, post-consumer)

Each cell has a weight from 0-100 of the “concern level”. This matrix can be used by policy makers to quickly search and access which areas of the pipeline have the most pressing issues, in order to prioritize mitigating inefficiencies in the most optimal manner.

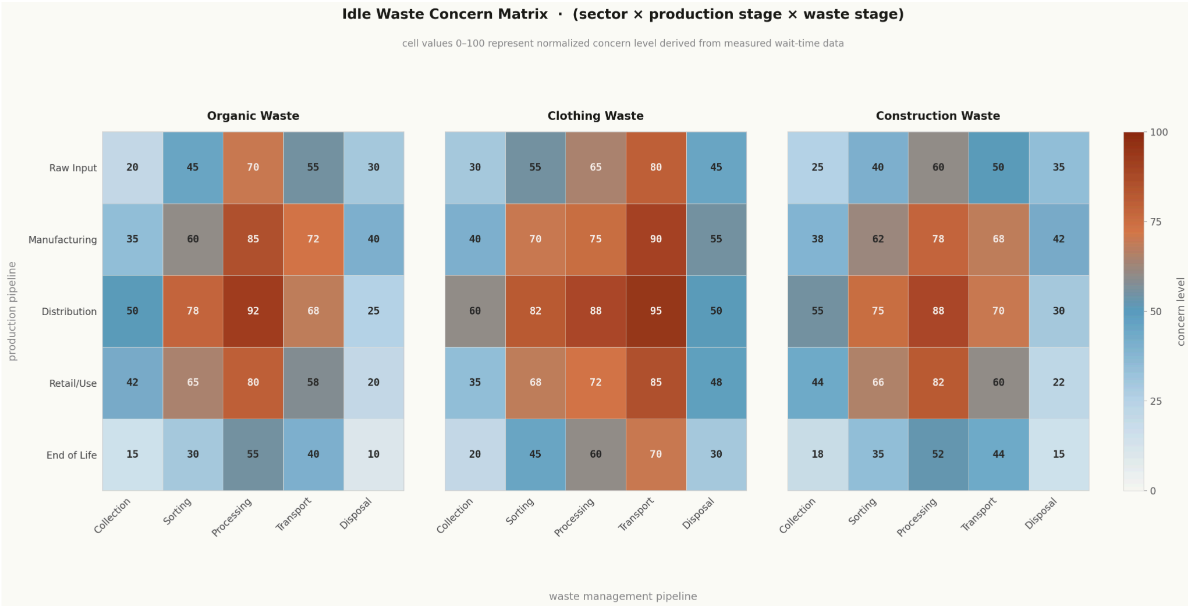

Figure 2. An example rendering of the proposed matrix of idle resources data with sample values

