Stop Filling the World with Trash:
A Study of Circular Waste Management Strategies in NYC

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of the Requirements for the Degree of
Master of Science in Urban Planning

By

Luis Argelis Gonzalez Samot

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Abstract

This thesis seeks to understand the impacts and ramifications of solid waste generation and waste management strategies in New York City. It is concerned with the relationship between solid waste and the mass production and mass consumption patterns associated with the take-make-waste industrial economic model. Additionally, the investigation examines the circular economy as an alternative to take-make-waste. Special attention is given to the environmental and societal implications of continuing in the current linear industrial system and the urgency to move towards a circular economy. “Stop Filling the World with Trash: A Study of Circular Waste Management Strategies in NYC” addresses the following questions: what are the current municipal solid waste management strategies? Where does the solid waste go post-collection and how is it transported? What policies are being considered to address the negative externalities related to solid waste and Waste Management? What role can the circular economy play in minimizing the negative environmental and societal impacts of waste management? What are the implications of adopting a circular economy? Does moving to a circular economy require changes to the regulatory framework? The findings suggest that shifting to a circular or sustainable economic model is urgent. If we continue in the linear system of mass production and mass consumption, the negative effects to people and the environment may become irreversible. However, making this paradigm shift will entail a concerted effort among the public and private sectors, and civil society.

I. Introduction

In recent years, concerns over climate change and the negative impacts related to the over-extraction of natural resources have led organizations and governments to adopt sustainable practices across different industries and services. The circular economy (CE) has surfaced as an alternative to the current linear industrial economic model — characterized by its take-make-waste pattern and based on two strong presumptions; a sort of boundless and easy availability of natural resources, and the idea that the earth has a limitless ability to regenerate. Unlike the take-make-waste model, which results in vast quantities of waste and the depletion of natural resources, the CE is regenerative in nature. It seeks to design out waste and pollution, and to decouple economic activity from the consumption of finite resources (The Ellen MacArthur Foundation, 2017).

The CE framework will likely play a pivotal role in addressing climate change and waste. Over the past five years, the planet's temperature has increased at an alarming rate, with global average surface temperature in 2018 approximately 1°C above the pre-industrial baseline (1850-1900) (World Meteorological Organization, 2018). The evidence suggests that natural resource extraction related to the take-make-waste industrial economic model beginning at the turn of the 20th century is responsible for global warming. The accelerated rate in which the climate is changing has led to an unprecedented number of natural disasters like wildfires, hurricanes, floods, and sea level rise costing billions of dollars in damages. Unless we make fundamental changes to the industrial system, atmospheric changes will outpace the planet's ability to adapt, resulting in grave disruptions to economic and social activities. Greenhouse gas (GHG) emissions like carbon dioxide and methane are known contributors to global warming

due to their heating effect. By reducing the consumption of resources and pushing for the creation of self-sustaining production systems in which materials are placed in feedback loops, the CE will minimize GHG emissions associated with waste and the extraction of natural resources like fossil fuels.

One area receiving considerable attention is waste management. The take-make-waste model generates immense amounts of solid waste, most of which is dumped into landfills. This waste causes GHG emissions that exacerbate climate change and global warming. Organic waste, in particular, generates methane gas — a GHG with an exponentially greater heating effect than carbon dioxide. Additionally, waste stored in landfills produces a toxic liquid substance called leachate, which overtime seeps into groundwater sources; and flows into rivers, streams, lakes, and oceans. The hazardous contaminants present in leachate are known to pose threats to public health and cause the deterioration of ecosystems.

In light of the negative externalities associated with waste generation and waste management strategies directly linked to the current take-make-waste industrial economic model, it is important to investigate highly urbanized and densely populated areas where most of the solid waste is generated.

New York City (NYC) is an ideal place to study precisely because it is characterized by the features mentioned above. This thesis seeks to understand the impacts and ramifications of solid waste generation and waste management strategies in NYC. It is concerned with the relationship between waste and the economic values of mass production and mass consumption associated with the take-make-waste model — which lead to unfettered and unchecked waste generation. Additionally, this

investigation examines the circular economy as a potential replacement to the current linear industrial economic model. By looking at the CE's theoretical framework, circular business case studies in London, England and in NYC, and policies and regulations directed at transforming NYC into a circular city it shows that it can be feasible to make this transition. Moreover, it highlights the environmental and societal implications of continuing in the current linear industrial system and the urgency to move towards a circular economy.

II. Methods and Limitations

This investigation's data collection and analysis framework consists of both qualitative and quantitative methods. Semi-structured interviews were conducted with key actors in the waste management sector to get a better understanding of existing and proposed initiatives to mitigate greenhouse gas emissions and spatial social inequalities related to waste management operations. Additionally, questions were asked to discern the regulations that make landfilling the primary waste management strategy in NYC, and to gauge the degree to which the circular economy model is engaged. Snowball sampling was used to recruit additional participants, along with directories of key government and academic institutions to include the Department of Sanitation of New York, GrowNYC, Cornell University, and Columbia University. Snowball sampling consists of having existing research subjects recruit participants from their social network in order to access key experts and practitioners in the field of study.

Additionally, site visits were conducted at waste management facilities and at facilities experimenting with alternative waste management technologies to grasp the intricacies of the overall processes and to get a sense of what they would look like in the context of NYC. These facilities include the Newton Creek wastewater treatment facility in the Greenpoint section of Brooklyn, NY; municipal waste transfer stations in Greenpoint and East 91 St in Queens; Sims Municipal Recycling in the Sunset Park section of Brooklyn; and the Golisano Institute for Sustainability at the Rochester Institute of Technology in Rochester, NY. Anecdotal information and casual conversations with circular economy scholars and entrepreneurs from a Columbia

University Graduate School of Architecture, Planning, and Preservation summer workshop on the circular economy in 2019 are also referenced in this body of work. The researcher analyzed secondary data from city government agencies such as strategic plans and reports that aim to address the negative impacts of waste management in NYC and to identify policies directed at reducing solid waste through circular practices. An analysis of the waste management policy framework was conducted in order to identify areas that can be exploited to incentivize alternative waste management strategies and technologies and move NYC towards a circular economic model.

The subjects interviewed during this investigation do not provide a significant statistical value to reach any sort of generalization. Rather, their interviews provide insight and expertise regarding the policies and infrastructure that perpetuate landfilling as NYC's primary waste management strategy, identifying challenges preventing a transition to a circular framework, and how to overcome these obstacles.

Due to the COVID-19 pandemic, the researcher was not able to conduct the intended number of interviews. Expert information is limited to interviews with:

- David Hurd, Director, Zero Waste Programs at GrowNYC
- Professor Johannes Lehmann, Soil and Crop Sciences Section, School of Integrative Plant Science, Cornell University, Primary Investigator, Cornell KILN (Cornell’s Pyrolysis Facility)
- Akio Enders, Lead Technician, Cornell KILN
- Professor Thomas Trabold, Department Head, Department of Sustainability, Golisano Institute for Sustainability, Rochester Institute of Technology

- Professor Nickolas Themelis, Stanley Thompson Professor Emeritus of Chemical Metallurgy, Director of the Earth Engineering Center

Also, the quantitative data presented comes from secondary sources published by organizations such as the United Nations, the World Bank, the Department of Sanitation of New York, the City of New York, among other mainstream news media reports.

Initially, the researcher sought to conduct cost benefit analyses of circular waste management systems and strategies, but the pandemic curbed efforts to access adequate data to accomplish this task. As a result, the information contained in this report is more qualitative in nature than originally intended.

Lastly, there were unanticipated limitations placed on the availability of the researcher related to the pandemic, which made it impossible to conduct research during daytime hours. This hampered access to scientists and scholars, government officials, and other industry experts on sustainability and the circular economy.

III. Why Circular Economy

The circular economy (CE) has surfaced as an alternative to the linear take-make-waste industrial economic model. At its core, the CE aims to reduce energy consumption and minimize the extraction of raw materials to allow the planet enough time to replenish itself. It does this by designing out waste and pollution, keeping products and materials in use for as long as possible, and regenerating natural systems. In doing so, the CE decouples economic growth from the over-consumption of natural resources and focuses on using available materials and ecosystems more effectively.

Rather than taking a linear approach, the CE cycles finite and biological materials through multiple feedback loops before they are safely returned to nature. In the take-make-use-waste model firms extract raw materials from ecosystems which are in turn sold to parts manufacturers, product manufacturers, service providers, users and consumers. In contrast, the CE puts renewables and finite materials through two main flows; renewables flow management and stock management. Renewables flow through a biological cycle, while finite materials flow through a technical cycle. Parts manufacturers, product manufacturers, and service providers remain in place, but renewables and finite resources are put through biological and technical cycles that regenerate ecosystems and extend the life of products and their components for as long as feasibly possible.

The Ellen MacArthur Foundation created the “butterfly diagram” below (see Figure 1) to capture the ethos of the CE. Although it builds on various schools of

thought, it is most influenced by Cradle to Cradle's two material cycles (Braungart & McDonough, 2020).

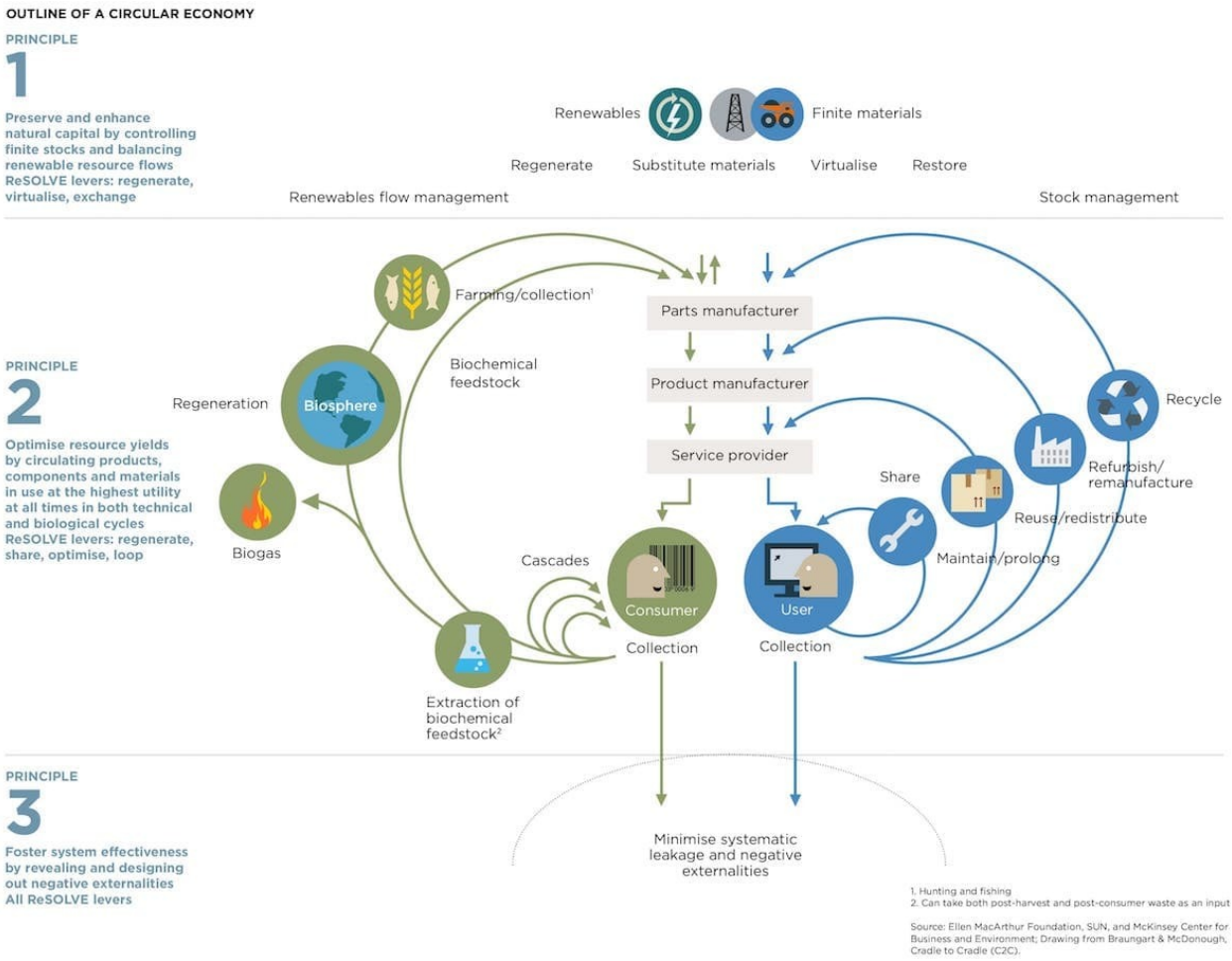


Figure 1. The butterfly diagram represents the essence of the circular economy model. From *Infographic: Circular Economy System Diagram.* (https://www.ellenmacarthurfoundation.org/circular-economy/concept/inf). Copyright 2017 by Ellen MacArthur Foundation.

The innermost loop of the technical cycle (the right side of the diagram) shows the strategy of keeping products and materials in use by extending their lifespan for as long as possible through designing for longevity, ease of maintenance and repair. These durable products can then be used for a prolonged period of time by its original

user or shared among other users who enjoy their service without having to manufacture a new product. In the next loop of the technical cycle, products and materials can be reused multiple times and redistributed to other users with little change or minor modifications. Refurbishment and remanufacturing are two similar processes that aim to restore value to a product. They vary in the degree of intensity that goes into enhancing or changing the product. When a product is remanufactured, it is taken apart to the component level and rebuilt to as good as new condition with the same warranty of a new off the shelf product. In refurbishment, products are repaired, usually without disassembly or replacement of major components. As it is the most intense process in the technical cycle, recycling is the last loop. Recycling entails reverting the product back to its original basic material level, allowing those materials to be made into new products. Despite being an important process in the CE, the high degree of intensity and energy, loss of embedded labor and materials, make recycling a lower economic value process than those closer to the center of the system diagram (for additional information see Webster, 2015).

In the biological cycle, the cascades loop refers to the process of putting used materials into various uses and extracting stored energy and material order — the different functions that the material serves as it degrades. This order declines until the materials need to be returned back to the environment as nutrients.

The CE's regenerative approach affords a viable business opportunity to tackle environmental priorities, drive performance, innovation and competitiveness, and stimulate economic growth and development (Gerholdt, 2015). Some of the identified

business models in a CE include but are not limited to: circular supplies, resource recovery, product life extension, sharing platforms, and product as service.

