Increasing Transparency and Understanding of Landfill and Energy Recovery Practices in NYC's Municipal Solid Waste Management System in Driving a Zero Waste Goal

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Submitted in Partial Fulfillment of the
Master of Science in Sustainability degree

City College of New York
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December 2016

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Acknowledgements

We would like to express our gratitude to our advisor, Professor Marco J. Castaldi, PhD (Associate Professor, Chemical Engineering Department, CCNY, CUNY), for his support and guidance. In addition, we would like to thank George Smith (Administrator, Sustainability in the Urban Environment Program, CCNY, CUNY), Hillary Brown (Director, Sustainability in the Urban Environment Program, CCNY, CUNY) and our other professors in this excellent program. We also want to take this opportunity to share our appreciation for the supportive experts who extended their time and insights to help facilitate our research. They include:

- Sarah Bloomquist, Member, Communications Committee, Manhattan Solid Waste Advisory Board (SWAB)
- Donald Chahbazpour, Director, Climate Change Compliance, National Grid
- Vasil Diyamandoglu, PhD, Professor, Solid Waste Reuse & Recycling, CCNY, CUNY
- Sarah Dolinar, SWM Director of Environmental Compliance/Contracts, NYC Department of Sanitation
- Mark Eyeington, Chief Operating Officer, Solid Waste Authority of Palm Beach County
- Paul Gilman, Chief Sustainability Officer, Covanta
- Ted Michaels, President, Energy Recovery Council
- Kate Gouin, Senior Policy Advisor, NYC Mayor's Office of Sustainability
- Jim Pynn, former Plant Superintendent, Newtown Creek Wastewater Treatment Plant, NYC Department of Environmental Protection
- Cole Rosengren, Freelance Journalist, Wastedive.com

Abstract

By bringing more understanding and transparency to NYC's current landfill and energy recovery practices, we seek to analyze and understand the fullest impacts of municipal solid waste management in achieving the OneNYC goal of "Zero Waste by 2030." In doing so, we unpack the technological, social, political, and environmental barriers to implementing potential best practices within the integrated municipal solid waste management plan. We start by researching and analyzing the ways waste destination communities outside New York City are affected by current landfill and energy recovery practices. We then discover additional streams of waste disposal to landfill that OneNYC does not include in the Zero Waste baseline, but does include in its "80 X 50" greenhouse gas emissions reduction plan, a key driver for reducing landfill disposal of solid waste. We conclude by evaluating challenges towards implementing current strategies and whether increased waste-to-energy practices, such as rapidly advancing thermal combustion technologies, will be necessary for New York City's integrated solid waste management plan in achieving zero waste to landfill over the long term.

Key Words: waste to energy, WtE, energy from waste, gasification, MSW, zero waste, OneNYC, 80X50, greenhouse gas reduction, sustainability, landfill diversion, thermal treatment, waste to landfill, non-putrescible waste, anaerobic digestion

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1. Objective

By bringing more understanding and transparency to NYC's current landfill and energy recovery practices, we seek to analyze and understand the fullest impacts of municipal solid waste management in achieving the OneNYC goal of "Zero Waste by 2030." In doing so, we will unpack the technological, social, political, and environmental barriers to implementing potential best practices within the integrated municipal solid waste management plan.

The project team conducted extensive research including data collection from the scientific literature, conversations with industry and academic experts, community members, representatives of municipal and county agencies, waste facilities, and other stakeholders. Much of the information gathering was accomplished through attendance at events, meetings and conferences, including the International Solid Waste Conference in Austin, TX in April 2016; the North American Waste-to-Energy Conference in West Palm Beach, FL in April 2016; the Megacity Waste Management Dialogue: The NYC Roadmap for Waste as a Resource in Manhattan in April 2016; and, the Annual New York Water Environment Association Conference, in Manhattan in February 2016. In addition, the team toured the SIMS Municipal Recycling Facility in Brooklyn and joined two monthly NYC Solid Waste Community Board (SWAB) meetings in Brooklyn and Manhattan, the NYC Department of Environmental Protection (DEP)'s Floatables Working Group kickoff in Brooklyn, and the GreenHomeNYC Forum on Waste Management in Manhattan.

The objective was to continue the process of acquiring a greater, fuller understanding of New York City's integrated solid waste management picture to date. For research outside city boundaries, media interviews and other sources were scoured for data acquisition prior to analysis.

2. Background Research

2.1. MSW, Management & Waste Transfer Station Definitions

Municipal solid waste (MSW) is the waste that is collected from our homes, schools, hospitals, and businesses. Industrial process wastes, agricultural wastes, mining waste, and sewage sludge are not considered MSW.

Municipal solid waste management is commonly understood as a hierarchy of best practices and illustrated as an upside down triangle, whereby the top is the most preferable (avoiding waste altogether), the bottom is the least (waste disposal), and the best to least flows downward.

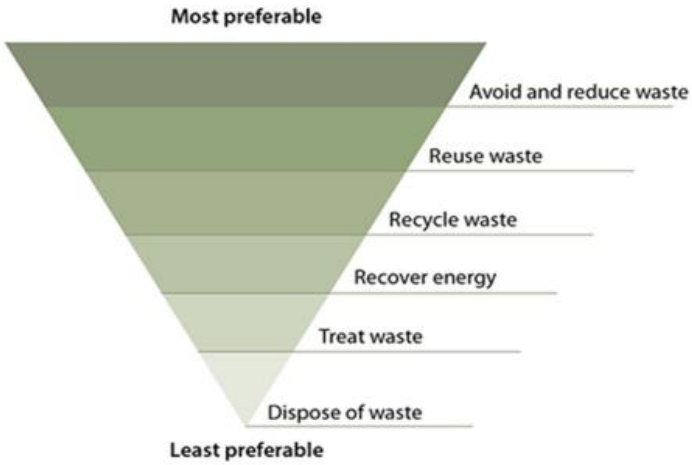


Figure 1: Waste Management Hierarchy
Source: U.S. Environmental Protection Agency

The EPA regulates household, industrial, and manufacturing solid and hazardous wastes under the federal Resource Conservation and Recovery Act (RCRA). RCRA provides protection from a range of impacts from improper management of waste. Priority areas include statutes enforced to set standards and regulatory guidelines for the disposal of hazardous waste. RCRA also provides legal guidance on recycling and recovery with the aim to conserve energy and natural resources, reduction and elimination of waste, and mandate for cleaning up waste which may have spilled, leaked or disposed of improperly.

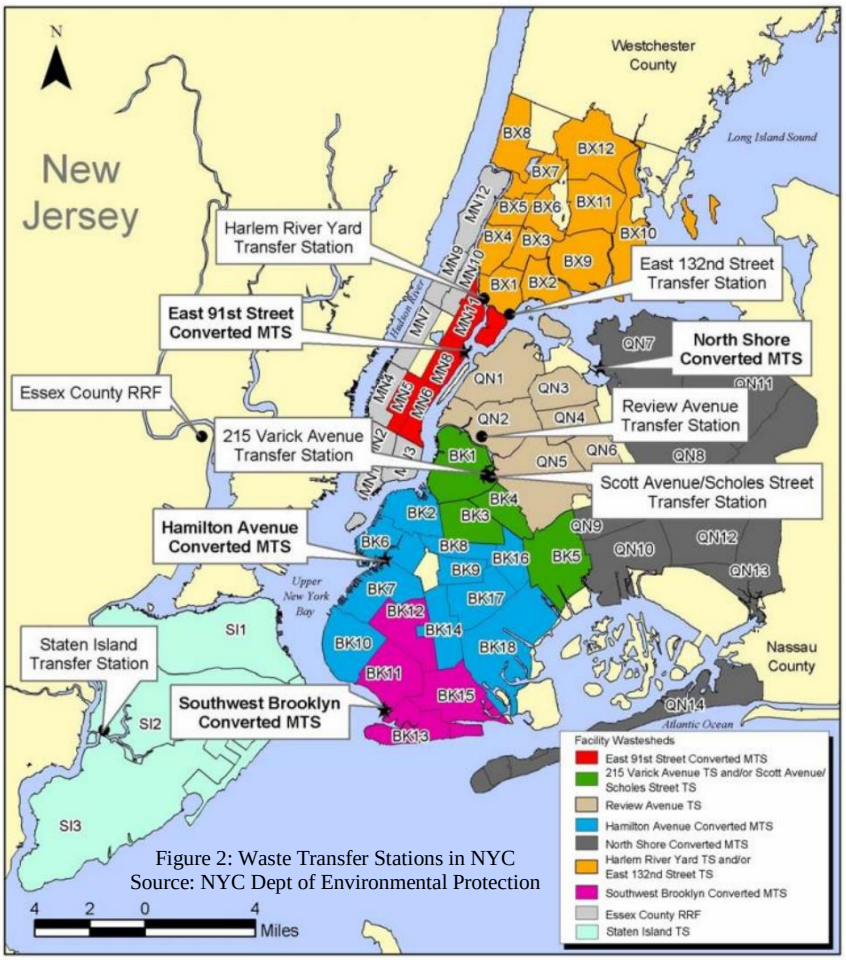


Figure 2: Waste Transfer Stations in NYC
Source: NYC Dept of Environmental Protection