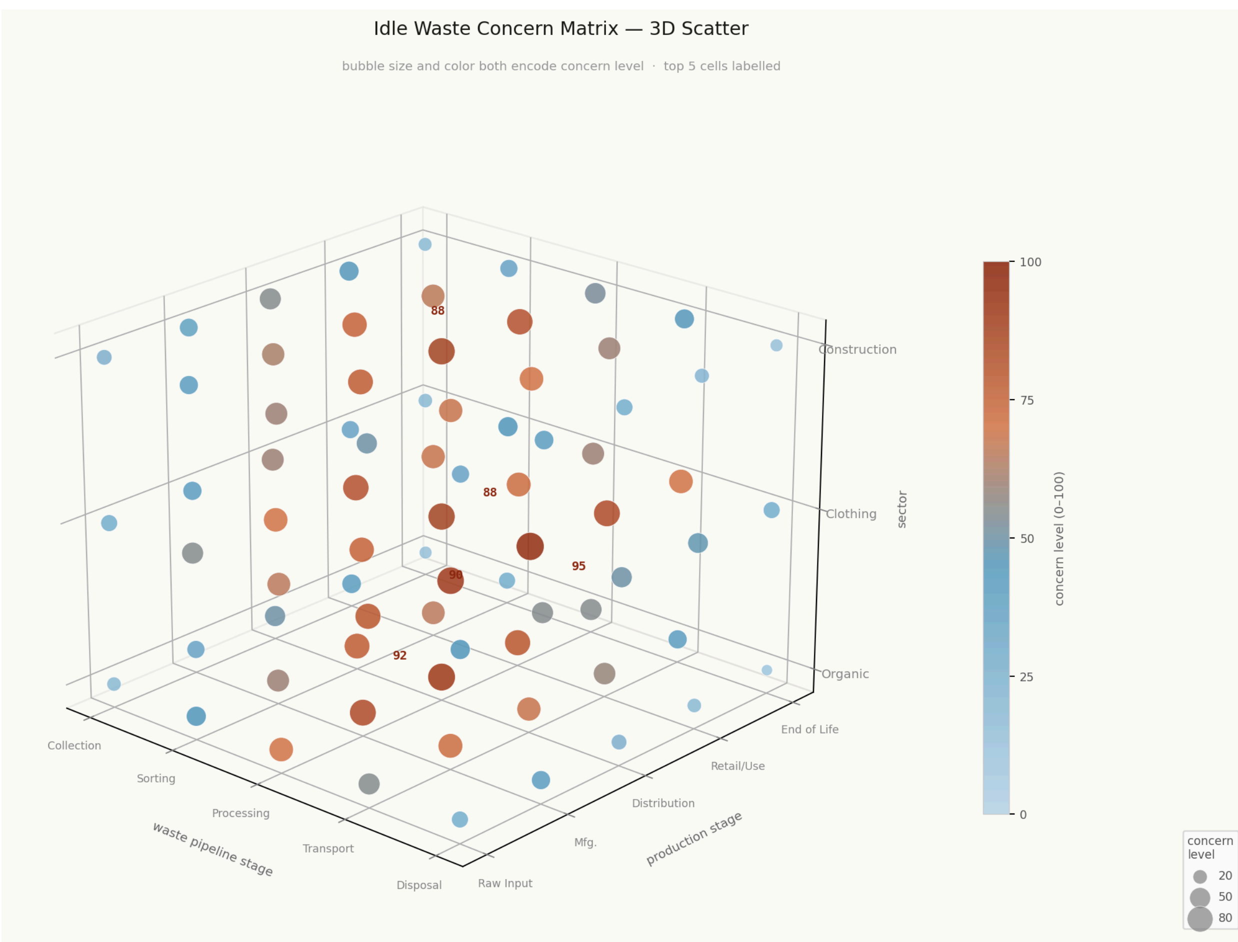

Figure 3. An example rendering of the matrix, 3D view.

Along with the urgency score from the matrix, it will be helpful to track the value decay of idle resources. Each resource will enter the pipeline starting at market price. As time passes, the value of the material will decay according to set decay rates based on the category of the material. For example, organics would have a faster decay rate compared to e-waste. This allows the weights of the matrix to be even more biased towards areas of concern that need immediate action.

For example, if we were tracking how much idle waste is in the clothing sector, we would give more weight to waiting time (closet time) and inventory (deadstock). In this case, we may define the time it takes for clothing to become idle as 6 months after it was last touched (which can be measured by the chemical sensor). The amount of value being lost per day can signal to waste professionals which zipcodes are suffering from more bottlenecks.

Supplementary metrics can be used to track idle resources, including:

- Average dwell time of materials at each point of the waste management pipeline to identify stagnation points across multiple tracked samples.
- Velocity variances between sectors of waste can allow professionals to prioritize when dwelling time leads to material waste.
- Modifying Lean tools, such as Waste Assessment Model (WAM) and Value Stream Analysis Tools (VALSAT), to score idle resource accumulation instead of manufacturing inefficiencies

Measuring idle resources in different stages of the waste management pipeline, in relation to the phases of the manufacturing pipeline, can help policy makers determine which sectors would benefit most from intervention at any given time. By taking the timing and location data from each point in the waste management pipeline, phases in the pipeline where materials end up idle are highlighted.

Once quantitative data is collected, it can inform targeted interventions, including extended producer responsibility programs, reuse infrastructure funding, and mandatory recycling pre-entry sorting requirements. By targeting stagnation and bottlenecks upstream, policy can prevent materials from entering the disposal streams in the first place, minimizing the ever-increasing load on our aging systems.