Resource recovery is particularly important in reducing the amount of waste that is dumped in landfills. This business model leverages technology to recover and reuse resource outputs that eliminate residual materials and maximizes economic value. The excess materials are reprocessed and turned into new materials. Bio-bean (https://www.bio-bean.com/coffee-logs/) is a coffee ground recycling company based in the United Kingdom. Their business model consists of recovering coffee grounds from commercial establishments in London and turning this excess waste into new products such as biomass pellets for industrial biomass boilers that serve as an alternative source of energy for heating, and coffee logs that provide an alternative to high carbon wood charcoal for wood burners and stoves. According to Bio-bean, their product burns hotter and longer than wood, minimizes greenhouse gas emissions and waste from landfills related to coffee grounds. Bio-bean also reduces some of the negative externalities related to imports like poor labor conditions in developing countries and environmental pressures from transporting products from distant jurisdictions nationally and abroad.

IV. Waste Globally

As the world population continues to migrate to urban areas and people in developing countries achieve higher levels of wealth, overall waste generation is expected to surge. The United Nations is forecasting that 68 percent of the global population will live in an urban setting by 2050 (United Nations, 2018). This high urbanization rate is accompanied by economic development strategies based on the linear growth industrial model — the mass production and consumption of goods — which in its current iteration results in vast amounts of waste. A World Bank report on the global state of waste estimates municipal solid waste (MSW) generation at 2.1 billion tons (See Figure 2). On average this translates to 1.6 lbs of MSW per capita.

There are major differences between the amount of waste generated by the rich and poor. Countries in East Asia and the Pacific and Europe and Central Asia regions account for 43 percent of the total annual waste, while the Middle East and North Africa and Sub-Saharan Africa regions account for 15 percent (See Figure 3).

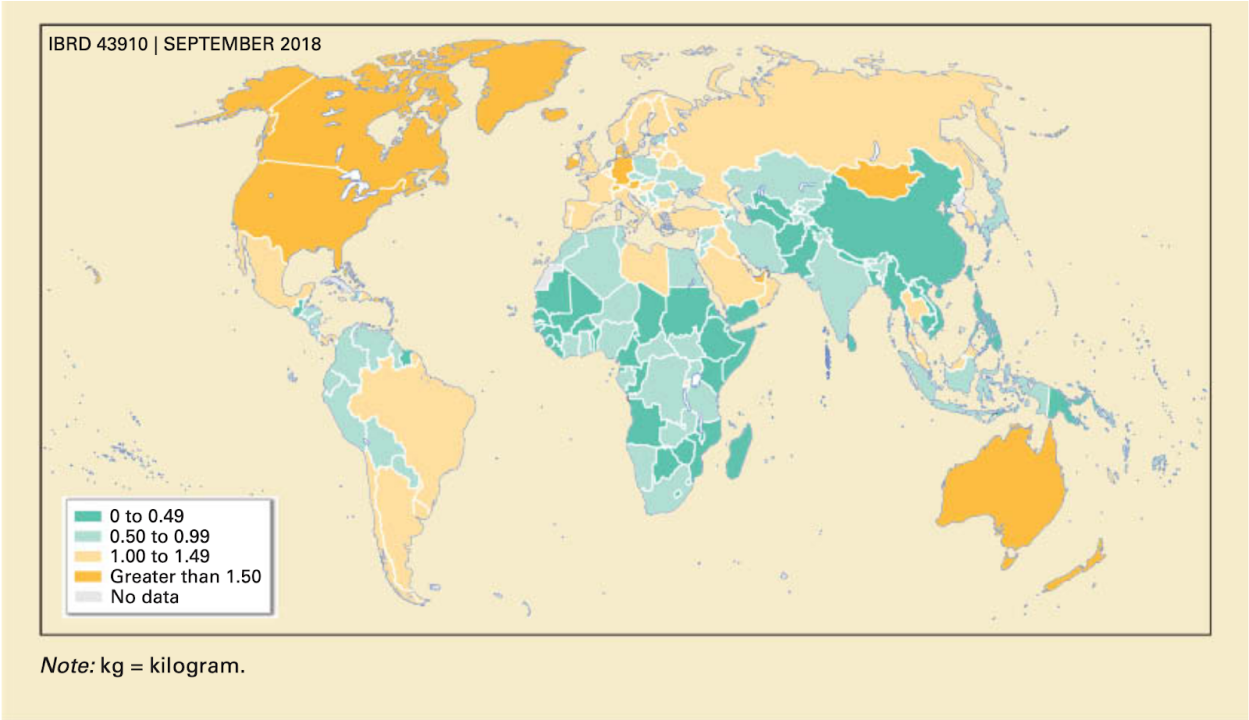


Figure 2. Waste Generation Per Capita. Reprinted from "At a Glance: A Global Picture of Solid Waste Management," by S. Kaza, L. C. Yao, P. Bhada-Tata, & F. Van Woerden, 2018, *What a Waste 2.0,* p. 19. Copyright 2018 by the World Bank.

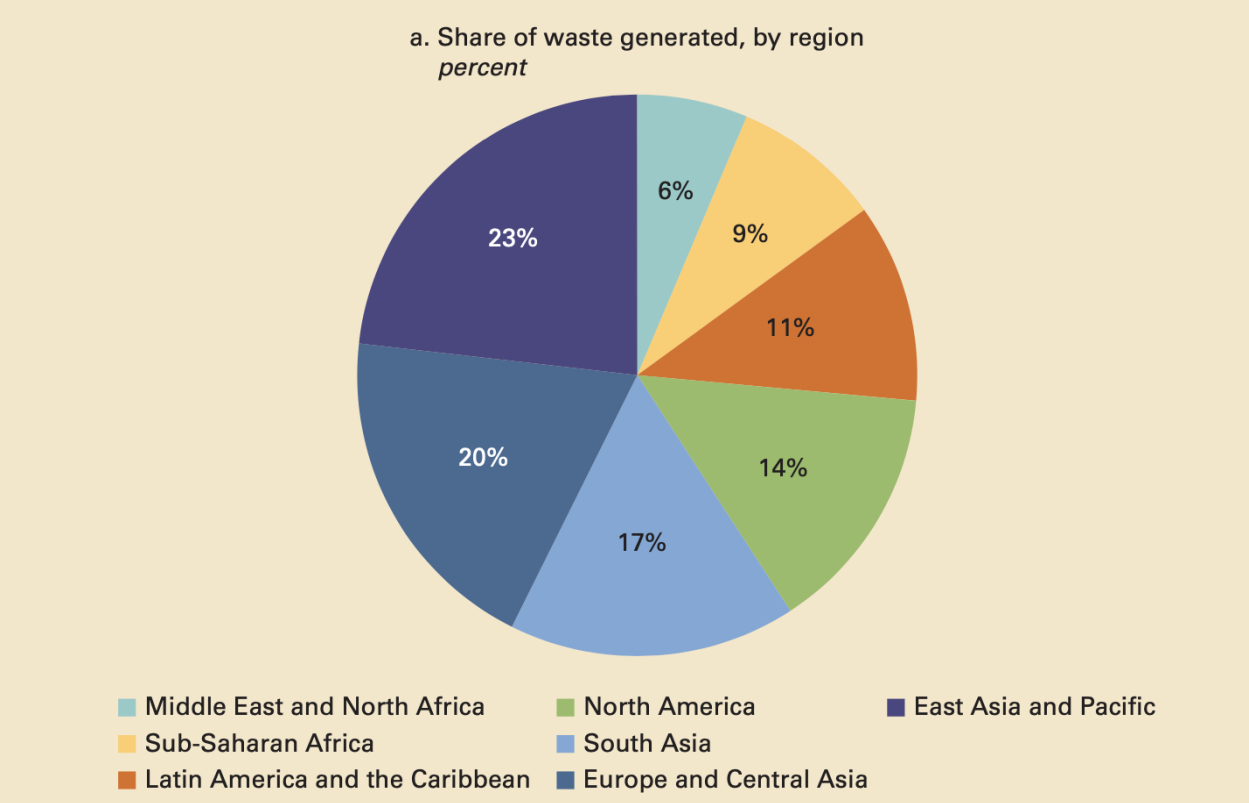


Figure 3. Share of Waste Generated by Region. Reprinted from "At a Glance: A Global Picture of Solid Waste Management," by S. Kaza, L. C. Yao, P. Bhada-Tata, & F. Van Woerden, 2018, *What a Waste 2.0,* p. 19. Copyright 2018 by the World Bank.

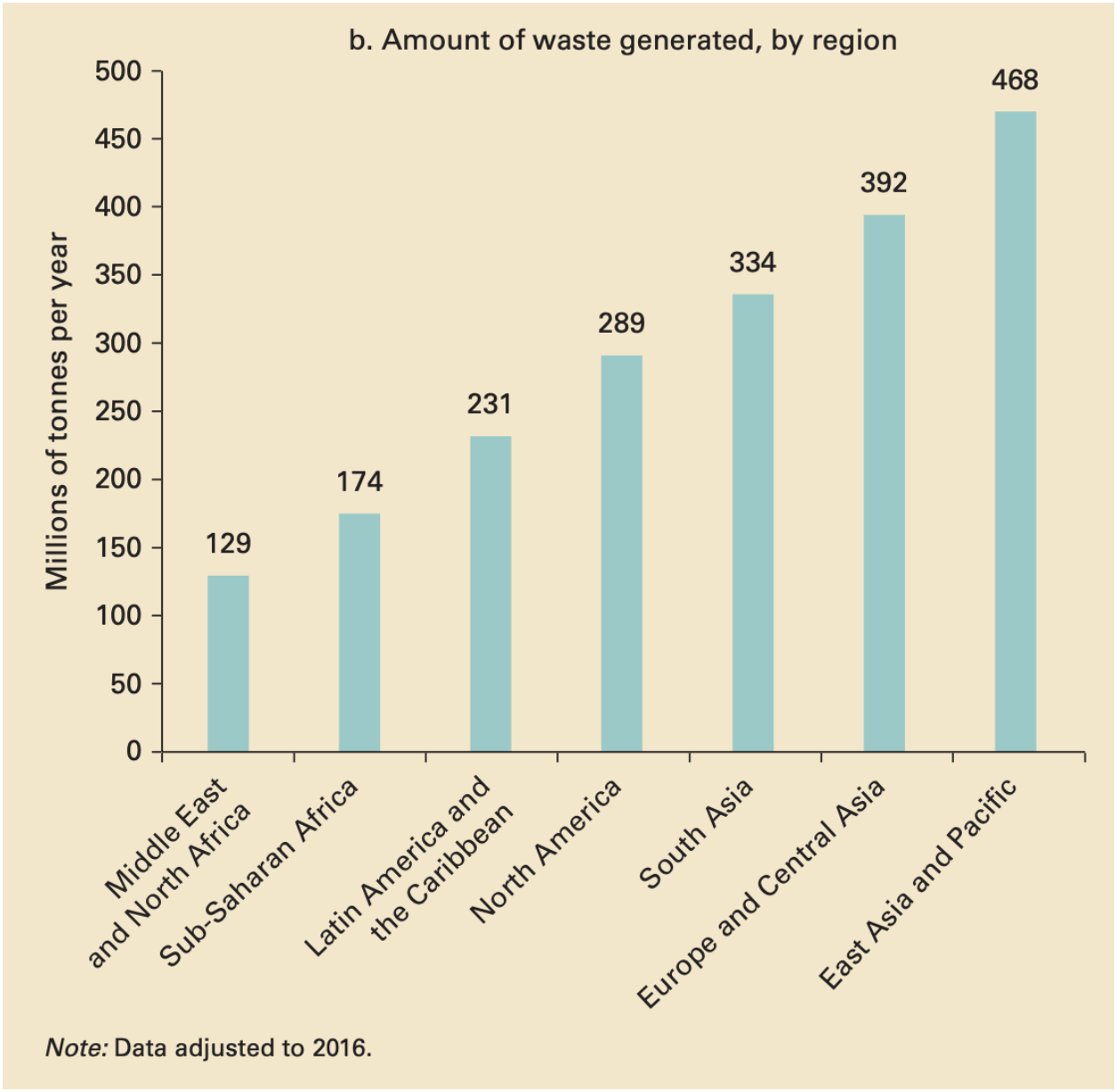


Figure 4. Amount of waste generated by region. Reprinted from "At a Glance: A Global Picture of Solid Waste Management," by S. Kaza, L. C. Yao, P. Bhada-Tata, & F. Van Woerden, 2018, *What a Waste 2.0,* p. 20. Copyright 2018 by the World Bank.

High-income nations produce disproportionally more waste than low-income nations. Despite only accounting for 16 percent of the global population, high-income countries generate 34 percent of the world's waste; low-income countries, on the other hand, account for 9 percent of the world's population but generate about 5 percent of the global waste (see Figure 5). Overall, there is a positive relationship between waste

generation and economic development. As income levels rise, waste generation is shown to increase.

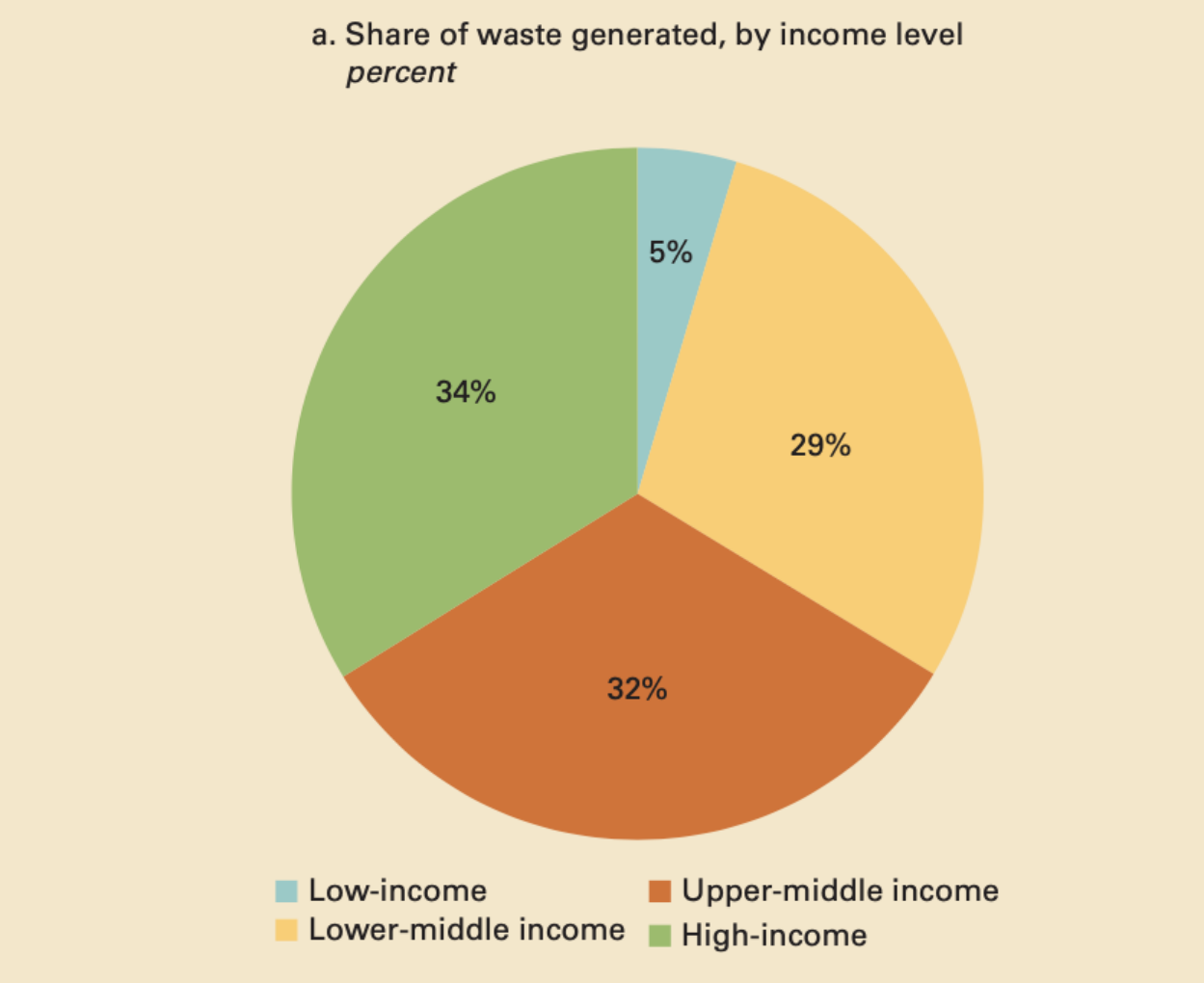


Figure 5: Waste generation by income level. Reprinted from "At a Glance: A Global Picture of Solid Waste Management," by S. Kaza, L. C. Yao, P. Bhada-Tata, & F. Van Woerden, 2018, *What a Waste 2.0,* p. 21. Copyright 2018 by the World Bank.