Waste transfer stations are facilities designed to make MSW management more efficient in geographically expansive areas. They make it possible for multiple vehicles to collect and unload MSW into these facilities temporarily so that waste can be loaded onto long-distance vehicles from fewer pickup locations and then shipped to disposal facilities. Waste transfer stations can congest streets and cause air and noise pollution for adjacent residents if not planned and

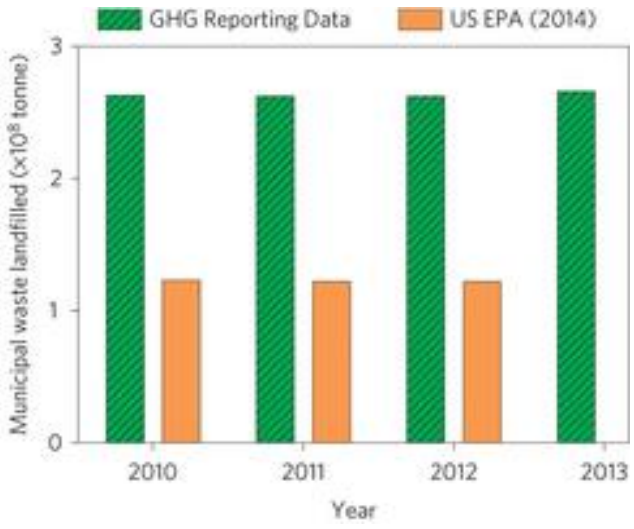
managed effectively, even though they reduce overall impacts of more frequent trips to and from disposal sites (EPA, archive)

2.2 Landfill

2.2.1. Definition (EPA)

A landfill is an engineered structure built into or on top of a ground surface in which trash, garbage or refuse is stored and isolated from the surrounding environment. The surrounding environment is composed of the air, soil and water adjacent to the site. Landfill technology has evolved from its most basic form of massive holes where waste is dumped to advanced landfilling with multiple layers of protection for soil and water, emissions control systems, and gas recovery for energy conversion. Non-hazardous waste landfills are regulated through the National Resource Conservation and Recovery Act (RCRA), Subtitle D, and hazardous waste landfill disposal sites are regulated under RCRA, Subtitle C.

Modern landfills are composed of a constructed area to store waste, a liner to protect the surface from leaching contaminants to the soil or water, and a covering material, most likely soil, which protects the decomposing material from emitting into the atmosphere. Non-hazardous landfills are filled with household waste, industrial waste, larger institutional waste, commercial waste, and construction waste. Residential waste is managed by the NYC Department of Sanitation (DSNY) as Municipal Solid Waste (MSW), while other streams are regulated by DSNY. A majority of waste sent to landfill comes from the private sources and is managed by a separate regulatory structure with little visibility or accountability. Calculations on total amounts in landfills nationwide has changed in the past three years sparked by a Yale University study in 2013 which estimated over 125% more than same year EPA estimates. The EPA now uses more precise projections. Per their calculation, the weight of waste sent to landfills was 289 million tons.



This study calculated the 'GHG Reporting Data' columns. **Reported US EPA (2014)**

Landfills are considered by many researchers to be one of the largest contributors to anthropogenic methane emissions(IPCC in Climate Change 2013) Approximately 91% of the total methane emissions released by landfills are done by open landfills, those that are open to the atmosphere and usually covered with a layer of soil daily.

2.2.2 Timeline of NYC Waste Management Policy and Practices

Waste management today is a highly complex network of strategies based on a revision to a long-held solid waste management plan (SWMP) that, with the most current update, sought to more equitably distribute the way New York City handles trash across the five boroughs. While the current version of that plan will be discussed later in this paper, that original plan has roots that reach far back in history.

Waste management has a history dating back as far as 3,000 B.C. when, in Knossos (Pichtel), the first landfills were created in the form of large holes that were filled with waste and covered with dirt. In the city of Athens, they created a practice for refuse to be picked up and stored a distance no less than one mile from the city, signaling one of the first modern policies on waste management that is still emulated today. New York City, like many of the great cities of the past, has a history of progressive reforms in its development including its utilization and management of waste.

As one of the oldest and largest cities in the country, New York City, has been an epicenter for immigration, trade, industry, and entertainment for the better part of the 20th century. The City has had a steadily increasing population and a correlating spike in consumption of energy resulting from industrial industrialization. The handling of the enormous task of managing waste has been a challenge for New Yorkers for a long time. This challenge has seen many iterations and innovations. Some critics would say that the path has not always been progressive and that in some cases we have taken steps backwards in our proper management of waste. One thing that seems for certain is that our history of waste management leaves many informative examples and lessons learned which we can use in our decisions moving forward. This section will give a brief overview of the waste management practices in New York's history and a short reflection on the political climate of present day issues related to our waste.

1600-1900- The Beginnings of Waste Management and Recycling Policies

New York City waste history dates back as early as the 1600s. In 1657, New Amsterdam, now Manhattan, passed a law preventing residents from throwing garbage into the street. In 1866, The Metropolitan Health Department declared war on garbage, forbidding the "throwing of dead animals, garbage or ashes into the streets." In 1872, the city stopped its practice of dumping garbage off a platform into the East River. 1880 saw the removal of over 15,000 horse carcasses from the streets of New York by scavengers due to the inhumane care and maintenance of the animals. One of the biggest sanitation issues of its time was the proper disposal of dead horses and their manure. In 1881, the NYC Department of Street Cleaning was formed to take over the responsibility of collecting garbage and keeping the streets clear, a task formerly assigned to the police department. The Department of Street Cleaning evolved into what we know now as the

Department of Sanitation. In 1885 the first waste incinerator was built on Governors Island. Shortly after, there were about 180 incinerators built across the country. (Martin)

For the next century, incineration would be one of New York City's top methods for handling waste. Approximately one-third of American cities incinerated their waste. Shortly after the beginning of incineration, in 1896, New York City implemented a new mandate ordering residents to separate household waste. Food waste was to go in one tin, ash in another, and dry trash in a bag or bundle, a program which 40 policemen were assigned to oversee. In 1895, New York City finally saw concrete legislation preventing the dumping of garbage into the ocean and mandated recycling. Before this law was passed by Department of Street Cleaning, over 75% of waste was dumped into the Atlantic Ocean.(NYC Dept. Of Sanitation: History) The new waste management plan laid out distinct guidelines for waste separation and disposal. Food waste was steamed and compressed to produce grease and fertilizer; rubbish from paper and other materials were recovered; and ash was landfilled along with non-marketable rubbish. This became New York City's first recycling program (NYCWasteless – History). 1898 marked the year that New York City saw its first recycling sorting facility to deal with all the new material sorted from the new plan. Shortly after, federal legislation changed waste management practices for all major cities through the federal Rivers and Harbors Act, which restricted dumping waste into navigable rivers to keep them open for shipping. (USEPA)

1900-2000: The Origin of Waste-to-Energy

The 20th century kicked off with New York City's first Waste-to-Energy incinerator, which used its generated electricity to light the Williamsburg Bridge.(NYCWasteless:History of Recycling) The city had already employed incineration as a waste management strategy for two decades, but the turn of the century marked the first time technology was used to recover energy from waste and make it useful. Unfortunately, the incinerator boom came to a crash by 1908. Most incinerators were inadequately built or managed and had to be decommissioned. Approximately 102 of the 180 incinerators built since 1885 were shut down before they reached their 30-year anniversary (Martin). America, although fully explored, was much less dense and urbanized as it is now. This means there were many places to dump garbage without immediate backlash from the public. At the time, dumping garbage was considered a relatively low cost option for managing waste, and that is exactly what most cities did--dump.

In the early 1900s, approximately 80% of that waste was coal and wood ash, mostly from incineration for heating. Waste and energy infrastructure was and still is intrinsically linked. World War I forced a different perspective on waste and the value of it when raw materials became increasingly scarce. The Waste Reclamation Service was formed inciting industry with the motto "Don't Waste Waste--Save It." At the time, many innovative ideas around waste reclamation and reuse were pioneered, as well as many technological substitutes for what has become rare materials. Unfortunately, the post-war economic boom reversed the American's enthusiasm for thrift. In 1926, a large step in the consumerist economy made way with the first super market. Clarence Saunders was the first to open a market with pre-packaged

food and self-service packaging, to help increase selection and keep prices down. This drastically increased the amount of material in our waste stream.

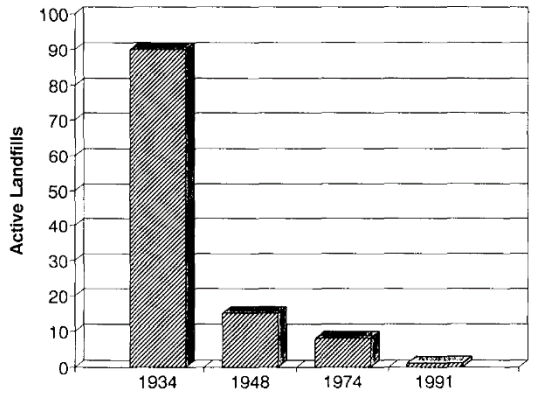


Fig. 1. Number of active landfills operated in New York City.