References

- Alamu, O., et al. (2021). Life Cycle Environmental Impact Assessment of a Waste-to-Energy Plant: A Case Study of the Baltimore Facility. Sustainability, 13(4), 1915.
- "Baltimore City's Proposed FY26 Budget Fails to Invest in Zero Waste Despite Significant New Solid Waste Revenue, Endangering the City's Zero Waste Commitments." Clean Water Action, 15 May 2025, cleanwater.org/releases/baltimore-citys-proposed-fy26-budget-fails-invest-zero-waste-despite-significant-new-solid.
- Baltimore County Department of Public Works, Bureau of Solid Waste Management. Ten Year Solid Waste Management Plan: 2019–2028. October 2018, Baltimore County Government, https://www.baltimorecountymd.gov/files/Documents/Public_Works/tenyearplan.pdf.
- Baltimore City Department of Public Works. SWMP Comments. City of Baltimore, 2026, https://www.baltimorecity.gov/swmp-comments.
- Brunner, P. H., & Rechberger, H. (2004). Practical Handbook of Material Flow Analysis. CRC Press.
- Chertow, Marian, and Lillian Childress. 'Improving the US Municipal Waste System: Toward a Circular Future'. One Earth, vol. 5, no. 11, 2022, pp. 1185–1188, https://doi.org/10.1016/j.oneear.2022.10.019.
- Das, Subhasish et al. "Solid waste management: Scope and the challenge of sustainability." *Journal of Cleaner Production* (2019): n. Pag.
- Daskin, M. S. (2013). Network and Discrete Location: Models, Algorithms, and Applications. Wiley.
- Ferronato, Navarro et al. "Introduction of the circular economy within developing regions: A comparative analysis of advantages and opportunities for waste valorization." *Journal of environmental management* 230 (2019): 366-378 .
- Iqbal, Asad et al. "Municipal solid waste: Review of best practices in application of life cycle assessment and sustainable management techniques." *The Science of the total environment* 729 (2020): 138622 .
- Kaza, Silpa, et al. What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. World Bank, 2018, hdl.handle.net/10986/30317.
- Mandpe, Ashootosh et al. "Circular economy approach for sustainable solid waste management: A developing economy perspective." *Waste Management & Research* 41 (2022): 499 - 511.
- Martuzzi et al. (2010) — "Inequalities, inequities, environmental justice in waste management and health", European Journal of Public Health.
- Maryland Department of the Environment. (2025). Maryland solid waste management and diversion report 2024. Maryland Department of the Environment.
- Massoud, May A. and Michel Mokbel. "Determinants of waste characterization in Lebanon and material recovery potential." *Journal of Material Cycles and Waste Management* 24 (2022): 1913 - 1922.
- Ozcan, Hüseyin Kurtulus et al. "Municipal Solid Waste Characterization According to Different Income Levels: A Case Study." *Sustainability* 8 (2016): 1-11.
- Padowski et al. (2024) — "Advancing sustainable transitions: A spatial analysis of socio-environmental dynamics of landfills across the United States", Elementa: Science of the Anthropocene.

- Tu, R., et al. (2025). Environmental Justice and Air Pollution Exposure from Waste Incineration in South Baltimore. Environmental Health Perspectives / PMC indexed study.

Interview Guide

For stakeholders in the regulatory system:
How have the challenges facing proper waste disposal changed since you entered the field?
What do you think are the next best steps to improving infrastructure?
Who do you think is responsible for improving waste management practices?
What sector do you think is contributing the most to waste? (Tech, fashion, food, etc.)

General interview questions for the average person:
Where does your trash go after you throw it out?
What are you doing to decrease or increase waste?
After you dispose of it (see how much of the pipeline the average person knows)?
What part of the waste management pipeline is the biggest part of the problem (government, waste collection, redistribution)?
What concerns you the most about how our waste management system is built right now?
What do you think needs to change?
What areas of waste are most important/relevant to you, what is most important to the world right now?
How does waste affect your life?