As mentioned, waste generation also has the tendency to increase with urbanization. Countries with higher levels of wealth are generally more urbanized and they generate more waste in total. The North America region, with the highest rate of urbanization at 82 percent, generates an estimated 4.9 lbs of waste per capita daily, while Sub-Saharan Africa, with an urbanization rate of 38 percent, generates about 1 lbs per capita per day (Kaza et al., 2018).

This high rate of urbanization paired with the linear industrial economic model paints a grim picture of the world's future. Global waste generation is expected to increase from 2.1 to 2.6 billion tons by 2030, and to 3.4 billion tons By 2050 (Kaza et al., 2018). As the amount of waste generated increases, so will pollutants and greenhouse gases that threaten the planet's existence.

Reports from world organizations on the contributions of waste to climate change have been alarming. The United Nations Food and Agriculture Organization estimates that food waste contributes 8 percent of total greenhouse gas emissions (Frischmann, 2018). Most of these emissions are methane gas, which has a heating effect much greater than carbon dioxide and thus is more effective at warming the planet.

The way in which municipal solid waste is handled today is detrimental to the environment, people and the economy. Close to 40 percent of all waste is disposed of in some form of landfill or informal dump; and food waste makes up 44 percent (1.3 billion tons annually) of the total municipal solid waste composition (Kaza et al., 2018). While decomposing, food waste in landfills releases methane into the atmosphere and places groundwater sources at risk of leachate contamination. Leachate results from rainwater and the natural degradation process of waste. The resulting byproduct percolates through the waste, collecting hazardous pollutants and creating a toxic stew at the bottom of landfills (Danthurebandara, 2012). Without proper controls in place, leachate can seep into the water table and drain into rivers and the soil, compromising public safety and valuable natural resources. Even in cases where a protective membrane is installed at the bottom of landfills, over time the material degrades, allowing leachate to

seep into the water table and potentially add contaminants to drinking water sources that are lethal to humans.

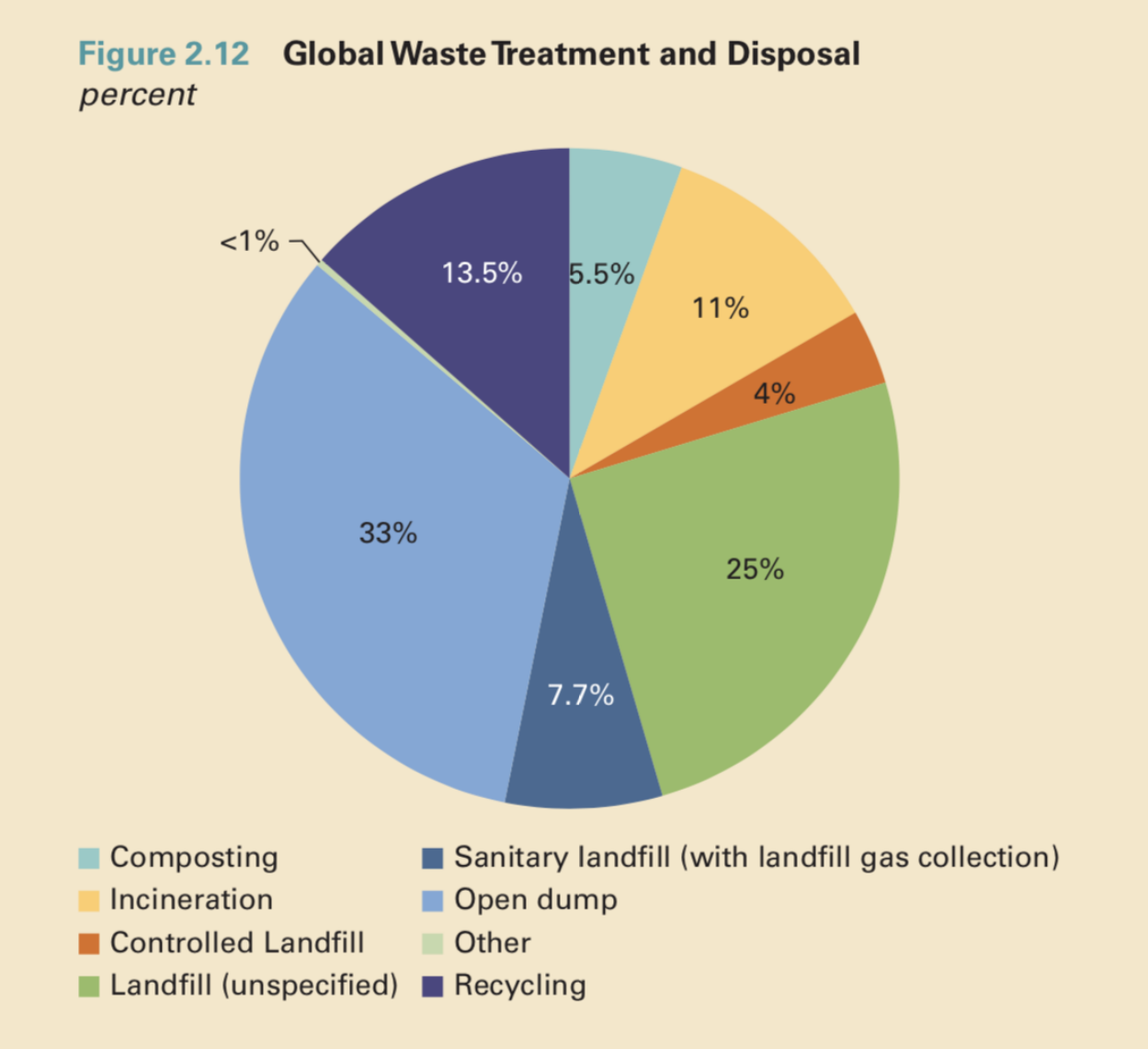


Figure 6. Global Waste Treatment and Disposal. Reprinted from "At a Glance: A Global Picture of Solid Waste Management," by the World Bank, 2018, *What a Waste 2.0,* p. 34. Copyright 2018 by the World Bank.

Besides contributing to climate change and global warming, poor waste management strategies — landfilling, open dumps, trash burning, among others — and unfettered waste generation have negative societal impacts. About one third of the total annual food production is lost or wasted. This comes at a cost of $25 billion per year or

2.5 percent of the world's GDP (Kaza et al., 2018). In addition to the economic loss, in 2018 an estimated 821 million people worldwide suffered from hunger (United Nations, 2019), a number that experts believe has increased substantially due to the COVID-19 pandemic.

Free market principles are currently applied to waste management around the world. As a result, low-income and vulnerable populations stand to suffer the most and bear the brunt of the burden. High-income countries have the financial capacity to pay low and medium-income countries to take their waste. This refuse is generally stored in poor communities — often communities of color or of ethnic minorities — who have to deal with the foul odors, and pollution from unregulated waste processing facilities and transportation, which evidence suggests leads to high rates of medical conditions like asthma and cancer (Moss, 2016).

Moreover, in low-income countries (and oftentimes in poor middle and high-income countries) inadequate or informal solid waste collection systems, unfettered dumping or burning of trash still takes place today, polluting natural resources and entire ecosystems. More than 15 million people have livelihoods that are intertwined to the informal waste sector (Kaza et al., 2018). The demographic composition of waste pickers is predominantly women, children, the elderly, and unemployed, all vulnerable populations exposed to hazardous airborne pollutants and who often lack proper healthcare, housing, and familial support.

Unfortunately, most scientific forecasts predict more tumultuous times ahead. They paint a picture of the future filled with severe atmospheric events related to global warming and climate change — leading to further displacement of vulnerable

populations — gaping economic inequality, civil strife and global conflict, inadequate food and water.

V. Waste in the US

Despite being the richest country in the world, the United States (US) has an extremely poor track record when it comes to solid waste generation and waste management. The US leads all countries in waste generation, producing about 268 million tons of municipal solid waste annually or about 4.5 pounds per person per day (EPA, 2020). Not surprisingly, the biggest offenders are major cities, home to millions of residents. For instance, Los Angeles, with a population of close to 4 million generates approximately 6.3 million tons of municipal solid waste annually (CALPIRG EDUCATION FUND, 2018). Meanwhile, in the East Coast, New York City, with a population approximating 10 million produces an estimated 6.5 million tons of solid waste (OneNYC, 2015).

In the US, cities and states are not always responsible for storing their solid waste — NYC, for instance, does not have operating landfills. Often solid waste finds its way into landfills in communities with a fraction of the population of the largest waste producers in the nation. The entire state of Michigan, for instance, has a population of 10 million, yet it ranks first for the most accumulated waste in place per person with an astounding 62.4 tons of garbage buried for every individual in the state (Eusebio, 2020).

Out of the total amount of municipal solid waste generated in the US each year, about half is landfilled. That is 139.6 million tons of solid waste annually, according to the EPA (2020). A large quantity of this waste gets buried in landfills in the upper Midwestern states. Not only do these states have the most solid waste buried in their land per capita, but they are poised to take in the most new waste in the upcoming

years. Indiana leads all states with a landfill waste acceptance rate of 2.4 tons per year per resident (Eusebio, 2020). Michigan is a close second with a waste acceptance rate of 2.3 tons per year per person (Eusebio, 2020). The upper Midwestern states had manufacturing-intensive economies and were some of the most negatively impacted by offshoring and outsourcing to developing countries. They have resorted to landfilling to try to make up for that lost revenue.

But accepting other states and cities' waste for cash is not environmentally or socially sustainable. Landfilling operations often compromise the public health and ecosystems of low-income communities and communities of color. The leachate present in these facilities is particularly problematic, as 44 million Americans depend on groundwater sources for drinking water (U.S. Geological Survey, 2017).

In Flint, Michigan, a predominantly African American community, leachate runoff along with waste associated with industrial and agricultural waste drained into the Flint River. After years of unanswered complaints from residents, testing of the city’s drinking water found lethal levels of lead. Nearly 17 percent of water samples registered above the federal action level of 15 parts per billion, the level at which action must be taken (Denchak, 2018). A pediatrics report published in 2015 found that for 18 months nearly 9,000 children in Flint had been supplied water contaminated with harmful levels of lead (Denchak, 2018).

Similar to global solid waste trends, food waste makes up most of the total municipal solid waste composition in the US. 21.9 percent of the total solid waste stream flowing to landfills is composed of food waste, followed by plastics and paper, which make up 19.2 and 13.1 percent of the total waste composition respectively

(Eusebio, 2020). In the US, like in the rest of the world, landfills are a major source of climate change. These facilities are big producers of methane, which has a heating effect 80 times more potent than carbon dioxide (Greenpeace USA, 2019). According to the Environmental Protection Agency, landfills were the third greatest source of human-related methane emissions in the US, at 14.1 percent (EPA, 2020).

As the world approaches the climate change horizon, increasing landfill waste acceptance rates seems counterintuitive. However, many of the landfills in Midwestern states are privately owned or operated jointly under public private partnerships. So long as there is a demand for space to dump waste in and is profitable, waste acceptance rates, landfill expansions, and even new landfills will continue regardless of the negative impacts.

The US is on pace to run out of landfill space within 18 years (SWEEP, 2018). The tables below show regional net capacity changes from 2016–2021, using 2015 figures as a point of reference. Over this timeframe net capacity is mostly negative. Landfill capacity in years varies according to region. On the lower end, the Northeast region has 8 years of landfill capacity remaining, while on the opposite side of the spectrum the Western region has 22 years of capacity. These figures assume that no new landfills or additional cells will open in existing landfills. But unless policy is enacted to address waste generation and waste management deficiencies, it is difficult to foresee any other alternatives.

Table 1: Net Capacity Changes 2016-2021 ('000 tons)

Region	2016	2017	2018	2019	2020	2021	Vs. 2015	% loss
Northeast	9,222	-23,737	-34,192	-39,225	-41,429	-41,858	-171,220	-30.3%
Southeast	-16,922	-43,239	-44,375	-56,047	-70,617	-77,923	-309,123	-15.3%
Midwest	16,570	-46,265	-64,787	-65,372	-69,889	-79,839	-309,583	-24.1%
Western	14,630	-13,294	-24,114	-35,905	-57,813	-59,643	-176,138	-8.8%
Pacific	81,794	-24,230	-39,117	-41,431	-48,448	-49,320	-120,753	-11.1%
USA	105,293	-150,765	-206,584	-237,980	-288,196	-308,584	-1,086,817	-15.6%

Table 1. Net capacity changes 2016-2021 ('000 tons). Reprinted from "The Time is Running Out: the US Landfill Capacity Crisis," 2018, Copyright 2018 by the Solid Waste Environmental Excellence Protocol (SWEEP).

Table 2: Remaining Landfill Capacity in 2021 and Annual Rate of Capacity Loss

Region		Remaining Capacity (years)	Annual rate of loss
Northeast		8	-5.0%
Southeast		14	-2.5%
Midwest		11	-4.0%
Western		22	-1.5%
Pacific		17	-1.9%
USA		15	-2.6%

Table 2. Remaining landfill capacity in 2021 and annual rate of capacity loss. Reprinted from "The Time is Running Out: the US Landfill Capacity Crisis," 2018, Copyright 2018 by the Solid Waste Environmental Excellence Protocol (SWEEP)

Although most solid waste in the US is diverted to landfills, recycling and composting rates are at their highest in history. The Environmental Protection Agency estimates that over 94 million tons of municipal solid waste in 2017 or 35.2 percent of the total solid waste were recycled (EPA, 2020). The bulk of the recycled and composted materials are paper and yard trimmings. Paper and paperboard account for 46.9 percent of the total recycled and composted materials, while yard trimmings made up 25.9 percent (EPA, 2020).