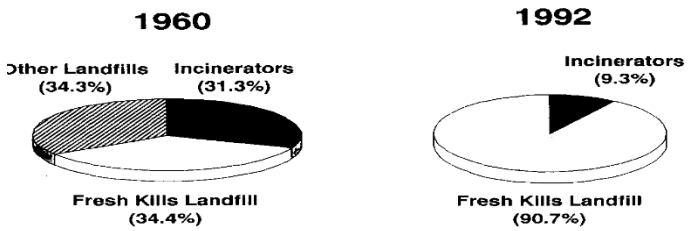


Fig. 3. Comparison of waste disposal methods practiced in New York City between 1960 (left) and 1992 (right). Values for 1992 are projected from current waste disposal statistics.

(Walsh)

The 1930s saw the first mass production trash collection trucks with built-in compactors. This efficiency allowed them to reach distant areas of the city. In 1934, communities in New Jersey obtained a court order to stop New York City from dumping waste into the Atlantic Ocean. The Supreme Court upheld the decision but stipulated that it only applied to public waste and not to commercial or industrial.(ATSC Garbage Timeline)

In 1947, the Fresh Kills Landfill was opened as a temporary solution to the ban on ocean dumping. Covering over 200,000 acres, Fresh Kills, at the time, was the largest landfill in the world.(Miller) After World War II, the country saw a unprecedented spike in consumption of goods, with the growth of convenience foods and its packaging changing the nature of our waste stream dramatically. In the late 1950s, The American Society of Civil Engineers published a guide to "Sanitary Landfilling," primarily to guard against rodents and noxious gasses. The suggestions were as simple as compacting waste and covering it with soil.

1960-2000: The Environmental Agenda

The environmental impact of waste became a leading consideration, which influenced a change in the focus of waste management. In 1965, the Solid Waste Disposal Act (SWDA) was enacted. One of its central focal points was to provide improved research and best practices on managing waste. President Johnson commissioned "Community Solid Waste Practices," a national survey which aggregated the first comprehensive data set of cities waste since the time record keeping began in the early 1900s. **(EPA Facts and Figures)** The 1970 amendment of the SWDA, referred to as the Federal Resource Recovery Act, shifted the focus from merely disposal to recycling material and reusing recoverable and organic materials in solid waste. This was also the first introduction of waste-to-energy in federal legislation. Although waste to energy was called out as a potential solution, the 1970 Clean Air Act lead to many incinerator shutdowns because they did not meet the new emissions guidelines.(History of Solid Waste Management) The Toxic substance Control Act Amended the previous Resource Conservation and Recovery

Act limiting the ability for individuals and businesses to legally dump hazardous chemicals into landfills. (USEPA)

In 1978, the 'dump or burn' strategies of major cities saw a significant shift. The Supreme Court ruled in Philadelphia vs. New Jersey, a case in which New Jersey refuse to accept waste from Philadelphia, that waste is protected by the Interstate Commerce Clause.(Legal Information Institute) The ruling signified that a state cannot refuse or ban waste or "goods" from one state to another. This case went all the way to the U.S. Supreme Court, with fierce debate on whether the right to rescind the right for a state to transfer "goods" or commerce would precede over the apparent environmental hazard associated with it. The U.S. Supreme Court ruled it "un-constitutionally illegitimate" to isolate a state's interest from the national economy, essentially attacking the preconception of state preferred rights, even if those rights are to protect the natural ecology or safeguard against contagion.(American Law and Legal Library) The ruling set up an open invitation for big cities to prospect and find dumping grounds nearly anywhere in the United States. In 1984, the Hazard and Solid Waste Act was amended to add tougher regulations on landfills yet without restricting interstate exchange.(EPA: History)

Landfilling by nature is a relatively invisible part of New York City's infrastructure, however in 1987, it made headline news when Mobro, a barge from Long Island, carrying 6,000 tons of garbage was rejected by six states and three countries (United States, Belize and Mexico). After being out to sea for 173 days, it was brought back to Brooklyn and incinerated. This event brought awareness to the limited capacity of landfills serving metropolitan New York. By 1993, legislation had evolved to include regulation for almost all landfills in the country. The last remaining operational landfill within New York City's boundary was at Fresh Kills, which was fed through an elaborate network of barges transporting the city's garbage there for disposal. With increasing concerns about population growth and poor air quality, the city decommissioned the last active incinerator in 1999, which ended the era of incineration as a waste disposal option within New York City's borders. Two years later in 2001, Fresh Kills Landfill was closed. For the first time in its history, New York City did not have a site to burn, bury or store its waste. The city sent most of the waste to private transfer stations in Brooklyn, Queens and the Bronx to be exported to out of state landfills (Martin).

2001-Present: From Fresh Kills to Zero Waste

In 2001, Fresh Kills, the last landfill in New York City was closed. This marked the first time that New York City did not have a place within the five boroughs to bury or burn it's garbage. The immediate response was to increase the amount of waste diverted to landfills and as the landfill capacities started to decrease the sites spanned further away from the city. In 2006 New York City adopted the long term Solid Waste Management Plan (SWMP). The focus was on developing less hazardous and cost effective ways to export waste.

The SWMP also was designed to minimize the community impacts on the outer-boroughs, where most of the waste was being sent, by implementing a more evenly distributed transfer station system and using rail and barge transport as a means to export waste instead of long-haul trucking (City of New York, PlanNYC 2030). The 2007 release of PlaNYC featured a detailed outline for solid waste management listing a host of new initiatives, some of which included

targeted recycling incentives, opportunities for organics recovery from the waste stream, diversion of waste from landfills by 75%, reducing greenhouse gas (GHG) emissions, and overall efficiency improvements (City of New York, PlanNYC 2030). The 2010 revision of the plan formalized the partnership with Sims Metal Management to open the Materials Recovery Facility (MRF) at the South Brooklyn Marine Terminal. By January 2012, approximately 32% of New York City's waste was being transported out of the state to landfills. The plan included reducing GHG emissions by 34,000 tons by diverting 2,000 tons of waste per day from land-based solid waste transfer stations in Brooklyn and Queens to marine transfer stations (City of New York, 2014). Soon after New York City opened the MRF at the South Brooklyn Marine Terminal, which sorted metal, glass and plastic, DSNY was able to expand its curbside recycling to include all rigid plastics.

In 2013, DSNY piloted the voluntary residential organics recycling program in select neighborhoods in Brooklyn, Staten Island and the Bronx, in addition to expanding school food waste composting in 400 public schools. In the same year, DSNY also piloted events for textile, clothing, electronics, and household waste recovery as well as increasing public recycling containers to 2,190. City Council proposed the Commercial Organics Law which would require large-scale commercial waste generators, like restaurants, to have their organic waste privately collected and hauled (City of New York) In the spring of 2015, Mayor Bill de Blasio announced the rebranding of PlaNYC to OneNYC, which includes the city's commitment to Zero Waste by 2030 ("0X30") a plan to divert 90% of municipal solid waste away from landfill. The initiative would provide a means to manage waste-related GHG emissions, a key carbon pollution category identified with the Mayor's commitment to reduce the city's emissions 80% of 2005 levels by 2050 ("80X50").

New York City is currently pursuing several different strategies to improve waste management, including increasing recycling capture rates; encouraging residents and businesses to divert organic material from landfills; and overcoming permitting obstacles related to waste-to-energy

2.2.3 Profile of Major Disposal Sites Contracted by NYC

This paper focuses on New York City's integrated municipal solid waste management (MSWM) challenges. That focus is concerned with gaining a better understanding of and more transparency for New York City's solid waste management practices, which include impacts to MSW destination communities and geographic areas outside New York City that host landfills and energy recovery facilities. There are 56 final destinations for a New Yorker's residential solid waste, 15 of which are landfills and 7 are waste-to-energy facilities. (DSNY, 2016) These landfills are all located outside of the New York City area. Some of them as close as upstate New York and some as far as Kentucky and South Carolina

As you can see from Table 1 (Appendix), much of New York City's MSW goes to landfills in poor communities. 73% of waste goes to communities with poverty levels below the national average. Graphic 1 (Appendix) shows the locations of these facilities. The dots are graded for size based on how much waste was transported there in the calendar year 2015. All of the information for this map is sourced from Table 3 (appendix).

The waste that travels to Virginia and South Carolina does so by rail. Rail is an easy way to cut GHG emissions stemming from the transport of waste, and also reduces truck traffic around waste facilities. The railcars are owned by Waste Management Inc., the same company that owns the landfills. This intermodal form of transportation has not yet been made available for WTE facilities contracted by NYC, and represents a definitive disadvantage in contract possibilities as the city tries to work towards its 80 x 50 GHG reduction goal. High Acres landfill estimated that the use of rail reduced GHG emissions stemming from waste transport to the site by 75% (Orr, 2016).

The true socio-economic and environmental impact that the disposal sites have on the communities that hosts them is explored further in Section 3.
.

2.3. Waste to Energy

2.3.1. Definition

Energy recovery from waste is the conversion of non-recyclable waste materials into useable heat, electricity, or fuel through a variety of processes, including combustion, gasification, pyrolization, anaerobic digestion, and landfill gas (LFG) recovery. This process is often called waste-to-energy, or "WTE" (EPA). WTE uses thermal means to convert waste materials into electrical and heat energy (Castaldi, 2015). Thermal processes include mass-burn, pyrolysis, gasification, plasma arc, combustion, depolymerization, catalytic cracking, and others.

With one exception in Edmonton, Alberta, most facilities in North America are mass-burn operations that combust non-recyclable, non-petrucobile MSW to capture residual heat to make electricity, steam or district heat. WTE plants generate an ash byproduct, in quantities roughly equivalent to 20% of the weight of MSW processed (Sylvan, 2014). That ash is commonly used for landfill cover in the United States, although it can be used in construction for roads, a standard practice in Europe.

Technologies differ in terms of oxygen concentrations levels and temperature requirements, usually, within the range of 800 degrees F to 8000 degrees F, yet all convert solid material into combustible flue gas. The flue gas flows through a heat exchanger that converts water to steam. That steam turns a turbine generator to make electricity. Thermal processes can also render potentially valuable byproducts including liquid bio-oils, diesel fuel and combustible synthetic gases ("syngas"). Others include nutrient-dense products like ash and bio-charcoal (or "biochar") that can be used for purposes other than energy including building materials and agriculture, respectively.

Although WTE plants require high upfront costs, rapidly emerging thermal technologies may enable lower cost solutions due to their energy output (Castaldi, 2015). With demand for energy expected to increase by 56 percent between 2010 and 2040 (U.S Energy Information Administration, 2013), the sector remains a viable investment area, as demonstrated by development of facilities across Europe. Arguments in favor of exploring more diversion to WTE facilities in or near New York City also leverage regulations that mandate pursuing methods for increasing percentage of MSW to beneficial use **(RCRA)**.

Anaerobic digestion is often grouped into the WTE category, but is not considered a traditional thermal process as combustion, gasification, pyrolysis, and plasma arc. Yet, anaerobic digestion, which uses bacteria in a heated, oxygen-free environment to decompose organic matter, remains a commonly proposed, WTE management solution for organics in MSW (Sylvan, 2014).

Whether stand-alone, or as part of the municipal wastewater treatment process, anaerobic digestion provides an efficient method for treating organics. In wastewater treatment, organics can be added to sewage sludge to increase the energy value from methane, its main by-product. The stabilized product, once dried, can be used as an EPA-compliant fuel source. Like separated yard waste or food waste, including recycled cooking and trap grease, and other materials described in the federal renewable fuel standard, §80.1426(f)(5)(i), decontaminated sludge, or the bio solids produced by anaerobic digestion, can be combusted as both a waste management solution and energy recovery opportunity. Methane, a significant byproduct of anaerobic digestion, can be harvested for its energy value as well, and is typically used by the facility to generate the process heat needed to run the digesters (USEPA).

When looking at U.S trends in energy recovery from technology, we can see an increase along with recycling, composting and other methods following source-separation.

Activity	1960	1970	1980	1990	2000	2005	2008	2010	2011	2012
Generation	88.1	121.1	151.6	208.3	243.5	253.7	252.5	250.4	250.4	250.9
Recovery for recycling	5.6	8.0	14.5	29.0	53.0	59.2	61.9	65.0	66.3	65.3
Recovery for composting*	Negligible	Negligible	Negligible	4.2	16.5	20.6	22.1	20.2	20.6	21.3
Total materials recovery	5.6	8.0	14.5	33.2	69.5	79.8	84.0	85.2	86.9	86.6
Discards after recovery	82.5	113.0	137.1	175.0	174.0	173.9	168.5	165.3	163.5	164.3
Combustion with energy recovery†	0.0	0.4	2.7	29.7	33.7	31.6	31.6	29.3	29.3	29.3
Discards to landfill, other disposal‡	82.5	112.6	134.4	145.3	140.3	142.3	136.9	136.0	134.2	135.0

* Composting of yard trimmings, food waste, and other MSW organic material. Does not include backyard composting.

† Includes combustion of MSW in mass burn or refuse-derived fuel form, and combustion with energy recovery of source separated materials in MSW (e.g., wood pallets, tire-derived fuel).

‡ Discards after recovery minus combustion with energy recovery. Discards include combustion without energy recovery.

Details might not add to totals due to rounding.

[3] Source: For 2002 data: BioCycle 2006.
For 2012 data: EPA, Municipal Solid Waste in the United States: 2012 data tables and BioCycle, 2013.

Table 2. Generation, Materials Recovery, Composting, Combustion With Energy Recovery, and Discards of MSW, 1960 to 2012 (in millions of tons)
SOURCE: EPA, Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2012

2.3.2. Most Current WTE Innovation

On December 10, 2016, a GoogleScholar search for the term "WTE" resulted in hundreds of peer-reviewed articles exploring new approaches to pyrolysis, gasification, and other applications of thermal treatment of solid waste. With that level of data populating in the scientific literature, it is clear these rapidly emerging technologies offer a new perspective on solid waste management. For example, one of the most recent studies published in December 2016 found that the thermochemical process of briquetting and gasifying solid vegetable waste is feasible for both recovering its energy and subsequently generating power. This research further demonstrates gasification as an option for municipal organics disposal with products producing a range of heating values depending on the type of feedstock processed (Narnaware, 2016). With such acceleration of research and development, it is believed that thermal technologies will become more affordable, including hydrolysis and gasification, which are reaching the end of their MSW disposal demonstration phase (Sylvan, 2014). This trend is promising as population growth and policy continues to make the shift toward evolving shared and circular economies (City of New York, 2015), which are leading to shared, digital and greener consumption and behavior that is expected to improve MSW management in New York City.

In September 2016, the NYC Mayor's Office of Sustainability published "New York City's Roadmap to 80X50," pursuant to Local Law 66 of 2014. In full alignment with this OneNYC goal, WTE offers a strategic approach to reducing greenhouse gas emissions. As a benchmark, the EPA determined that WTE facilities reduce GHG emissions by one ton of CO2 equivalents (CO2e) for every ton of MSW diverted from landfill and processed. With national MSW throughput at approximately 29,722,559 tons in 2014 (Energy Recovery Council, 2016), WTE facilities prevented nearly 30 million tons of greenhouse gas emissions in accordance with that federal standard. This scale of performance becomes even more promising when considering the EPA's Clean Power Plan, which allows WTE facilities to generate tradable emission rate credits, or ERCs, under a rate-based state plan to reduce GHGs from the power sector (EPA, 2015).

However, there are no existing plans to locate WTE facilities within New York City (Garcia, 2016, Megacities conference). Instead, DSNY executed a 20-year contract with Covanta in 2013 to transport 800,000 tons of garbage to WTE plants in Niagara, New York and Chester, Pennsylvania. Additional MSW disposal in the short-term would involve increasing capacity at those and the Convata facilities in Hempstead, NY and in Newark, NJ already receiving New York City's MSW. Expansion at those facilities, which already currently service other municipalities, and would require upfront expenditures of an unprecedented scale.

From a national perspective, while there is increasing justification for WTE technologies as viable alternatives to landfilling, the United States has become less friendly toward development of such facilities for several reasons. Upfront cost, high tipping fees for WTE disposal, competing low landfill tipping fees, and community opposition in New York City have brought the conversation to a near halt (Rosengren, 2016). DSNY Commissioner Garcia called building a WTE inside New York City's borders a "non-starter" at the Megacities conference at City College in April 2016, giving the example of resistance that the city encounters at the mere suggestion of a sanitation garage being cited in any neighborhood within the five boroughs (Garcia, 2016).

With the current abundance of natural gas, the United States has an affordable fuel supply, which means that the market for energy from waste is less stressed. As cities continue to recycle more, plants will receive less tonnage to incinerate, which will negatively affect their positive cash flows from the secondary commodities market as well. For this reason, Covanta will be closing a transfer station in Wallingford, CT (that was previously a WTE facility) at the expense of contract termination fees with four nearby municipalities. Wallingford, CT will also suffer from the revenue lost (Rosengren, 2016). The bottom line is that many factors are stacked up against the WTE option in the short-term.

At the International Solid Waste Association meeting in Palm Beach County in June 2016, which this team attended, we heard that WTE efficiency is up, or that electricity is being generated on less solid waste than it was a decade ago (Michaels, 2016). Despite the advances, there are only 77 mass-burn WTE facilities in the United States as of April 2016, down from 84 in the previous year (Michaels, 2016). Other more recent developments include shrinkage of markets for metals, plastics and glass, commodities that are revenue streams WTE facility operators depend on for operations. Despite the downturn, an average of one or two new WTE facilities are being built per year in the United States, including six new facilities that have upgraded capacity and processes in 2015. That growth and expansion demonstrate continued interest and demand for a more expedient solution to solid waste management, despite the need for owners and operators to weather the commodities markets and forecast revenues by nervously watching iron ore pricing, as well as other strategies, to manage their businesses (NAWTEC, 2016).