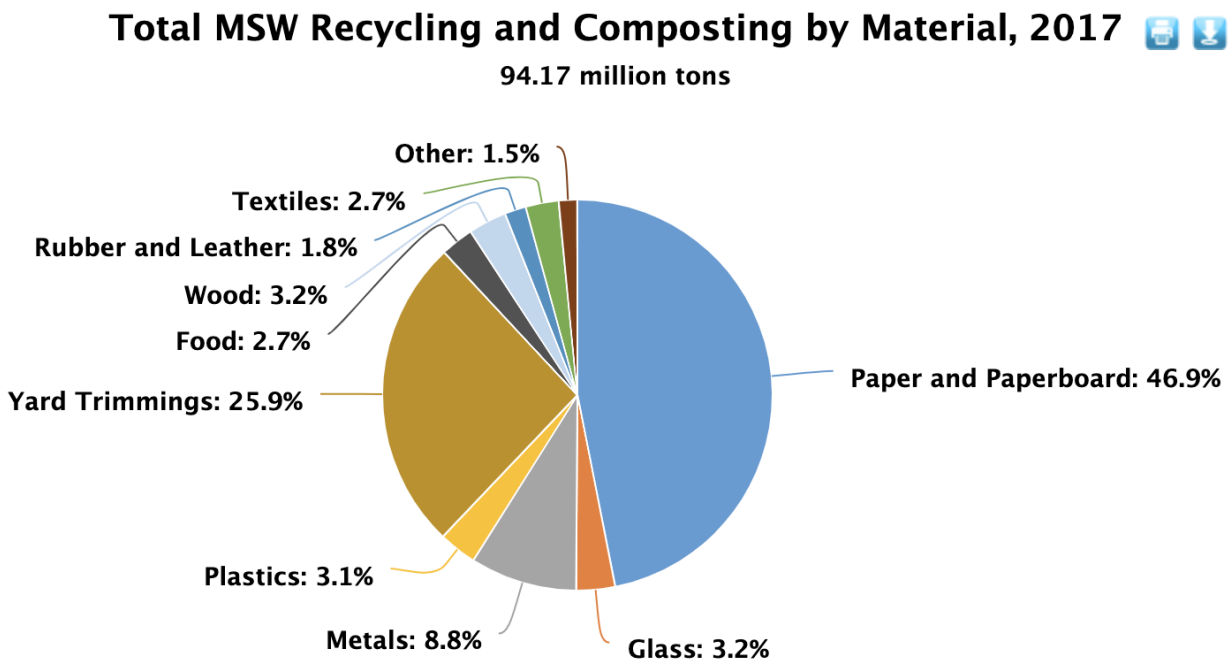


Figure 6. Total MSW recycling and composting by material in 2017. Reprinted from *National Overview: Facts and Figures on Materials, Wastes, and Recycling*, https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials#Landfilling. Copyright 2017 by the United States Environmental Protection Agency (EPA).

US recyclables, however, had for decades been tied to the Chinese market for recyclable materials. Since the 1980s, China has served as a recycling center for most of the developed world. This came to an almost complete halt in January of 2018, when the Chinese government enacted the “National Sword” policy, which banned the import of recycled materials (Katz, 2019). The policy was an effort to stop the flood of contaminated materials overwhelming Chinese processing facilities and burdening the country with environmental problems. Since then, Chinese plastics imports have decreased by 99 percent, leading to a shift in where and how countries handle their recycled materials (Katz, 2019). China’s move has triggered a recycling crisis in the US. Prior to the ban, 70 percent of the US’s recycled plastics were sold and shipped to processors in China, where they would be repurposed by manufacturers (Katz, 2019).

Since China is no longer importing plastics, states and cities across the US have curtailed collection or halted their entire recycling programs, which means that recyclable materials are being tossed in the trash. Overwhelmed by the high volume and continuous deluge of materials, recycling processors are paying private haulers to transfer plastics, paper and other recyclable materials to landfills and waste-to-energy incineration plants.

VI. Waste in NYC

With nearly 10 million inhabitants, New York City (NYC) is the most populated city in the US, and consequently one of the highest waste generation centers in the country. Its high population density and waste management challenges makes NYC an ideal place to study and test the circular economy model. Annually, the city generates approximately 6.5 million tons of MSW, with 3 million tons of residential waste and 3.5 million tons of commercial waste , and a per capita generation of 3.4 pounds per day (OneNYC, 2015). Despite the Department of Sanitation of New York (DSNY) providing a curbside recyclables collection service for the past 29 years and collecting about one third of the materials, only 15.4 percent were diverted from the waste stream (OneNYC, 2015). The remaining amount is mostly taken to landfills.

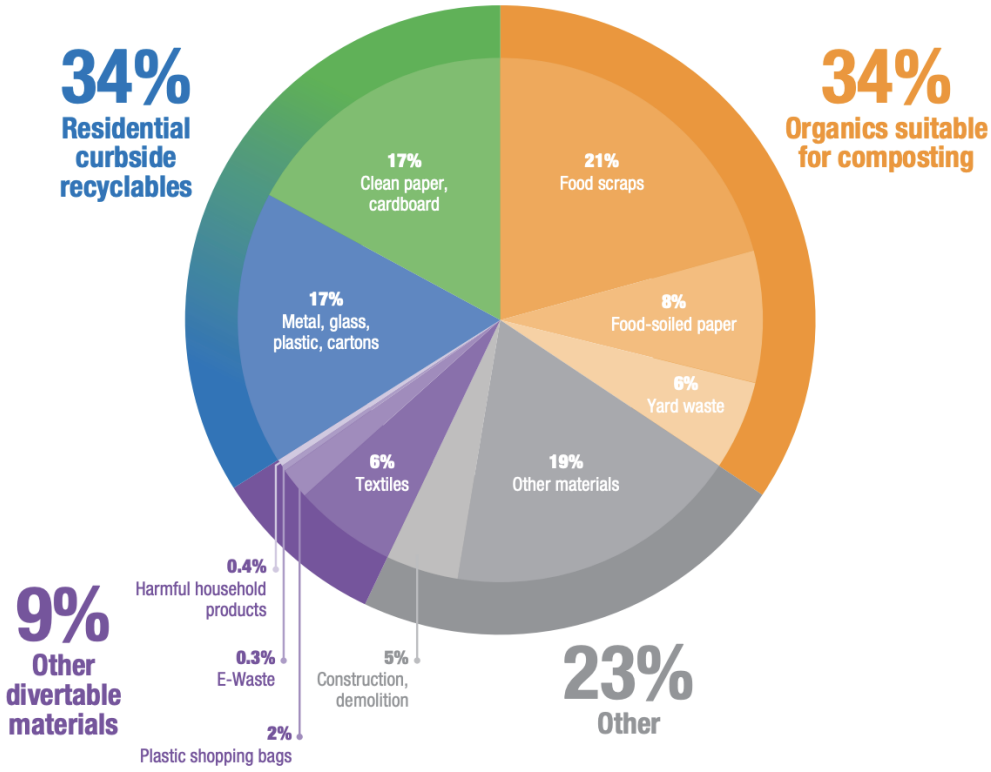


Figure 7. NYC Residential Waste Profile in 2017. Reprinted from "Results: Residential Curbside Collections," by The New York City Department of Sanitation (DSNY), 2017 *NYC Residential, School, and NYCHA Waste Characterization Study*, p. 11. Copyright 2017 by the DSNY.

DSNY also provides a residential curbside organics collection service to make and sell compost. The city created the program in an effort to divert food waste that would otherwise flow into landfills, where it would sit for years releasing GHG emissions into the atmosphere. The program consists of partnering with compost processors to turn food scraps into fertilizer. The DSNY launched a pilot servicing the residents of Waterleigh, Staten Island in 2013. Brown bins were issued by the city for residents to drop their food scraps in and the bins were collected curbside by DSNY. Today, the compost program is available in all five boroughs, servicing 3.5 million residents (Collins, 2018) and diverting organic waste — forming about a third of the total residential waste stream — away from landfills and turning it into a resource that regenerates the soil and generates revenue for the city (OneNYC, 2015).

Unfortunately, despite being the nation's largest organics collection program, it fails to capture the bulk of the residential food waste stream. Currently, residents only put about 10 percent of their food scraps in the brown bins, throwing the rest in the landfill bound garbage bins (Collins, 2018). Some residents attribute the compost program's shortcomings to the foul smells of the degrading food waste and having to clean the bins. Others worry that the bins will attract pests like roaches, mice or rats.

City officials, on the other hand, believe that the compost program's inefficiencies stem from inadequacies during the pilot phase. During an interview with The New York Times, Sanitation Commissioner Kathryn Garcia suggested that lack of participation in the neighborhoods where the pilot was conducted led to inefficiencies and high costs related to the logistics of the program (Collins, 2018). Often, garbage trucks with special compost compartments are moving about with little to carry, leading to losses in

potential revenue and cost overruns. In 2017 the city spent $15.7 million on the program, which earned the city $58,000 (Collins, 2018). The program's financial woes have carried over to present time. As a result, the DSNY has halted the expansion of the program until it is reconfigured to address financial inefficiencies. Today, the compost program has been suspended until further notice due to budget deficits related to the COVID-19 pandemic, and its future is uncertain.

Waste collection services in NYC are rendered by the public and private sectors. DSNY is responsible for handling residential waste and refuse from public buildings, while private sanitation companies handle the commercial waste stream. While DSNY has invested in new infrastructure like barge operations to transfer waste and reduce garbage truck trips, the perceived low cost of landfilling encourages private haulers to dispose of waste in landfills. As these companies often operate in the cover of the night, it is difficult to provide adequate oversight and characterize waste generated in the commercial sector, lessening the opportunity for capturing and reusing materials and recycling.

Hauling waste into landfills cost NYC millions of dollars each year. In 2016, landfilling cost the city $316 million, a figure that is projected to increase to $421 million by 2021 as the city continues to open additional waste transfer stations (Calder, 2017). The average cost per ton to export refuse in 2016 was $129 (2017). This price would be much higher if impacts to the environment and global warming, whose effects are thought to be responsible for natural disasters causing billions of dollars in damages, were factored in.

Waste management in the city is also a social justice issue locally and nationally. The waste processing and transfer stations are located in the low-income neighborhoods of the South Bronx, North Brooklyn, and Southeast Queens, where less prosperous residents, predominantly low-income neighborhoods and communities of color, are disproportionately burdened by waste management operations like truck exhaust, loud noises, and bad smells from putrescible waste. This waste is then transferred to landfills upstate New York, and across the northeastern region of the US, reaching as far south as South Carolina. This waste is eventually sorted and exported to poor countries in the global south. NYC's wealth allows it to pay less affluent neighborhoods, often desperate for funding for essential services, to store their waste, transferring the environmental and health risks associated with landfill operations to the poor.

Landfill Name	Location
High Acres Landfill	Perinton, New York
Seneca Meadows Landfill	Waterloo, New York
Keystone Sanitary Landfill	Dunmore, Pennsylvania
Grand Central Landfill	Pen Argyl, Pennsylvania
Bethlehem Landfill	Bethlehem, Pennsylvania
Commonwealth Environmental Systems	Pottsville, Pennsylvania
Tullytown Landfill	Morrisville, Pennsylvania
Blue Ridge Landfill	Chambersburg, Pennsylvania
Atlantic Landfill	Waverly, Virginia
Shoesmith Bros. Landfill	Chester, Virginia
Lee County Landfill	Lee County, South Carolina

Table 3. Non-exhaustive list of landfills that NYC uses to store its waste. Reprinted from *Where Does New York City Garbage Go? [An Animated Journey of 3 Million Tons of Waste]*, by M. Galka, 2016, http://metrocosm.com/where-new-york-garbage-goes/. Copyright 2016 by the Metrocosm.

The reason why NYC needs to pay other jurisdictions to take its waste is because of the city's dark past with landfills. NYC used to be mined with these facilities to dispose of its waste. Among them, miles of marshland in Queens where Brooklyn burned its garbage, described by F. Scott Fitzgerald in The Great Gatsby as the "valley of ashes," and the notorious FreshKills landfill in Staten Island, the largest in the nation before it was shut down in 2001 (Jacobs, 2016). At its peak in the 1990s, FreshKills spanned 2,200 acres and received 29,000 tons of waste daily (*ibid*). Concerns regarding runoff leachate, airborne pathogens and other polluting agents led Staten Island officials to file a lawsuit against the city for violating the Clean Air Act. FreshKills closed its doors in 1996, which marked the closure of NYC's last landfill.

More recently, in response to the negative effects related to landfilling, NYC vowed to send zero waste to landfills by 2030 (OneNYC, 2015). The city plans to achieve this goal through a series of place-based initiatives. Expanding the residential organic waste collection service to all residents and enhancing the recycling program by implementing a single-stream processing system are two overarching plans intended to divert waste from landfills. However, these initiatives are not faring well. The expansion of the organics collection program, which was supposed to be mandatory by 2018, has been halted. Meanwhile, China's ban on foreign waste has reduced the price of recyclable materials and increased the waste stream to landfills. In the textiles and apparel front, non-profits are at the forefront. Organizations like Goodwill and the Salvation Army, along with a plethora of independent and chain thrift stores, collect and redistribute clothes at an affordable price point. At the government level, "the City's re-fashioNYC program, in partnership with Housing Works — a chain thrift store — offers in-building collection for apartment buildings with 10 or more units and currently serves more than 100,000 households in 553 apartment buildings and complexes" (OneNYC, 2015). Despite these efforts, used clothes and textiles still make up six percent of the city's waste (OneNYC, 2015). Thus, achieving zero waste by 2030 will require more radical solutions.

VII. Spatiality & Inequalities of Waste in NYC

New York City (NYC) is one of the richest cities on the planet and is regarded as a bastion of arts and culture. It is home to some of the best universities and medical centers in the country, and it's arguably the financial center of the world. Yet, it suffers from severe social inequalities. Economic inequality is a pressing human rights issue in NYC. The opportunities and quality of life available to those towards the bottom of the economic ladder — education, health and safety — are often determined by their zip code.

As economic inequality has increased over the past 40 years, poor neighborhoods have been left at the mercy of the free market. In NYC, poor neighborhoods — often communities of color — have inadequate public services and living conditions. One area that deserves attention is waste management. Although waste is generated by everyone, low-income communities in NYC bear the brunt of the burden.

This section explores social and economic inequality through the lense of waste. The type of spatial exclusion discussed here is not about impeding access to groups of people from a particular place or space, but rather it examines how waste management infrastructure is delimited to low-income neighborhoods and communities of color. In this way restricting people to spaces with high levels of air and noise pollution, foul odors, and unsightly land waste transfer stations, and excluding them from access to adequate living conditions.

In order to understand the underpinnings of economic inequality and the colossal generation of waste that disproportionately affects low-income communities, an analysis

of the current industrial model is warranted. This economic model is characterized by its take-make-waste pattern and it's based on two strong presumptions; a sort of boundless and easy availability of resources, and the idea that the earth has a limitless ability to regenerate. As capitalism has become unfettered through neoliberal ideas of free and deregulated markets, the take-make-waste system has led to ever-growing amounts of waste that are detrimental to the environment and public health.

The circular economy presents an alternative model to the take-make-waste industrial model. Unlike our current industrial system, CE aims to dissociate economic activity from the consumption of finite resources, and design waste out by promoting workable relationships between ecological systems and economic growth. In this sense, CE is designed to close waste loops across supply chains, minimize waste generation and allow our planet enough time to regenerate before tapping into raw natural resources. This model is studied here as a potential solution while considering some pitfalls that could perpetuate economic inequities in the city and beyond.

Special attention is paid to NYC's waste management structure and to key policies intended to reduce waste disparities in overburdened low-income neighborhoods and communities of color.

Although NYC is arduously trying to address the issue of inequality, efforts fall short because the underlying problems are rooted in our industrial economic model. This becomes apparent through the inspection of waste transfer stations which are located in poor neighborhoods and communities of color, and the limited success of policies directed at waste management deficiencies. Even if policies succeeded at

minimizing waste, the problem would just be passed along to other less affluent jurisdictions across the nation as free market principles are applied in the waste sector.

Annually, New York City generates approximately 6.5 million tons of municipal solid waste (MSW), with 3 million tons of residential waste and 3.5 million tons of commercial waste, and a per capita generation of 3.4 pounds per day (OneNYC, 2015). Although most of the MSW is generated in areas of high commercial activity in Manhattan, for decades the bulk of the waste has been handled at waste transfer stations located in low-income neighborhoods in the South Bronx, North Brooklyn and Southeast Queens where less prosperous residents — predominantly low-income neighborhoods and communities of color — are disproportionately burdened by waste management operations like diesel truck exhaust, loud noises, and vile smells from putrescible waste. The maps below illustrate the unequal distribution of waste transfer stations in the city and the correlation between the location of stations and low-income communities of color.

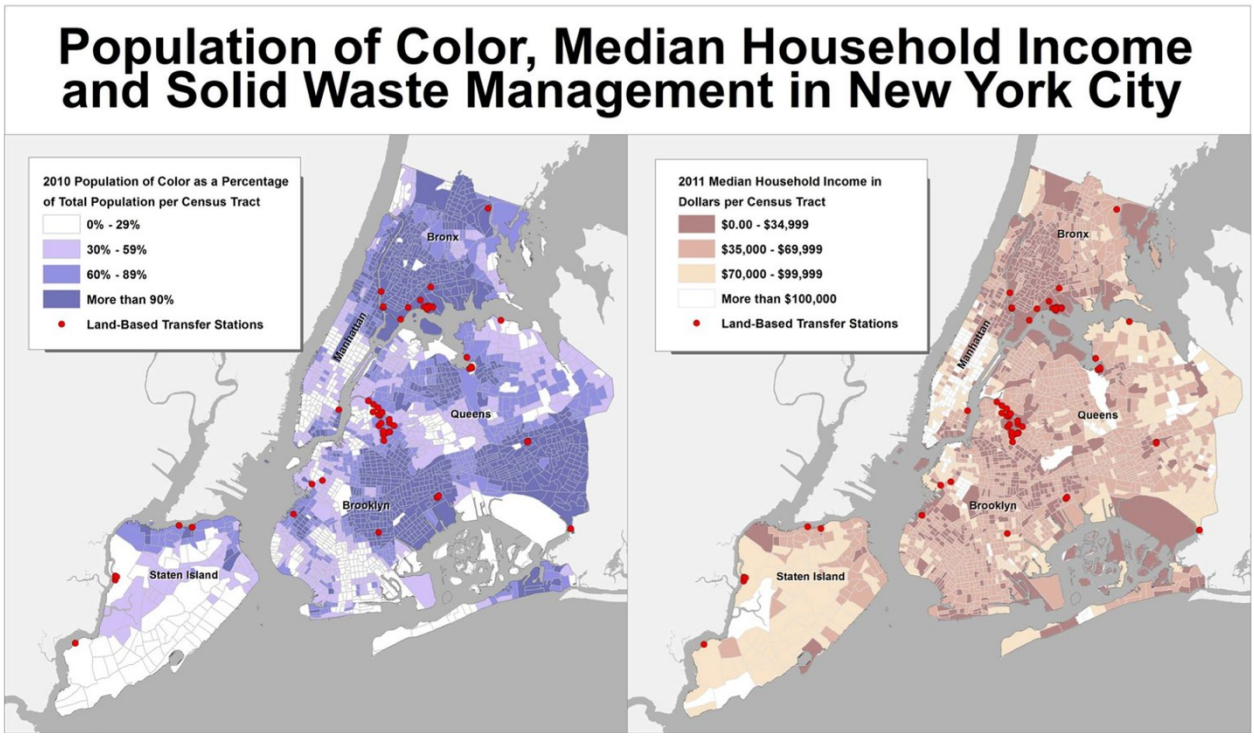


Figure 8. Population of Color (left) and Median Household Income (right) and Solid Waste Management in NYC. Reprinted from *Cleanup North Brooklyn*, 2016, http://www.cleanupnbk.org/news/2016/11/13/placement-of-waste-transfer-stations-in-nyc-a-not-surprising-correlation. Copyright 2016 by New York Environmental Justice Alliance.

NYC's waste collection is serviced by public and private operators. The public sector is responsible for handling waste from residences and public buildings, while the private sector handles all commercial waste. Since Mayor Bill de Blassio took office, the city has made substantial investments in solid waste and recycling infrastructure to achieve the equity and sustainability goals of the 2006 Solid Waste Management Plan (https://www1.nyc.gov/assets/dsny/site/resources/reports/solid-waste-management-pla). The portion of the waste stream managed by the city is now processed at barge and rail stations and mitigates some of the harmful effects from diesel garbage truck trips. "These facilities exported 87 percent of NYC's residential waste in 2018, with just 13 percent hauled out of the city in diesel trucks, and are estimated to eliminate 60 million diesel truck miles per year, including five million miles on local roads and streets,"

(Transform Don't Trash NYC, 2019). In doing so, DSNY has significantly phased out the use of private truck-based waste transfer stations for residential waste.

These efforts, however, are being undermined by the commercial waste system. As DSNY has minimized the use of private waste transfer stations, private waste haulers have increased the amount of commercial waste to these facilities. 26 of NYC's 38 waste transfer stations are located in low-income communities of color in the South Bronx, North Brooklyn, and Southeast Queens (NYCCSSWM, 2018). Just in the past four years, the amount of commercial waste flowing through private transfer stations has increased from 1.7 to 2.3 million tons per year (35 percent), hampering the progress made by the city (Figure 10).

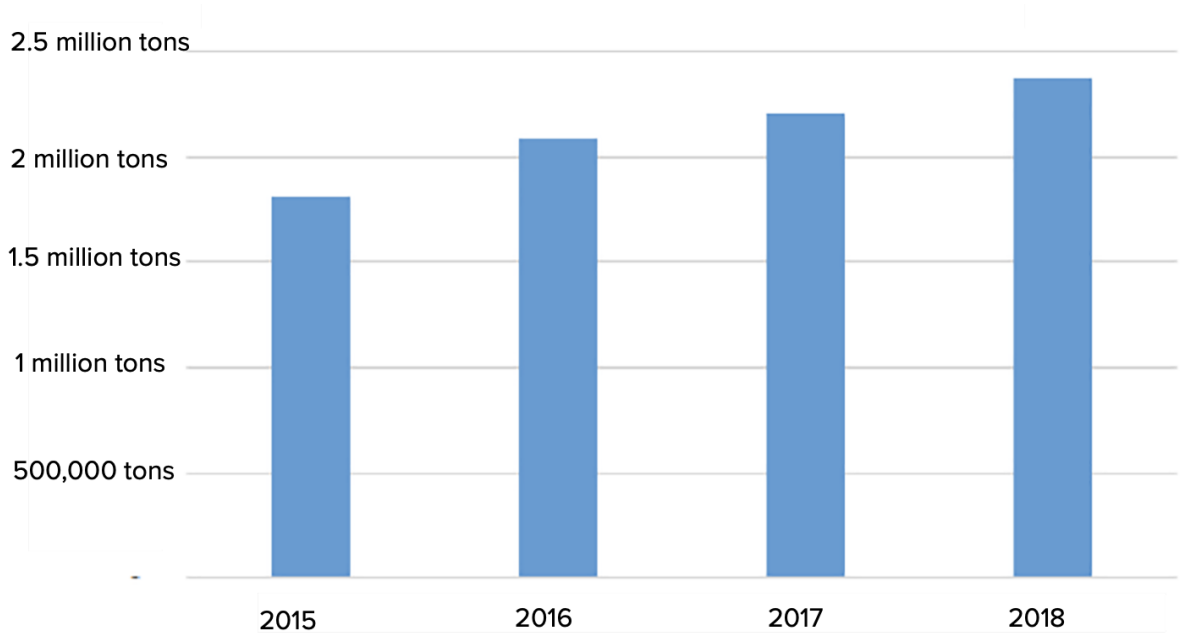


Figure 9. Amount of commercial waste has increased for the last four year between 2015 and 2018. Reprinted from "Trashing New York's Neighborhoods," 2019, p. 2. Copyright 2019 by the Transform Don't Trash NYC coalition.

In an effort to address deficiencies in the commercial waste system, DSNY has approved two major policies: Intro. 157-C of 2018 and LL199 of 2019. 157-C will reduce the capacity of private transfer stations in North Brooklyn by 50 percent and in the South

Bronx and Southeast Queens by 33 percent (Rosengren, 2018). This will greatly reduce the number of garbage truck trips — potentially by 50 percent — in these communities and promote a cleaner environment and overall better living conditions for residents. LL199, better known as the Commercial Waste Zones law, divides the city into 20 zones, each served by three private carters selected through a competitive process (DSNY, 2019). Currently 90 commercial carters service NYC, crisscrossing neighborhoods with few enforced restrictions and little oversight. This has made it difficult for city agencies to track and classify commercial waste and to police recycling violations. The Commercial Waste Zones is expected to incentivize more ethical waste management practices in the private sector and reduce the number of garbage truck trips to transfer stations.

Waste management is a social justice issue in NYC. As mentioned, low-income communities of color are burdened with waste-related hazards despite the waste being generated by all city residents and businesses. More than 75 percent of the commercial waste stream goes to these communities, disproportionately overburdening its residents (Transform Don’t Trash NYC, 2019). The figure 11 displays the amount of daily waste hauled to waste transfer stations situated in these neighborhoods.

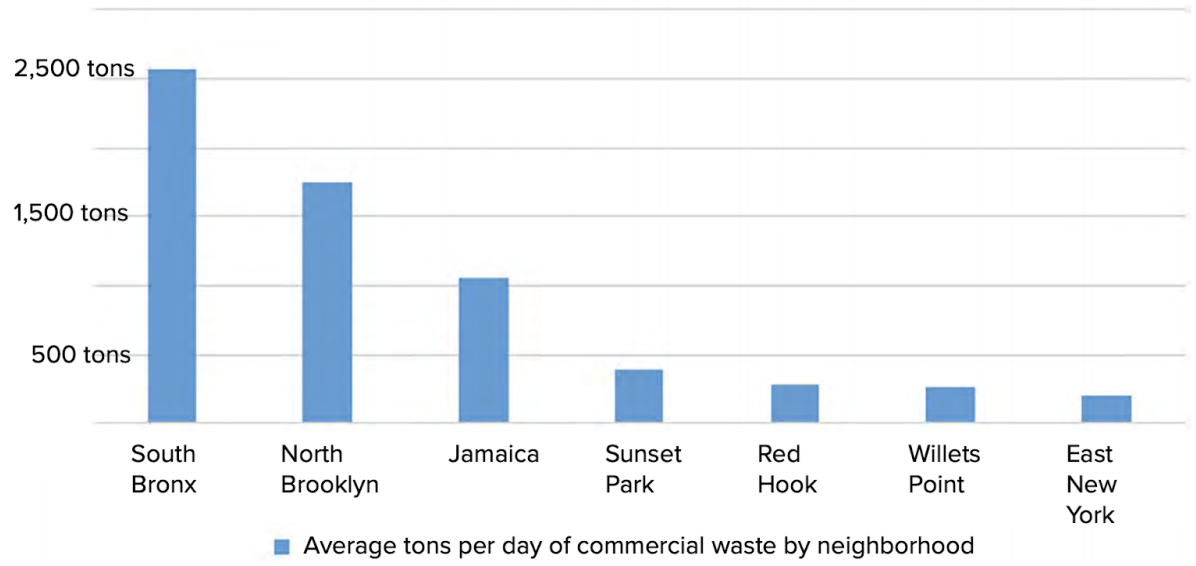
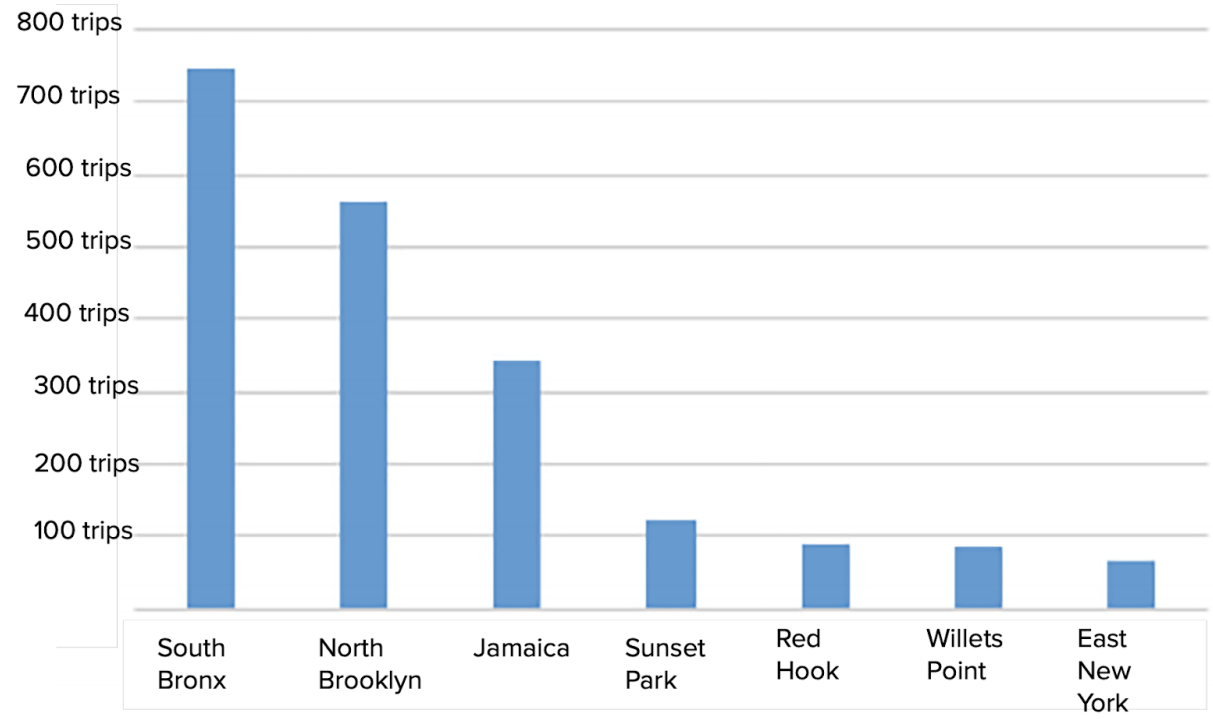


Figure 10. Average tons per day of commercial waste by neighborhood. Reprinted from "Trashing New York's Neighborhoods," 2019, p. 7. Copyright 2019 by the Transform Don't Trash NYC coalition.