As an industry, WTE is driven by energy markets for syngas and electricity. Generating approximately 500-600 kilowatt hours per ton of MSW processed, WTE facilities are essentially power plants that were originally built for waste management, the industry's original challenge and incentive. (NAWTEC, 2016). With oil commodity prices declining over the two to three years, the WTE industry in the United States has been focused on managing shrinking energy markets, its most fundamental challenge. Waste markets, or the recycled products of waste management, were the initial driver in WTE facility development.

Yet, on a visit to the SIMS municipal recycling plant in Brooklyn, the team was told that markets for recycled glass remained viable (SIMS). The opposite was heard at NAWTEC earlier in the year, that revenues from recycled glass were shrinking, though not at the same rate as plastics, a secondary market which has virtually disappeared (NAWTEC, 2016). In alignment with SIMS, the Gas Recycling Coalition released a statement on December 13, 2016 noting a significant market capacity and growing demand for glass beneficiation, the process of generating a higher grade product (Glass Recycling Coalition, 2016).

2.3.3 WTE Policy Developments to Date

The United States Department of Energy confirms that 31 states classify WTE as a renewable resource, yet the lack of a federal ruling on this classification is a key obstacle limiting expansion of facilities and further implementation of emerging technologies (NAWTEC). The Energy Recovery Council also suggests that there are over 20 federal statutes and policies establishing WTE as renewable. In the last five years alone, they include the EPA's Clean Power Plan, the Consolidated Appropriations Act, 2016, the Tax Increase Prevention Act of 2014, and the

American Taxpayer Relief Act of 2012. However, the WTE industry is not expecting for the federal regulatory environment to change in the near term. The groundwork is laid, but it will take an unanticipated act of U.S. Congress for a federal classification to happen, WTE to be subsidized, and landfills to be taxed, which together, would incentivize municipalities to fast track WTE investments as solution for MSW management (NAWTEC).

On the state and city levels, New York City has also evaluated proposals for in-city and regional anaerobic digestion facilities for treatment of organics from the city's waste stream over the years. These WTE proposals have included commercial and public-private partnerships from ArrowBio, Valorga and a non-attributed feasibility study of a facility in Hunts Point (Sylvan, 2014).

More recently at a Brooklyn Solid Waste Advisory Board meeting this July 2016, which this team attended, American Organic Energy presented a proposal for the first major large-scale anaerobic digestion facility to serve New York City, to be located 60 miles away in Yaphank, Long Island. The facility, which already serves its local area with a successful prototype that handles yard waste, will have the capacity to process the more than 1,000 tons per day of food waste that New York City could divert from landfill, and projects that it can handle 180,000 tons on an annual basis. It is also designed to produce 1.9 million diesel gallons equivalent of compressed natural gas (CNG) and 2.0 MW of electricity for meeting the project's own process energy needs (Vigliotti, 2016).

The current project has been operating for 30 years under Long Island Compost, and maintains an established business producing quality-controlled soil conditioners for large urban planting projects in New York City. Projects for this compost have been completed for the United Nations, Brooklyn Botanic Garden, Columbus Circle Reconstruction, JFK International Airport's AirTrain stations, and many others. American Organic Energy's public-private scheme would cost $50 million, and involves commitments from investors including GE Water, Scott's Miracle Grow and others (Vigliotti, 2016). However, the NYC Department of Sanitation has not yet announced an RFP process for a large-scale anaerobic digestion as a key solution for reaching the OneNYC Zero Waste goal.

The City of Albany, NY has been burning its bio solids for energy since 2013, and others including Washington, DC and Hampton Roads, VA plan to do the same. Albany's North Wastewater Treatment Plant estimates that 75% of the facility's process energy comes from burning sludge that it first dries to makes it combustible, which saves taxpayers an estimated $400,000 per year.

Chicago, which manages 1.2 billion gallons of wastewater flow per day, has pledged to become the first large municipality to go energy neutral by 2023 by producing all of its own energy through wastewater treatment. It is investing $10 million to expand anaerobic digestion efforts at its Calumet plant on Chicago's South Side.

2.4 Zero Waste

2.4.1. Definition

The definition of "Zero Waste," as established by the Zero Waste International Alliance (ZWIA), revolves around managing resources using an approach whereby all waste is reused or recycled in some manner. Front end resource management has been successfully utilized by companies such as brewer Sierra Nevada (Sierra Nevada, 2016). These efforts very often not only reduce the amount of waste a company produces, but provides an economic benefit.

2.4.2Tensions Between the Zero Waste and WTE communities

Scaling this philosophy up to a municipal level is much more complicated. The main controversy centers on ZWIA's dogmatic stance against thermal energy recovery facilities of any kind (ZWIA, 2016). Their official position is that "existing incinerators must be closed and no new ones built," although they suggest a 10% cap on utilizing thermal alternatives before they revoke a company or municipality's "Zero Waste Designation."

This signifies a rift within the waste management and environmental community. New York City, which already utilizes WTE for over 20% of its MSW (DSNY 2015 Disposal Sites), is seeking to increase that to 30% in the near future (K. Garcia, personal communication, April 25, 2016). The possibility of constructing a new WTE facility was laid out in OneNYC, but there has been no indication that any progress has been made in this regard. Still, this would also fly in the face of ZWIA's definition of a Zero Waste plan. Cities such as Austin, TX, on the other hand, have embraced the ZWIA philosophy behind Zero Waste and has capped their thermal conversion of waste at 10%, with the intention to eventually eliminate it altogether (City of Austin, 2016).

Through extensive research, communication and attending respective conferences, it has become clear that this rift has transcended the scientific realm, existing on a plane more closely related to ethics and concepts of environmental justice. It is the opinion of the researchers that thermal WTE technologies can, will, and must play a role if NYC has any hope of achieving its goal of sending no waste to landfill by 2030. However, there can be no denying that the stigma surrounding the technology, as well as major pushback from organizations such as ZWIA, as well as the U.S. Zero Waste Business Council, will hamper the expanded use of WTE in the United States.

Among the challenges toward successfully integrating proven waste management strategies are the historical and political ideas which formulate public perceptions. The history of incineration and its subsequent negative environmental consequences have left a painful and palpably permanent scar in the minds of most New Yorkers. In fact, these woes among New York City policymakers are not unique to the Empire State, but rather mirror similar sentiment across every municipality that has attempted to prioritize implementation of sustainable waste management practices.

The essential problem of waste is that it is the most easily forgotten and invisible part of our modern infrastructure. People do not like to think about what happens to their waste and are seldom challenged with options on how to deal with it. One of the greatest hurdles therefore becomes not just the technological, but the challenge of perception as well. For these reasons,

the wording of initiatives and the technological benefits promoted and tracked have become paramount to promoting sustainable waste management

3. Current Integrated Waste Management in NYC

NYC has a complex waste management system that collects, transports, and annually disposes more than 15 million tons of waste, including non-organic construction waste, of which 6 million tons is managed by DSNY **(OneNYC, 2014)**. The city's waste transportation and disposal add up to more than 2 million tons of emissions per year, 4 percent of the city's total **(www1.nyc.gov).** OneNYC plans to reduce the amount of waste sent to landfills from New York City by 90% from the 2005 baseline of approximately 3.6 million. **(NYC Mayor's Office of Sustainability**). If we were to reduce our waste to landfill by the proposed goal we would be sending approximately 360,000 tons to landfills. DSNY Municipal Waste picks up more than 11,500 tons of recyclables, organics, yard waste and garbage a day **(DSNY Biennial Progress Report 2014-15).**