The putrescible portion of the commercial waste stream is taken to diesel truck-based transfer stations that degrade air quality, safety and public health in already overburdened and vulnerable communities of color. Less than 13 percent of this waste goes to less polluting rail and barge transfer stations and has led to an increase in commercial waste that requires more than 450 added truck trips in and out of local communities each day (Transform Don't Trash NYC, 2019). A chart from the Trashing New York's Neighborhoods report (2019) below shows the number of garbage truck trips that go to social justice communities each day.



Approximate Commercial Waste Truck Trips per day per neighborhood, 2018[4]

Figure 11. Approximate commercial waste truck trips per day per neighborhood in 2018. Reprinted from "Trashing New York's Neighborhoods," 2019, p. 7. Copyright 2019 by the Transform Don't Trash NYC coalition.

Contaminants released into the air by the high volume of diesel trucks going in and out of neighborhoods have caused adverse health effects to residents of the aforementioned communities. A study conducted by the Centers for Disease Control (CDC) in 2015 found that there is a correlation between the placement of stations and communities with high rates of asthma. In the South Bronx neighborhoods of Mott Haven and Melrose, for instance, the number of asmatics reaches up to 17.7 percent in some corners; that is more than twice the national average (about 8 percent) and almost twice NYC's average (10 percent) (CDC, 2015). The map below shows the incidence of asthma in NYC. Upon examining the map you will notice that the

neighborhoods with the highest levels of asthma correspond with the placement of waste transfer stations in low-income communities of color.

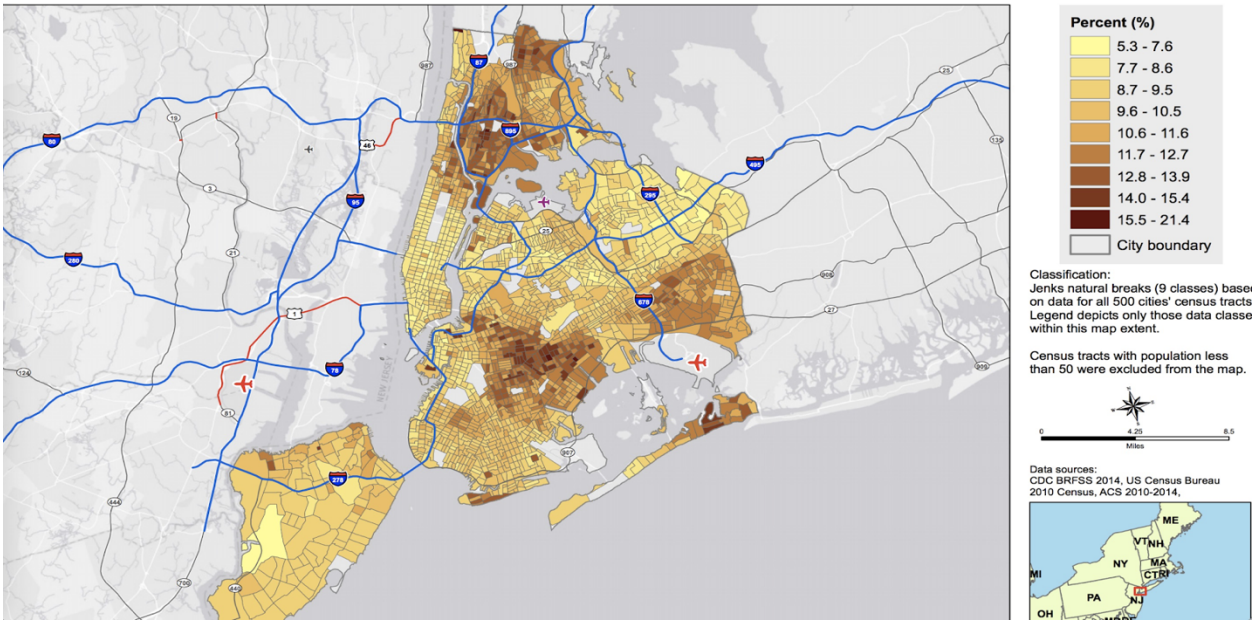


Figure 12. Asthma prevalence in NYC in 2015. Reprinted from *500 Cities: Local Data for Better Health,* 2015*,* https://www.cdc.gov/500cities/map-books.htm#accordion-12-card-6. Copyright 2015 by the Centers for Disease Control and Prevention (CDC).

There are other factors that contribute to the health disparities seen in these communities. The South Bronx is criss-crossed by three major highways — the Major Deegan, Bruckner, and Cross Bronx Expressway — which emit high levels of carbon dioxide emissions. Meanwhile, many of the transfer stations in North Brooklyn and Southeast Queens are situated near areas that generate pollutants related to industrial activity. Additionally, medical experts at Montefiore Hospital in the Bronx believe that "there is pollution, high pollen concentration, changes in the weather, and then there is a susceptible population; the inner city, urban, African-American and Latino population," (Butini, 2018). Regardless, there is evidence pointing at waste management as a

contributor to the higher rates of preexisting conditions in these neighborhoods and action is needed.

The current form of the industrial economic model is closely tied in to the idea of linear growth permeating the global economy today. It is based on extracting natural resources, manufacturing goods at the lowest cost possible, selling these products, and eventually disposing of the goods. Although the idea might be financially beneficial to companies that extract natural resources like oil and gas, it causes a huge financial hardship to society at large. Landfill tipping fees per metric ton in NYC cost $129; as the city opens additional transfer stations the cost of landfilling is expected to increase to $421 million per year by 2021 (Calder, 2017). The number of asthma related hospitalizations of low-income people also places burdens on the Medicaid system. Ultimately, these costs are paid by taxpayers, and the undesirable effects shouldered by the poorest and most vulnerable people.

Over the years, different forces have contributed to the current state of affairs. After World War II there was a shift in the United States from frugality and manufacturing long-lasting products to a frenzied consumption boom where status became defined by the amount of goods consumed rather than the quality of products. The ideas of economist Milton Freedman in the 1970s, adopted and championed by the Reagan Administration, establishing that the only responsibility of business was to increase profits, set precedent for the shareholder and executive primacy, unfettered extraction of natural resources to meet the consumption bug, and gaping economic inequality experienced today — ignoring local communities and the environment.

The circular economy represents yet another shift in our industrial economic model. This transition will require fundamental changes to our lifestyle. People have become accustomed to the conveniences of single use products. Despite efforts to ban single-use plastics they remain ubiquitous in most of the packaging of products. Can consumers change their behavior and the types of products they buy? Will they abandon the convenience of plastic bottles, cups, and bags? Many countries in the global south simply do not have the infrastructure to implement a circular economy. Places like China, Indonesia, India, Vietnam, and Thailand, producers of large quantities of waste, would need to invest tremendously in recycling systems and strategies throughout supply chains. We are also engaging in business models that promote fast consumption and waste in perpetuity. The fast fashion industry is one that depends on the feverish extraction of natural resources and production of low-quality and inexpensive products, resulting in massive amounts of waste handled and disposed of in poor communities around the world.

Implementing a circular economy will also require a social justice approach to include communities that have been deliberately excluded from past economic booms. Already elite business circles are selling the circular economy model as the next industrial revolution and the discourse is dominated by the same neoliberal free market principles that have led to some of the highest levels of inequality in recorded history. A grassroots movement will be necessary if we are to succeed in making the economy work for everyone. Green youth movements around the world inspire hope. NYC has adopted its own version of the Green New Deal aimed at reducing greenhouse gas emissions, waste, and nurturing a cleaner environment. Partnerships among different

movements and regular people will be key in including frontline and vulnerable populations in this new economy.

A paradigm shift in this direction is crucial to address the fundamental problems causing issues of waste disparities and broader economic inequality. Policies at the local level can yield positive results and improve the lives of residents significantly. However, rather than solving the problem, policies pass it along to less prosperous jurisdictions. Consider the two policies approved by NYC to address waste disparities discussed earlier in this chapter. Although they will greatly reduce the amount of greenhouse gas emissions related to garbage truck trips and the amount of garbage handled at transfer stations in vulnerable communities, it still sends millions of tons of waste to landfills located in low-income communities across the nation. Local policy is certainly important, especially in the short-term, but solving the problem will require fundamental changes and ideas like the circular economy.

VIII. Potential Solutions

This section looks at some of the available and prospective solutions to the waste crisis in NYC. Some of the solutions focus on repurposing materials while others propose a shift from our linear industrial economic model towards a regenerative or circular economic structure. These include waste-to-energy incineration facilities, thermochemical conversion or pyrolysis, recycling, composting, and examples of circular business models.

During a meeting with Professor Nickolas J. Themelis, Stanley Thompson Professor Emeritus of Chemical Metallurgy and director of the Earth Engineering Center at Columbia University, in December 2019, he asserted that the most efficient way to handle municipal solid waste is through waste-to-energy plants. These facilities treat solid waste by burning it in combustion chambers. The resulting steam from the burning process is sent to turbine generators to produce electricity, which in turn can be fed to the power grid or sold. Dr. Themelis believes this process will play a major role in addressing the waste crisis because it is able to handle vast quantities of solid waste rapidly and repurpose trash into energy, which reduces the need for fossil fuels.

Figure 13. The Essex County Resource Recovery Facility in New Jersey. 2012. http://www.lseacorp.com/portfolio/pany.html. Copyright 2012 by the LS Engineering Associations Corporation.

It is true that waste-to-energy plants can treat large volumes of solid waste and generate renewable energy through gasification, but there are a few pitfalls related to this process. The most concerning one is that it has the potential to perpetuate the take-make-waste economy. Because waste-to-energy is so effective at eliminating large quantities of waste through combustion, unlike landfills where waste lay follow for many years, it can encourage the continuation of the take-make-waste model and over-extraction of natural resources for manufacturing, which can have devastating effects to the environment and society.

The second concern is related to the byproducts of the incineration process. In the past, incinerators have been the culprit of public health crises due to the ash that results from the combustion process. There are two types of ash, bottom ash, the ash left over at the bottom of the incinerator, and the ash coming out of the exhaust. Since municipal solid waste is burnt indiscriminately in this process, the ash contains metals and other matter harmful to humans. The bottom ash used to be stored in landfills designed to handle such material, and the other residue would be expelled through the exhaust and go on to pollute the air. This contaminant, known as fly ash, caused conditions like asthma and cancer in communities neighboring the facilities. Consequently, waste-to-energy is perceived negatively by the public and opposed by community and environmental groups.

Dr. Themelis confirmed that these adverse effects have been addressed and believes that although well intentioned, environmentalist groups are misguided. To address the bottom ash, scientists figured out how to process it, recover valuable materials that are left over after the combustion process, and store the remaining ash in a way that sequesters carbon that would otherwise contribute to climate change and pose a threat to public health. The bottom ash is sent past a potent magnet, which picks out metals like steel and iron. The rest are sent through eddy current separators — spinning magnets that send a current through the ash and separate non-magnetic metals (Eco Sustainable Solutions, 2020). Whatever ash remains is used in cement mixed. The fly ash from the gasification process is removed by sophisticated filtration systems, which essentially turn the fumes into clean air.

Despite these advancements, concerns around oversight remain. Waste-to-energy detractors worry that plant operators can circumvent environmental regulations to save on costs, which can result in damages to people and the environment.

The second solution to the waste crisis is the use of thermochemical conversion or pyrolysis to treat waste. This process entails sending waste through a pyrolysis machine which in turn heats the materials at extremely high temperatures — over 800°F — in a chamber in the absence of oxygen. Depending on the temperature setting, this process yields three main products; biochar, biogas and liquid that can be used as alternative fuels and fertilizer. The uses of the biochar will vary depending on the types of materials used.

In interviews and correspondence with Akio Enders, pyrolysis technician at Cornell University's KILN, and Professor Johannes Lehmann, lead scientist at the KILN and soil and crops expert at Cornell's School of Integrated Plant Science, they discussed the advantages and caveats of thermochemical conversion through pyrolysis. Dr. Lehmann is mainly interested in the agricultural applications of pyrolysis or waste-to-fertilizer. For example, the waste generated in farming and ranching operations can be fed into a pyrolysis machine and turned into energy and/or biochar to be applied to the soil as a fertilizer or a remediation agent. Dr. Lehmann suggested that in the context of NYC, this technology could be used to process vegetative debris at parks and used the resulting biochar as fertilizer. He indicated that pyrolysis is most suitable for waste containing very low levels of moisture. Otherwise, the device would need to use excessive amounts of energy that can be counterproductive to sustainability goals, in this context reducing energy consumption. In NYC, this technology could be used

successfully in parks where vegetative debris like dry leaves and branches could be used as the input biomass to produce biochar that can then be used as fertilizer or sold in the market. The gas output could be used to power the pyrolysis machine, creating a closed loop process.

Figure 14. KILN facility at Cornell University (Technician Akio Enders examines biochar after it is removed from the new pyrolysis kiln*).* From *Cornell Chronicle,* by Jason Koski, 2018, https://news.cornell.edu/stories/2018/05/trash-treasure-cornells-pyrolysis-kiln-opens-may-24. Copyright 2018 by Jason Koski/University Photography.

Besides applications in the agricultural sector, pyrolysis can also be used to process all sorts of solid waste. During a visit to the Rochester Institute of Technology, Professor Thomas Trabold, Department Head of the Department of Sustainability at the Golisano Institute for Sustainability, seemed confident that this process will play a key role in addressing waste management and minimizing greenhouse gas emissions related to waste management operations. Dr. Trabold mentioned that one of the industries that is heavily invested in this technology is the automotive tire manufacturing industry. Tires are colored with carbon black, a material used in various products like

ink-jet toners, printing, plastics, fuel caps, and pipes to name a few. Carbon black can be recovered through pyrolysis and reused or resold in the market.

One of the greatest advantages of this technology is its scalability. Pyrolysis machines can be manufactured in different sizes according to the intended use. At the Golisano Institute, Dr. Trabold runs experiments on a pyrolysis machine no larger than a residential power generator. This high degree of flexibility gives pyrolysis machines mobility, the equipment could easily be transported where needed, and does not require large tracts of land for development unlike more robust technologies such as waste-to-energy plants.

Despite its strengths, pyrolysis is not free of constraints. Although the technology can be scaled up to produce large quantities of biofuels and renewable energy, it is not yet financially feasible. According to Dr. Themelis, this is due to the lower heating value generated in this process. The low heating value results in lower quality energy, which makes pyrolysis financially unfeasible in its current iterations. Research on the quality and applications of the biochar, gas and fuel is still ongoing. Scientists and students in academic institutions and the private sector continue to experiment with different inputs and catalog potential applications.

With that said, all scientists interviewed for this investigation are confident that pyrolysis will play a role in addressing waste issues and reducing the over-extraction of natural resources as they can be recovered through this process.

On the policy front, the OneNYC strategic plan (2015) delineated a series of ongoing and proposed initiatives directed at sending zero waste to landfills by 2030. Expanding the market for recyclable materials and extending the composting program

to all city residents are two key policies in this effort. As mentioned in an earlier section of this investigation, about half of the collected recyclables are diverted from the waste stream. The city aims to address this problem by creating and expanding markets for reusable materials. To do so, it signed a 20-year contract with Sims Municipal Recycling to process and sell recyclable materials. As for the curbside organics collection or compost program, the city aims to make it available to all residents and eventually making it mandatory on the public and residential side.

However, both of these initiatives have been under heavy scrutiny by budget watchdogs like the Citizens Budget Commission. These organizations argue that waste management strategies like recycling and composting come at a heavy cost to taxpayers with little to show for by way of revenues. On a report about the cost of recycling in NYC, the Citizens Budget Commission found that the city spends $411 million dollars on recycling (Gamerman, 2016) but makes a fraction of that expenditure in revenue. For instance, New Yorkers spend approximately $203 million to collect 296,000 of paper from which they receive $3.6 million in revenues (Husock, 2020). The residential curbside organics collection program faced similar financial challenges. It cost the city $15.7 million in 2018 and generated $58,000 in revenue from selling compost (Collins, 2018). The Citizens Budget Commission estimates that implementing a mandatory organic waste recycling program will cost taxpayers between $177 million and $251 million per year (Barnard, 2020).

These budgetary concerns, however, do not consider negative externalities that are also burden taxpayers. As mentioned, the logistics of waste management disproportionately burden low-income neighborhoods and communities of color, causing

higher rates of diseases like asthma and cancer, and increasing the cost of Medicaid. Additionally, these reports do not quantify the costs associated with climate change, which given the rise in natural disasters is in the hundreds of billions of dollars — hurricanes Sandy, Irma, Maria and Harvey; and wildfires in California have cost taxpayers hundreds of billions of dollars. Until these variables are seriously considered and quantified, it will be extremely difficult to make more objective determinations.

Unlike policymakers, there is a sector of the business community that is adopting and applying principles from the circular economy in their ventures. The women's apparel store Eileen Fisher, for instance, created Reuse, a take-back program that extends the life of their clothes. Customers bring their worn or torn Eileen Fisher pieces to any Eileen Fisher or Renew store and get a $5 rewards card for every item. The clothes are then reconditioned and resold or turned into other products (*EILEEN FISHER Renew - lightly used clothing*, 2020). Another example of a circular business is Toast Ale ((https://www.toastale.com/about-us), a craft beer brewery that recovers bread waste from bakeries, which it uses to replace barley in their beer recipe. By replacing virgin barley for surplus bread, Toast Ale reduces the demand for land, water and energy, and avoids greenhouse gas emissions. Toast Ale began in London, England in 2016, and in 2017 expanded production to the Bronx, NY. Specializing in the construction sector, Building Product Ecosystems (https://www.buildingproductecosystems.org/) is piloting two projects to reduce the need for new raw materials in buildings. The first entails diverting post-consumer recycled glass into glass pozzolan to be used as a replacement of cement in concrete; and the

second pilot deals with source separation and closed-loop recycling of gypsum drywall to turn into new gypsum board, which would greatly reduce carbon emissions.

The greatest challenge for circular businesses is that the current linear economic model is not designed to support closed-loop operations. Meaning that supply chains are not circular and therefore, depend on the extraction of new raw materials. Unless all links in the supply chain adopt closed-loop practices, a true circular economy is out of reach. A second issue, also related to the current economic model, is that business owners find it less profitable to be circular. As more circular businesses are established, this belief is fading. The notion that being circular is expensive also involves a lack of accountability of producers over the goods they manufacture. Once sold, manufacturers are not responsible for what happens to their products when they reach their end of life. If the cost of managing the waste was transferred to producers rather than taxpayers, engaging circular practices or closed-loop operations would be perceived differently.

IX. Discussion

Climate change, the destruction of ecosystems and burdens carried by those who are most vulnerable and least responsible for the waste generated in highly urbanized areas such as NYC have made it abundantly clear that there is a real urgency to transition away from the linear take-make-waste economic model. The circular economy has surfaced as a potential alternative, but despite its design as a business-friendly framework, it has not been embraced on a large scale. An increasing number of businesses and start-ups are adopting circular business models, yet they are fitting into the existing economic system rather than replacing it.

There are multiple reasons why the circular economy has not been adopted more widely. For starters, the entire production, logistical and waste management infrastructure has developed alongside the linear industrial model over the past 200 years. Therefore, in terms of efficiency and optimization, businesses will find that in the short-term it is more profitable to engage the linear economy framework because entire supply chains function according to this model.

Most policymakers understand and acknowledge that continuing on the take-make-waste path is no longer sustainable. But there is discord on how to address the problem. Some policymakers advocate for a liberal approach to achieve a circular economy, while others believe that there is not enough time to wait for the market to solve this problem and government intervention is necessary. Those in the former camp believe that businesses themselves will realize the need to transition towards more sustainable business models if they are to survive, and that consumers will pressure them in that direction; while those on the other side of the spectrum view regulation as

the only way to shift the paradigm fast enough to address climate change and social inequities related to waste and the overconsumption of natural resources.

There are also consumer preferences that have been reinforced by our system of mass production and mass consumption. The idea of the consumer as owner, for instance, incentivizes producers to manufacture goods with shorter life cycles in order to sell additional units and new iterations of their products. It also encourages the design of products that are difficult to repair by the user, have single use parts that are not sold by the manufacturer or third parties, and whose components are difficult to recover and reuse and are often non-recyclable. Even though this configuration results in a lower consumer value, as products need to be replaced more frequently, owning consumer goods is generally preferred over other business arrangements.

The preference for brand new products is another challenge faced by circular business models. Consumers tend to have a negative perception of secondhand products, or even remanufactured products — which are sold in as good as new condition and carry the same warranty as new products — and do not seek out these items as their first alternative. This poses difficulties for circular businesses, since their focus is on advertising products as services rather than selling goods.

That said, younger, more conscientious consumers are increasingly spending their money on circular and service-oriented products. In recent years, shopping in thrift stores has become tremendously popular. Longstanding institutions like Goodwill, the Salvation Army, and Housing Works have experienced vast economic growth. Threadup's most recent resale report suggests that the secondhand market is expected to grow to $64 billion by 2024 (see Figure 16).

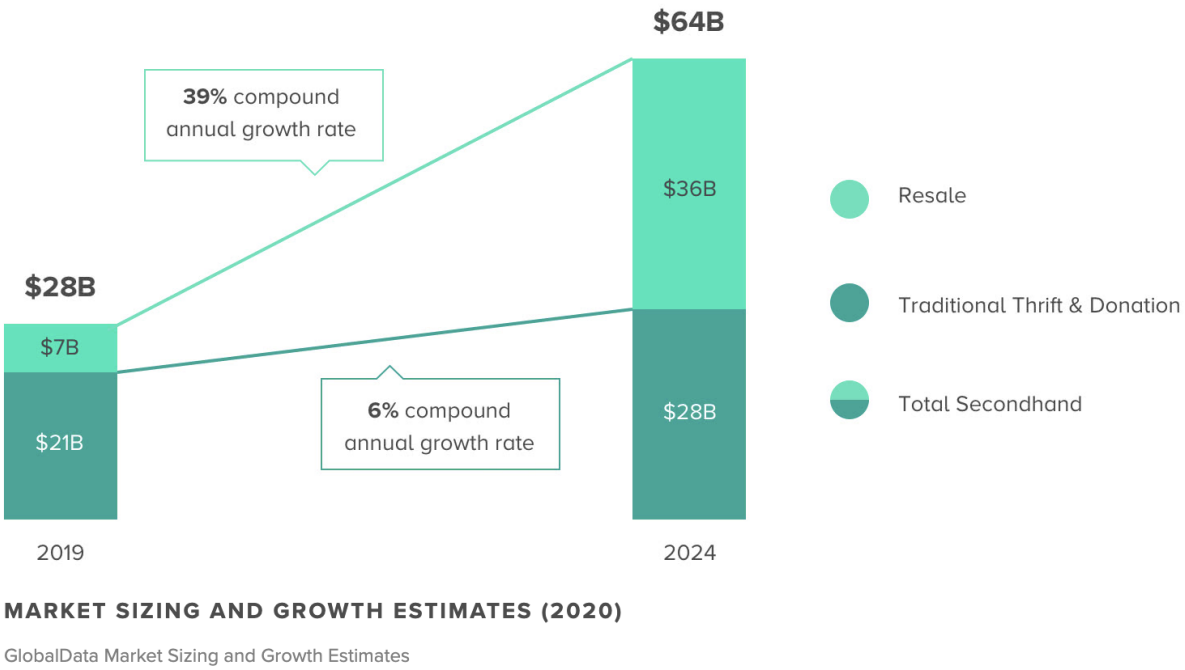


Figure 15. Market Sizing and Growth Estimates. Reprinted from *2020 Resale Report*, https://www.thredup.com/resale/#resellable-brands. Copyright 2020 by the thredUP.

Circular transportation businesses are also thriving in NYC. Citi Bike, NYC's bike share system, has become the main mode of transportation for many city duelers (Figure 17). The company, owned by rideshare giant Lyft and the largest bike sharing system in the country, now comprises 1,000 stations (Troutman, 2020), with 12,000 bikes and over 143,000 members (Citi Bike, 2020).

Another mobility business that has experienced a surge in popularity is Revel (https://gorevel.com/new-york/), a shared electric moped service. In recent months, these vespa-like scooters have experienced a surge in ridership. At this time they are available in the Manhattan, Brooklyn and Queens boroughs (Figure 18).

Figure 16. Citi Bike Share Service in NYC. Reprinted from Citi Bike: Day Passes, https://www.citibikenyc.com/pricing/day. Copyright 2020 by the Lyft, Inc.

Figure 17. Revel Electric Moped Service User in NYC. Reprinted from New York Post, by R. Harbus, https://nypost.com/2020/01/19/scooter-sharing-service-revel-is-racking-up-injury-lawsuits-months-after-launch/. Copyright 2020 by NYP Holdings.

For decades, the academic literature about sustainability and closed loop industrial systems lacked uniformity and was not inclusive of the business sector. Consequently, it never garnered support from this sector nor it gained significant traction as a substitute for the take-make-waste model. It wasn't until the Ellen McArthur Foundation, borrowing from various disciplines, assembled the framework in a way that spoke to industry and entrepreneurs that the model was given serious consideration as a new economic paradigm designed to measure up to the challenges of present time.

As the literacy of the circular economy becomes more widespread, more businesses have adopted its framework. Unfortunately, the biggest manufacturers across industries have not made significant strides in this direction. Those who have,

have done so on a limited scale. Companies like H&M and Eileen Fisher, who have released clothing lines and initiatives that aim to become more circular still remain heavily invested in the linear take-make-waste model (H&M Group, 2019). Often they advertise circular apparel right next to the more inexpensive fast fashion merchandise. The reason for this goes back to the ubiquity of the take-make-waste model across supply chains. As long as parts of the supply chain remain linear, it will be extremely difficult to achieve a true closed loop economy.

Figure 18. Eileen Fisher Renew Store in Irvington, NY. Reprinted from *Eileen Fisher Women's Clothing*, https://locations.eileenfisher.com/us/ny/irvington/womens-clothing-eus956.html. Copyright 2020 by Eileen Fisher.

In NYC, the private sector is spearheading the move to a circular economy. This is not to say that the city government is not taking measures to become more circular.

The DSNY has made substantial investments in logistical infrastructure like barge and freight waste processing stations, the Newton Creek bio-digesters (which processes sewage sludge and organic waste and turns it into energy), and the residential curbside collection programs for recyclables and organics, which contribute greatly towards this transition. However, the survival of these initiatives is often threatened by budgetary constraints, compliance and financial inefficiencies, as well as metrics that do not quantify the negative externalities related to waste such as high disease rates in communities that depend on Medicaid and the negative impacts to the environment. Because the private sector is profit driven, it can focus on those areas of the circular economy that yield positive revenue streams and exploit niche markets, which is why businesses are at the helm of this movement.

That said, businesses will do what is best for their bottom line or makes profit. This is another reason why we are not seeing the radical transformation to the economic model that you would expect in a time when climate change is posing an existential threat to our species. Evidence and the literature suggest that in eventuality businesses will transition to more sustainable systems, just like they have adjusted to challenges and technological innovations in the past. What is concerning is that this paradigm shift will not happen fast enough to curtail the effects of climate change.

Although cities like NYC, which produce some of the highest volumes of solid waste in the world, should be leading the way — given that the trash generated within its boundaries affects communities that are the least responsible — action needs to be taken at the national and at the global level. As it stands now, NYC's measures to become more sustainable and reduce waste related issues are not sufficient because

instead of addressing the culprit — the take-make-waste system — they shift the burden to less prosperous neighborhoods, which are often communities of color. This is not to say that the city should enter a state of paralysis, to the contrary, it needs to continue and expand its efforts, but given the magnitude of the problem it is necessary for the federal government to change the rules of the game so that businesses along supply chains are incentivized to enter the circular economy more rapidly.

X. Conclusion

This thesis set out to identify and understand the negative effects that unfettered waste generation and conventional waste management strategies have on the environment and residents of NYC. Interviews and casual conversations with experts and practitioners in the field of sustainability and waste management suggest that there is a direct link between the vast amounts of solid waste generated in NYC and the linear take-make-waste industrial economic model. In this linear model, economic activity is tied in with the extraction of finite resources, creating a vicious cycle. The current economic configuration is premised on mass production and mass consumption of goods. Raw materials are continuously extracted, goods are churned out, used by consumers and finally thrown in the trash — from where they are usually hauled into landfills or incineration plants. This process takes place continuously to support the bottom line: linear economic growth.