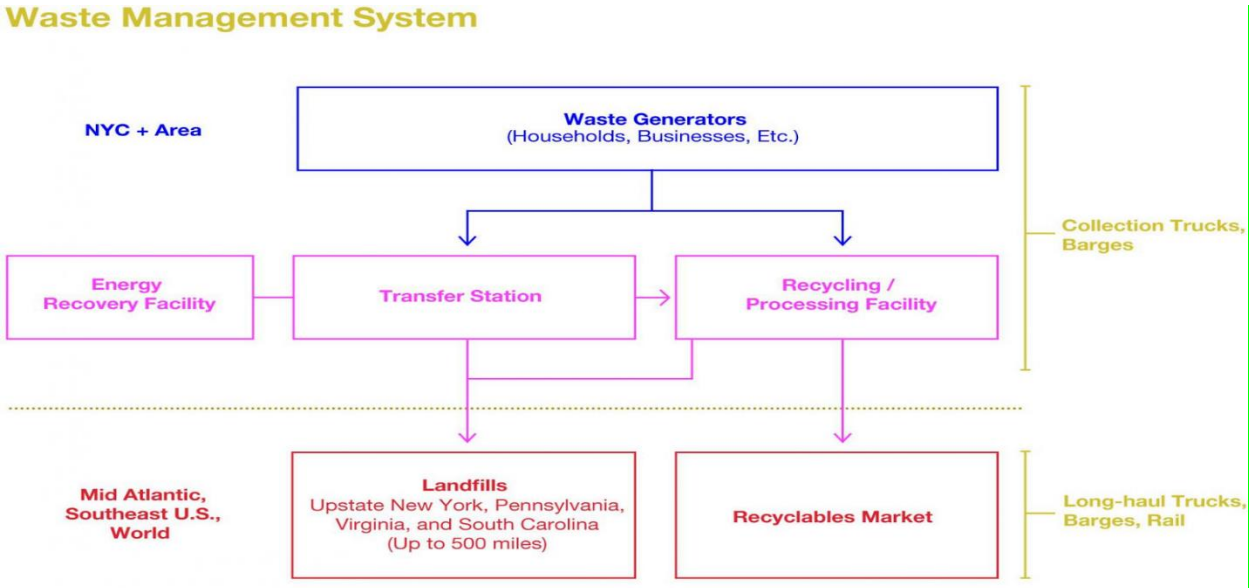
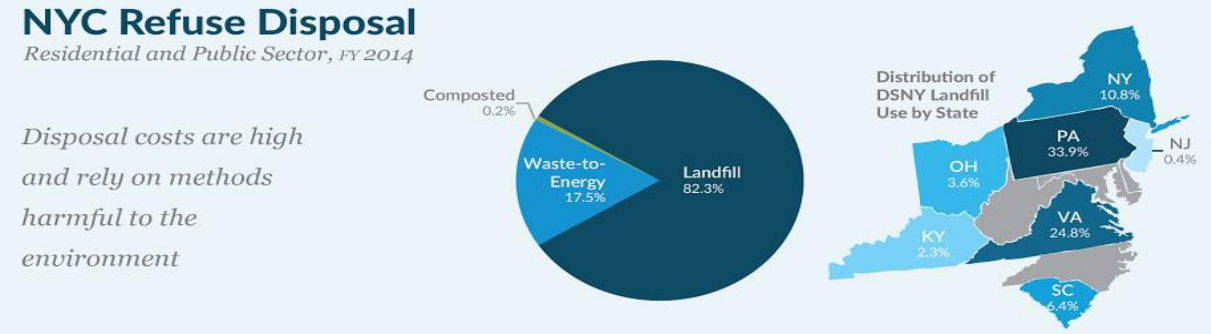


Figure (Source: OneNYC 2015)

3.1 Overview MSW streams to landfill and WTE

Of the total amount disposed, New York City sends 82.3% of its municipal solid waste to landfill, and 17.5 % to energy recovery facilities. Less than 1% of its waste is composted. The distribution of landfills varies but has the highest concentrations in Pennsylvania (33.9%), followed by Virginia (24.8%). Smaller concentrations can be found in distant landfills in South Carolina (6.4%) and Kentucky (2.3%).(Citizens Budget Commission 2014)



Source: http://www.cbcny.org/sites/default/files/DSNY%20Facts-01-01.png

More than 30% of that is food waste is organic almost 40% is paper, and another 17% is metal, glass, plastic and other recyclables. Diverting this compostable or recyclable material from landfill or incineration is one of the key mechanisms towards the goal of the Zero Waste program **(One New York: The Plan for a Strong and Just City, pp 186-187.)** In August 2013 the City signed a 20-year contract with Covanta, to transport 800,000 tons of garbage from marine transfer stations in Queens and Manhattan to waste-to-energy plants in Niagara, New York and Chester, Pennsylvania, near Philadelphia.(Ehren Gossen)

In OneNYC, there is a strong emphasis on the material side of waste, but not the energy side as it relates to secondary treatment of residuals, within the Zero Waste goal. Even recycling has residual by-products that are not captured in this cycle. The emphasis on diversion from landfills as a long-term strategy for sustainable waste management seems apparent in all of the literature, but what does not seem clear from OneNYC is what those pathways looks like with the existing limitations of our infrastructure. How will waste be divided, and what processes are going to be used across the interim stages until we get there, are the key questions that need to be more fully developed or shared with the public.

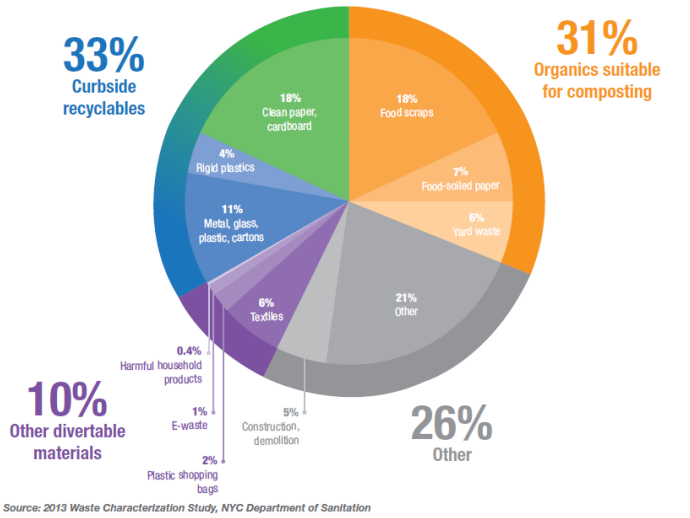
3.2 Analysis of current MSW characteristics



Results from the Department of Sanitation Commercial Waste Characterization Study in 2012 indicate that food scraps and other organics constitute 35% of the total commercial waste stream, paper constitutes 37%, and other recyclables make up another 17%. If one combines recyclables, organics and paper, it can be estimated that nearly 90% of the commercial waste stream has the potential to be diverted from landfill. NYC has made significant positive strides, but has much more ground to cover then they have previously, and must significantly increase the rate of diversion to come close to achieving the Zero Waste goal. (Zero Waste Challenge Report 2016)

The Residential of DSNY managed side of the equation is a bit different in terms of its organics composition. Residential waste has less organics and more metals than the commercial waste. The collection of organic material from both the commercial and residential side of the waste stream is a key element with cascading effects on waste processing.

Figure 1: NYC's Residential Waste Stream (2013)



Source: 2013 Waste Characterization Study, NYC Department of Sanitation

3.3 Zero Waste Programs in OneNYC

New York City has a strategy in place to manage its waste which is outlined in OneNYC: The Plan for a Strong and Just City, released on Earth Day in 2014. The report includes New York City's commitment to ongoing goals of the Solid Waste Management Plan (SWMP) and subsequent updated initiatives aimed at reducing greenhouse gas emissions 80% from the 2005 baseline by 2050 ("80 X 50"), and more efficiently managing waste resources through a comprehensive program to divert recyclable and organics waste from landfill called "Zero Waste by 2030." The Zero Waste initiatives includes:

1. Increasing organics collection: Access to sorting and processing throughout the five boroughs and within 100 miles of the NYC for all residents by 2030
2. Transition to single-stream recycling for curbside pickup. Mixed paper, glass, and metals processed in advanced sorting facilities.
3. The development of an equitable Save-as-You-Throw waste program to promote participation by all residents in waste reduction. Diverting accountability to individuals to sort and prepare their waste for extraction
4. Making all NYC Housing Authority facility developments are equipped for recycling and making public housing compliant with recycling laws
5. Making all public schools Zero Waste
6. New electronics and textile recycling programs
7. Reduction in the use of plastic bags
8. Reducing commercial waste disposal by 90% by 2030

(City of New York, 2015)

As of April 2015 the following milestones have been reached:

- The curbside organic collection program was expanded to serve more than 700,000 residents and collecting approximately 100 tons a week
- The Department of Sanitation of New York scaled up its household e-waste and textile collection program to more than 500,000 households

- Textile collection diverted more than 5 million pounds of textiles than the previous year. Approximately 685,464 tons of waste was recycled in fiscal year 2015, an increase of over 5% from the previous year
- DSNY collected more than 562,000 tons of recycled material a 3% increase from 2014
- NYC Housing Authority facilities program reached more than 850 buildings participating.
- DSNY's trucks have reduced particulate matter emissions by 90 percent since 2005 through filters, ultra-low sulfur biodiesel fuel, and other technologies
- As of July 2016 the commercial organics collection law is in effect which require large businesses with food service to source separate their organic wastes and arrange collection with a private hauler. (1NYC 2016 Progress Report)