Unfortunately, this dynamic comes at the expense of the environment, and vulnerable populations who are the least responsible. In NYC, low-income residents living near waste transfer stations have higher rates of asthma and cancer, and must put up with pollution, noise and vile smells from garbage trucks. Most of the waste is transported to landfills located in less prosperous areas in Upstate New York and in other states. The methane emissions coming from landfills contribute to climate change and the leachate that collects at the bottom of the landfill pits eventually seeps into the water table and other bodies of water — polluting the drinking water sources of some communities and decimating entire ecosystems and animal species.

Understanding the gravity of the current environmental crisis, scientists across multiple disciplines are advocating for a transition to a circular economy. The Ellen MacArthur Foundation has been particularly invested in promoting the circular economy as the future of business. This framework aims to dissociate economic activity from the extraction of finite resources, while regenerating the environment and expanding the life of products for as long as possible. To successfully move towards a circular economy, however, action needs to take place in all levels of government; local, state and federal. If the focus remains at the local level, wealthier jurisdictions like NYC will develop solutions that albeit benefitting city residents, pass waste and waste related problems to low-income communities.

Circular models also need to be widespread across supply chains if industries are to truly achieve closed loop systems. Although some industries have adopted circular principles in their business models, they are often limited in scale — sometimes coming across as marketing ploys for publicity. Fast fashion companies such as H&M, for instance, are engaging circular practices in their business models, but these products are often advertised side-by-side fast fashion items that follow the linear take-make-waste pattern. This is mainly due to the lower costs in different parts of the supply chain. Even though some apparel companies have take-back and reuse programs, they still manufacture new products whose original components, in this case fabrics, are not necessarily sourced by circular businesses. Thus, while some parts of the supply chain are closed loop, the industry as a whole is not.

So far proponents of the circular economy have focused on incentivizing businesses to adopt the framework, but little has been done to incentivize regular

citizens to sponsor circular products and services. The idea of owning subscriptions to services instead of products is central to the circular economy, but from decades of linear economy indoctrination — which promotes ownership and abundance — people have become accustomed to pay for products that they will own. Although the shared economy has moved customers in the direction of paying for services, second-hand and remanufactured products are still perceived as not being as good as brand new items. Literacy about the circular economy will have to expand to perhaps be included in K-12 school curriculums for the system to become more deeply rooted culturally.

On the policy front, NYC needs to continue expanding circular strategies in the public sector and adjusting the regulatory framework to encourage more circular thinking. The Department of Sanitation of New York is already doing this in various initiatives. That said, the city needs to approach these programs cautiously and given careful consideration to how they affect low-income communities — who are often disproportionately burdened by proggresive policies despite their good intentions. Outside of waste management strategies employed by the city, the government should reconsider who is liable for products at their end of life. At the moment, taxpayers cover the bill for sanitation services and landfilling waste. If producers were held accountable for their merchandise throughout their lifecycle, it could, at least in theory, lead to more circular business practices.

The world is already experiencing the dire effects of a decades long system of mass production and mass consumption where economic activity is intertwined with the extraction of finite materials. Entire ecosystems and territories have been sacrificed for the sake of tapping into natural resources to manufacture goods. Temperatures around

the world continue to steadily rise every year, causing severe droughts leading to disruptions in people's livelihoods such as the loss of agricultural lands. Furthermore, sea level rise and natural disasters are engendering a new generation of nationless people who have been forced to migrate away from their homes because they no longer exist or are no longer suitable for human habitation.

The circular economy presents an opportunity to slow down or even reverse some of these effects and fatalistic projected outcomes. But getting to a fully circular and closed loop economy will take an honest self-appraisal, genuine collective effort, and political will. As the world continues to urbanize at unprecedented rates and more people come out of poverty, waste and environmental problems are likely to increase. Considered by many as the capital of the world, NYC has the opportunity to position itself as a circular city model for the rest of the planet to follow.

Appendix: Interview Questions Protocol

Semi-structured Interview Protocol

Individual

1. What is your job title?
2. How many years have you been in this position? How long have you been at this organization?
3. What are your roles and responsibilities?

Organizational Background

4. What is the purpose of your organization?
5. How does your organization go about achieving its mission?
6. How many employees or members does your organization have?
7. What are some of the major challenges that your organization faces?
8. What are the opportunities for your organization?

Waste Management Questions

9. What waste management strategies does your organization focus on?
10. What alternative waste management strategies, if any, does your organization engage in?
11. What are your organization's operation and implementation costs?
12. What are the potential hazards associated with your organization's waste management strategy?
13. How does your organization mitigate health and environmental risks related to waste management practices?
14. Why does your organization uses landfilling as the primary waste management strategy?
15. Has your organization considered replacing landfilling with other waste management strategies? Why? What are the challenges?
16. What are the benefits to your organization's waste management strategy?

Questions specific to Circular Economy (CE) practices

17. Does your organization have a working definition of CE? If so, what is it?
18. How do the principles of CE (reduced resource consumption, reuse, recycled, recovered,
and shared) provide opportunities for your organization and for policies?
19. What are the main challenges that your organization has experienced so far?
20. What questions have businesses and nonprofits pitched at your organization about CE?

21. In your opinion, what are some policies and/or regulations that would be helpful for your
organization/community in implementing CE practices?
Questions specific to operation of organization
22. Are there specific targets or goals that your organization aims to achieve?
23. What other institutions or actors do you mostly work with (for instance, through collaborations, workshops, subcontracting work etc.)?
24. Do you rely on monitoring and evaluation to identify targets to track the progress of your
organization/community in implementing CE principles? If so, please elaborate.
25. One of the challenges for organizations adopting CE principles in their operations is how
to make it financially sustainable. How is your organization dealing with this challenge?
26. What is the long-term vision of your organization? What is your long-term vision for your city in terms of sustainability?
27. What are your local, regional, national and international collaborations and challenges?
Thoughts about Circular Economy More Broadly
28. What do you think the future is for CE as a way of living and what institutional changes
should be made to adopt CE principles?
29. Are there other major players or resources you would suggest?
30. Anything else you want to add that we didn't ask you?

References

Barnard, A. (2020, March 12). *Mandatory Composting in New York? It Could Happen*. The New York Times. https://www.nytimes.com/2020/03/12/nyregion/nyc-compost-recycling.html

Braungart, M., & McDonough, W. (2002). *Cradle to Cradle: Remaking the Way We Make Things* (1st ed.). North Point Press.

Butini, C. (2018, June 1). *Asthma By The Numbers - Asthma in the South Bronx*. Medium. https://medium.com/asthma-in-the-south-bronx/asthma-by-the-numbers-73553b2c9621

Calder, R. (2017, March 24). *It's getting expensive to ship NYC's garbage to landfills*. New York Post. https://nypost.com/2017/03/24/its-getting-expensive-to-ship-nycs-garbage-to-landfills/

CALPIRG EDUCATION FUND. (2018, November). *The State of Waste in California*. CALIFORNIA PUBLIC INTEREST RESEARCH GROUP (CALPIRG). https://calpirg.org/reports/cap/state-waste-california

CDC (Centers for Disease Control and Prevention). (2015). *500 Cities: Local Data for Better Health 2015*. https://www.cdc.gov/500cities/map-books.htm#accordion-12-card-6

Citi Bike. (2020). *About Citi Bike: Company, History, Motivate*. Lyft, Inc. https://www.citibikenyc.com/about

Collins, L. M. (2018, November 13). *The Pros and Cons of New York's Fledgling Compost Program*. The New York Times. https://www.nytimes.com/2018/11/09/nyregion/nyc-compost-zero-waste-program.html

Danthurebandara, M., Van Passel, S., Nelen, D., Tielemans, Y., & Van Acker, K. (2012). Environmental and socio-economic impacts of landfills. Linnaeus Eco-Tech, 2012, 40-52.

Denchak, M. (2018, November 8). *Flint Water Crisis: Everything You Need to Know*. NRDC. https://www.nrdc.org/stories/flint-water-crisis-everything-you-need-know

DSNY (The City of New York Department of Sanitation). (2019, November 20). *Commercial Waste Zones*. City of New York. https://www1.nyc.gov/assets/dsny/site/resources/reports/commercial-waste-zones-plan

Eco Sustainable Solutions. (2020). *What happens to Waste to Energy Incineration Ash?* https://www.thisiseco.co.uk/news_and_blog/what-happens-to-waste-to-energy-incineration-ash.html

Eileen Fisher. (2020). *Eileen Fisher Renew store in Irvington, NY* [Photograph]. https://locations.eileenfisher.com/us/ny/irvington/womens-clothing-eus956.html

EILEEN FISHER Renew - lightly used clothing. (2020). EILEEN FISHER. https://www.eileenfisherrenew.com/our-story

Ellen MacArthur Foundation. (2017). *Infographic: Circular Economy System Diagram.* https://www.ellenmacarthurfoundation.org/circular-economy/concept/infographic

Ellen MacArthur Foundation. (n.d.). *What is a Circular Economy?*. https://www.ellenmacarthurfoundation.org/circular-economy/concept

Eusebio, D. (2020, July 21). *American Wasteland: Which States Produce the Most Trash?* BigRentz. https://www.bigrentz.com/blog/which-states-produce-most-trash

Frischmann, C. (2018, July 31). *The climate impact of the food in the back of your fridge*. The Washington Post. https://www.washingtonpost.com/news/theworldpost/wp/2018/07/31/food-waste/

Galka, M. (2016, November 5). *Where Does New York City Garbage Go? [An Animated Journey of 3 Million Tons of Waste].* Metrocosm. http://metrocosm.com/where-new-york-garbage-goes/

Gamerman, T. (2016, February). *Can We Have Our Cake and Compost It Too?* Citizens Budget Commission. https://cbcny.org/research/can-we-have-our-cake-and-compost-it-too

Gerholdt, J. (2015, April 22). *The 5 business models that put the circular economy to work | Greenbiz*. GreenBiz Group. https://www.greenbiz.com/article/5-business-models-put-circular-economy-work

Greenpeace USA. (2019, October 4). *Natural Gas & Methane*. https://www.greenpeace.org/usa/global-warming/issues/natural-gas/

Harbus, R. (2020, January 19). *Revel Electric Moped Service User in NYC* [Photograph]. New York Post. https://nypost.com/2020/01/19/scooter-sharing-service-revel-is-racking-up-injury-lawsuits-months-after-launch/

Husock, H. (2020, May 29). *The smart way for post-coronavirus pandemic NYC to save money: Stop recycling*. New York Post. https://nypost.com/2020/05/16/the-smart-way-for-post-pandemic-nyc-to-save-money-stop-recycling/

H&M Group. (2019, June 13). *A Unique Partnership to Help Build a Circular Economy*. https://hmgroup.com/media/Our-stories/HMGroupandtheEMF.html

Jacobs, K. (2016, September 13). *How the world's largest landfill became New York's biggest new park*. Curbed NY. https://ny.curbed.com/2016/9/13/12891320/freshkills-park-nyc-staten-island-engineering-design

Katz, C. (2019, March 7). *Piling Up: How China's Ban on Importing Waste Has Stalled Global Recycling*. Yale E360. https://e360.yale.edu/features/piling-up-how-chinas-ban-on-importing-waste-has-stalled-global-recycling

Kaza, S., Yao, L. C., Bhada-Tata, P., & Van Woerden, F. (2018, September). *What a Waste 2.0 : A Global Snapshot of Solid Waste Management to 2050*. p.19-34. The World Bank. https://openknowledge.worldbank.org/handle/10986/30317

Koski, J. (2018). Technician Akio Enders examines biochar after it is removed from the new pyrolysis kiln. [Photograph]. Retrieved from https://news.cornell.edu/stories/2018/05/trash-treasure-cornells-pyrolysis-kiln-opens-may-24.

LSEA Corporation. (2012). The Essex County Resource Recovery Facility in New Jersey [Photograph]. Port Authority of NY and NJ. http://www.lseacorp.com/portfolio/pany.html

Lyft, Inc. (2020). *Citi Bike Share Service in NYC* [Photograph]. Citi Bike: Day Passes. https://www.citibikenyc.com/pricing/day

Moss, R. (2016, May 25). *Does Living Near A Landfill Site Increase Your Cancer Risk?* HuffPost UK. https://www.huffingtonpost.co.uk/entry/living-near-landfill-site-increases-cancer-risk_uk_574569d4e4b03e9b9ed4fa19?

New York City Committee on Sanitation and Solid Waste Management. (2018). Intro 157-C, Waste Equity Bill Hearing.

New York Environmental Justice Alliance. (2016, November 13). *Placement of Waste Transfer Stations in NYC. A not surprising correlation.* Cleanup North Brooklyn. http://www.cleanupnbk.org/news/2016/11/13/placement-of-waste-transfer-stations-in-nyc-a-not-surprising-correlation

OneNYC. (2015). The Plan for a Strong and Just City. http://www.nyc.gov/html/onenyc/downloads/pdf/publications/OneNYC.pdf

Rosengren, C. (2018, July 16). *New York City Council passes long-awaited transfer station capacity reduction bill*. Waste Dive. https://www.wastedive.com/news/new-york-city-council-vote-transfer-station-capacity-bill/527839/

Solid Waste Environmental Excellence Protocol (SWEEP). (2018). *The Time is Running Out: the US Landfill Capacity Crisis*. Northeast Resource Recovery Association. https://www.nrrarecycles.org/sweep/time-is-running-out-the-u-s-landfill-capacity-crisis

Transform Don't Trash NYC. (2019, October). *Trashing New York's Neighborhoods*. https://alignny.org/wp-content/uploads/2019/10/trashing-new-yorks-neighborhoods.pdf

Troutman, M. (2020, July 20). *Citi Bike Marks 100M Rides, 1K Stations Installed In NYC*. Patch Media. https://patch.com/new-york/new-york-city/citi-bike-marks-100m-rides-1k-stations-installed-nyc

United Nations. (2018, May 16). 68% of the world population projected to live in urban areas by 2050. *UN DESA | United Nations Department of Economic and Social Affairs*. https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

United Nations. (2019). *Food*. https://www.un.org/en/sections/issues-depth/food/index.html

United States Environmental Protection Agency (EPA). (2020, March 13). *National Overview: Facts and Figures on Materials, Wastes and Recycling*. https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials#Landfilling

U.S. Geological Survey. (2017, October 18). *Study Estimates about 2.1 Million People using Wells High in Arsenic*. https://www.usgs.gov/news/study-estimates-about-21-million-people-using-wells-high-arsenic

Webster, K. (2017). The circular economy: A wealth of flows. Ellen MacArthur Foundation Publishing.