3.4 Challenges in NYC Private Waste Disposal Industry

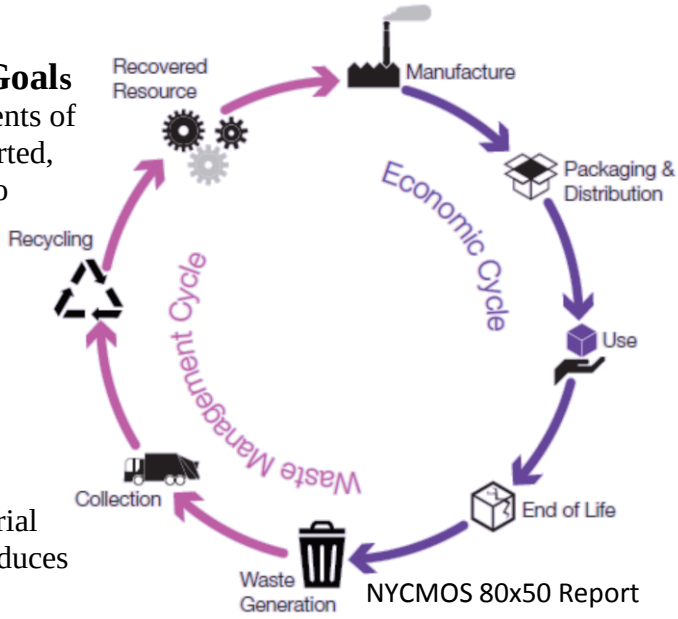
In light of the challenges of adequately categorizing and quantifying something as complex as NYC's waste management system this paper seeks to add as much clarity and practical understanding of the breadth of waste practices and its effect on our city. The focus of much of our assessment will be on Municipal Solid Waste which includes curbside pickup, institutions, public housing, parks and other wastes managed by the cities sanitation agency, the Department of Sanitation. Although this amounts to a tremendous amount of waste roughly 10 million tons a year there is still another 5.5 million tons of waste produced by businesses which is privately managed.(Halcrow Engineers) Of that 5.5 million nearly 4 million is sent landfills and not recycled. Approximately 10% of privately hauled waste is incinerated (NYC DEC Transfer Station Reports). New studies show that the 40% recycling rate posted in the 2011 version of Plan NYC was inflated and the real rate is somewhere in the order or 25%.(Halcrow Engineers) A study taken from the back end of the process capturing amounts processed via transfer station from the major haulers indicates the recycling rate may be as low as 9-13% in reality.(Transform don't Trash) The Halcrow study commissioned by DSNY reports that 66%, at least 700,000 tons, of cardboard and paper is landfilled or incinerated each year despite the existence of the infrastructure and market for these materials.(Halcrow Study Memo: Table 15)

One of the biggest travesties in the management of waste in the private sector is the logistical nightmare of pickup and transfer of waste within the cities borders. Private carting companies collect more than 3 million tons of waste a year. With no central management structure and competing companies all trying to undercut each other in pricing and service, what you have is a web of completely inefficient routes and contracts which are adding up the tally of emissions, traffic, and limited disposal options for haulers. You could say private disposal is a seller's market not allowing much financial leeway for haulers to explore alternate options for disposal. Halcrow estimates that commercial haulers drive about 12 miles to collect each ton of waste (including recycling). This estimates to traveling about 4 miles per ton of waste and recyclables collected.(NYC OPS:Fleet) Private collection trucks travel more than 23 million miles a year.(NYC.gov:Private Carting) Neighborhoods are having overlap of companies vying for business with as many as 79 different companies operating within the same district. Most of this private carting is done by a few companies leaving the remaining few to fight for the pickups no matter how dispersed.

The financial and policy structures that govern practices in the private sector of waste management can arguably be blamed for much of its poor performance by sustainability standards. More than 83% of businesses pay a flat monthly rate for garbage service regardless of the quantity, a financial structure that takes no account of weighting impacts on the system. Even the policies and laws disincentives recycling and other upstream practices. Recycling is only mandated for materials where the cost of recycling is equal or lesser than the cost of other methods of disposal like landfilling, which completely externalizes the environmental or social costs of transporting or exporting waste(Price Waterhouse Coope

3.5 OneNYC Impact to Date

Assessing Impact and Strategy of Zero Waste Goals



The diagram used in OneNYC outlines the major components of our waste management stream. Waste is collected, transported, sorted and prepared, and then typically transported again to its final destination. If one is only tracking the material value of waste, there are two end destinations for it, landfills or recycled materials put back on into market. Even recycling disposal has residuals. If one is tracking waste that can change form, one will also include WTE processing and its subsequent metals recovery and also, in some cases, advanced landfilling, which can capture the methane wasted from the anaerobic processes within the organic materials. Within recycling, not only is there material collected that cannot be salvaged, the refinement itself produces waste, and some materials that have no sustainable markets to justify further processing and are discarded. For the most part, these materials are then diverted back to landfills. The research on exact quantities is scarce and needs more resources to get exact numbers.

The larger goals and strategy for Zero Waste to landfills not only lessens the negative impacts of landfill practices related to transport and disposal but actually lends to increase efficiencies in other parts of our waste system. The primary benefactor is anaerobic digestion. More organics processed in anaerobic digestion reduces the distance of travel needed to final processing of waste. Anaerobic digestion also is much more efficient at capturing methane gases then even advanced landfilling.

A secondary benefactor of less organic material in our out of state waste transport and processing is to the WTE facilities. Excess moisture in waste adds another level to the process of incineration. The higher the moisture content in the batch of waste, the more energy is expended which reduces the conversion efficiency to create net usable energy. A dryer waste stream sent to WTE facilities will not only increase energy output but also reduction of transportation energy and emissions. The loads without the moisture will be lighter and take less energy to transport reducing overall emissions. As it stands now, without increasing the amount of waste sent to WTE facilities, any effort to reduce the organic materials within MSW's composition will help to reduce New York City's overall carbon footprint.

4. Comparative Strategies

There are several synergistic components that appear to make Europe successful at policy and implementation of green strategies, when reviewing public-facing data including media, scientific literature and organizational publications accessible online. Many of these new initiatives have not been around long enough to assess the full lifecycle of impacts, which leaves the question of their longer-term effectiveness open-ended. However, these initiatives also provide a potential model for the United States in that a mix of their key ingredients seem to span almost all successful European sustainability projects involving energy and waste. They include four management areas: **Governance, Incentive strategies, Educational strategies, and Technology.**

4.1 Governance

Governance is both how decisions are made but also how they are implemented. Some affectionately call the differences in our respective governance accredited to their practice as being "European way" but it was not always so. Many countries have developed their own individual sense of democratic governance that is not always shared across country lines. Although policies differ within the EU member countries, there are many similarities. Successful European countries like Sweden, Holland, Germany, and Denmark, which all have robust sustainability agendas, also all have a service-oriented approach to government. It is embedded into the educational, workforce and political system. The prevailing view is that the government is meant to provide services to the people. In many instances, lifting potential roadblocks to progress becomes an imperative. It also means that political candidates are not as polarized because the majority opinion guides the political agenda. When you have governance that changes vision as often as political office, it becomes difficult to push progress forward in a long-term sustainability agenda. Instead, European political forces compete for providing public benefit and innovation towards the common goal of sustainability. Resources and political will continue to increase over time, instead of competing with each other.

Another form of governance is in the role that the common citizen plays in their policy. Each of these countries is very sophisticated when it comes to making decisions about what they subsidize, and what they do not. Heavy subsidies can promote short-term economic growth, but also creates distance, or the avoidance of buy-in from citizens on how their contributions get measured and managed. For example, Germany has a universal healthcare system for all legal citizens, which covers about 85% of the population (Common Wealth Fund). In contrast, its average cost for energy in American currency is about 35 cents/kWh, which is the second highest cost per unit in the world. (Ovo Energy) Citizens in developed nations within the European Union invest heavily with their taxes and make sure that their voices are heard in the decision-making process. There is also more transparency in funds for public investment, and this information is accessible to citizens.

All of these nations are connected through a common vision via the European Union, which has includes political and economic components. The European Regional Development Fund (EDRF) has a vision to strengthen economic, social and territorial cohesion by correcting

imbalances between regions. Regions that are categorized as less developed, transitioning, and developed, are put into subsequent funding categories, and strategies are accounted for to create more equitable development. Without this type of collaboration, many individual countries would not be able to plan, fund or execute these initiatives. At least 20% of the European Commission's Budget will be dedicated to climate change-related actions between 2014-2020, according to the European Commission. (Europa).

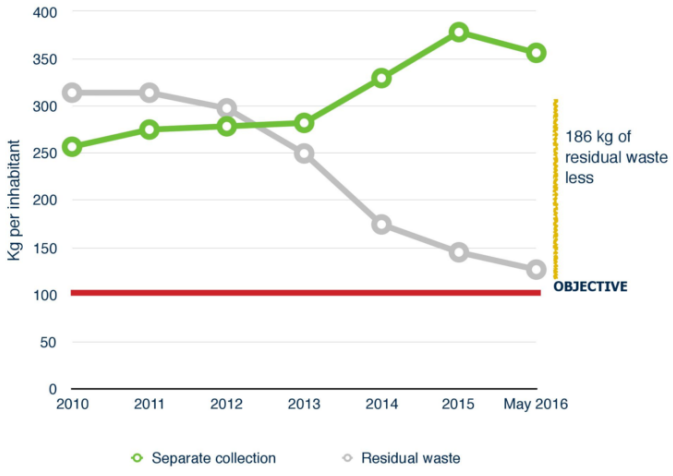
As noted, the alliance is both governmental and economic. Organizations are a central part of policy formulation, which allows for policy to be guided by its most potent actors, and sustainability to build into its foundation from the beginning. This structure allows stakeholders to voice their challenges while incentivizing participation. This increased collaboration around policymaking is exemplified in the Green Deal concluded in March 2016 between Netherlands, Belgium, France, and UK, with the objective of making better use of secondary raw materials "named as the North Sea's Resources Roundabout" **(European Budget Commission)**. By harmonizing policies on specific materials, including incinerator bottom ash and enhanced recovery of metals, they are working towards a circular economy by reducing energy and waste from virgin material extraction, as well as unsustainable waste disposal.

4.2 Incentives Strategies

The first thing to categorize when talking about incentives is- who are the relevant stakeholders. In order to facilitate benefit for someone you need to first identify them, their needs, and drivers. In many ways landfilling practice has disempowered our waste management market by allowing us to displace the burden of competing in markets for raw materials and subsequent lost opportunities to move towards a circular economics. When you are talking about sustainability and synergy, it can get a bit complicated because there are many stakeholders, which all need incentives specifically designed for them in order for them to buy in. In the case of Energy, the producers are the ones who make energy from fuels or through renewable technology and the consumers are the users of energy. In the case of waste, it seems that the average person or average business is the producer of waste and the processing or management side is the consumer. If you take another look at the waste management cycle there may be a way to change that prevailing producer-consumer perspective. Public waste management entities do not pay to consume waste; in fact they are paid to manage it. We pay them via our taxes. Interestingly enough, although pay as you throw may seem very uncommon in a New York City context, we are more familiar with it in the majority of the country. Almost all major cities have a shared economic responsibility between city government and private parties to pay for the management of wastes. What we must realize is that if we want to close one loop we must provide equal incentive on both producer and consumer side of the equation in order to reduce the chances another unsustainable loop will be opened. If you ban landfills - where does the waste go and whose responsibility will it be to manage it? If you add heavy taxes on incineration- what will we do with residuals? If you add pay as you throw programs- where may it add pressures to find cost saving unsustainable solutions to managing waste?

Some countries have been successful at this. For example, in Vaxjo Sweden they have a comprehensive incentive program which is supported by substantial behavioral research with an embedded iterative process of policy reform to teach and train their citizens to make better choices on waste and recycling. (Atkinson) They have an extremely high CO2 tax which is a top

down strategy but creates a big incentives for everyone to play active roles in reducing emissions. Companies see increased investments and consumer purchasing on eco products. They also create synergy by being a part of a public purchasing agreements for environmental standards and fair hiring practices. Higher real estate costs also forces homeowners to try to reduce their cost of living in other ways whether that is efficiency or displacing other high taxes. Waste disposal instead of charged through tax levy dollars are directly passed on to the producers of the waste. About 19 member states in the EU have landfill taxes in place for the disposal of non-hazardous municipal waste sent to legal landfills. Level of taxation ranges widely from 3 Euros in Belgium to 107 Euros per ton in the Netherlands. This is in addition to the gate fees which we can equate to tipping fees here in America. There is also taxes for incineration in 6 member states but the fees are much lower. Fees range from 2.40 Euros to 54 Euros. This leaves a very direct connection that is hard to ignore. Most of the policies mentioned are disincentives but when you think about the synergistic value of comprehensive waste management, certain types of waste are incentivized- like organics collection. So if I separate more then I save more. What cannot be recycled or separated gets incinerated. Because of the district steam system, residents can subsidize on heating and energy costs which is sorely needed because of high prices everywhere else. Businesses also benefit from types of subsidy. Energy and waste disposal costs can drive up any production cycle, but by working with other businesses they can internally they reduce those costs while at some points adding additional energy production capacity. Even on the residential level, with increased organics recycling policies, there is an added incentive to use organic material on site through composting for vegetation and food production. The classification of recycled material in itself is a distinction worthy of note. Recycled material is not tabulated by amounts of recyclable material sorted and collected but rather the quantity of recycled material returned back to the market. This is a much truer definition of the effectiveness of recycling practices that captures the market stability and does not discount the amounts of residuals from recycling that need to be managed post processing. The EU has even extended their accountability measures for intercountry Waste management to add authentication or certification for waste managed outside of the source country to ensure the destination country is protected from unsustainable practices. Stakeholders at all levels are incentivized and dis-incentivized in ways that makes working together with increased clarity and accountability an imperative and ultimately makes their governance and management of waste more sustainable. Sanford Maine recently implemented a trash metering system with an accompanying pay as you throw program and reduced the amount of refuse residents threw away by 50 percent overall. (Waste Zero) A study done in Parma Italy, a town of 190,284 residents, showed promising results with a increase in curbside collection and a pay as you throw system coupled with an intense public education program. (zerowasteeurope)



4.3 Educational Strategies

Public education is an essential part to any strategy that involves mass buy-in for it to work. Inequality and education have a strong negative correlation. When everyone does not have the right to education then you will create classism within the way information is shared and ultimately how decisions are made. A key to an informed and active population is by making public education a part of the government's duty and unequivocally free right of every citizen. This is the foundation of democracy. To create value beyond this and an incentive driven policy devoid of this basic premise is like giving free ice cream cones out on a welfare line to make it shorter. Most European countries, especially the more developed ones with sophisticated sustainability agendas, provide their citizens with free education. In addition to that, the academic and industrial sectors work very closely together. This is an important feature in developing strategies that are both relevant but also to empower a new generation of informed professionals leading these initiatives. Public awareness campaigns and educational programs have impact but are limited in their scope and range. A small idea like landfilling is unsustainable, ugly, and dangerous to our society, permeated through all levels of educational institutions is potentially more powerful than understanding comprehensive environmental impacts which only a select few individuals in our society are fluent in. Holland attributes much of its success managing waste and being on the forefront of renewable energy production to simple ideas like we just cannot tolerate landfills in our country. The EU ability to tackle their challenges of land scarcity and the unsettling appearance of landfilling in a clear directive has allowed them to move much further in their policies and technologies. In addition to land use, the dependency on foreign energy sources is another major determinant in waste management policies and undoubtedly affected the public opinion on WTE as a viable solution.

4.4 **Technology**

Technological innovation in waste practices are a direct result of the imperative to find alternate solutions to landfilling. Space and public opinion swayed many European countries to enact strong policy discouraging or even banning landfilling practice. That leaves two options export waste further from the highly developed areas to less developed areas like Western Europe. Or innovate and find solutions for managing waste within your borders. This lead to a technological revolution in Waste to Energy practices. Modern WTE technologies have advanced filtering and recovery of heavy metals which are processed and sold back to the market. Different from America's Waste to Energy Practice most plants are integrated within community structures and information about them is widely available.

Summary

Our opinion is that societal change cannot happen overnight, and that we must be willing to continue applying pressure during a long period of transformation. What seems apparent is a prevailing trend among the successful actors in their ability to make bold moves that force unsustainable systemic components to stand out and become subject to innovation. One can make the argument that if Europe was not been forced to contend with landfill practices, they may not have made strides in technology in recovering energy of material, and social acceptance of this advanced practice. Research and collaboration can help us identify levers and trends that can accelerate this process, however a willingness to make certain concessions that meet our

longer term objectives as well as our present challenges requires and deep level of acceptance and commitment as well. Integrated waste management and energy production are an attractive combination, but they do not come without costs. In order to fully understand why New York City can or cannot implement what Europe has been able to accomplish, we have to broaden our perspective. We have to ask ourselves not just how we achieve the success of implementing these other technologies, policies and educational programs, but also ask ourselves how New Yorkers should be able to live and prosper as a part, and as a whole, of this nation.

5. Methodology (Procedure)

The 2015 DSNY inventory of disposal sites for New York City's MSW is not currently available online, but can be requested, and was provided by email by DSNY SWM Director of Environmental Compliance/Contracts, Sarah Dolinar. Some discrepancies arose between the volume of waste sent by DSNY, and the amount claimed to be received by the landfills in State Solid Waste reports. In such cases, the researcher deferred to the State number, although it is unclear where the fault lies. Such was the case for Lee County Landfill, in South Carolina. The numbers in Table 3 should only be viewed as approximations.

The bulk of data on the local impacts of disposal sites was gathered by searching through local newspapers, the EPA ECHO database, and the various State Environmental/Health Departments. The enormous amount of information and potential factors leading to the exact impact, made narrowing the relevant data very challenging. Using a combination of anecdotal evidence gathered from local sources and quantifiable data gathered from government sources and statistics, an attempt was made to come up with reasonably justifiable recommendations.

Background on Zero Waste was conducted by attending the United States Zero Waste Business Council Conference in June 2016. The conference was held in Austin, TX, where the researcher learned about the ZWIA influence on municipal waste plans. Interviews were conducted with various experts, including Gary Liss, the Vice President of the USZWBC. Similar research was conducted on the status of Waste-to-Energy technology and policy in the United States and beyond by attending the North American Waste-to-Energy Conference (NAWTEC) in June 2016. Conversations took place with Energy Recovery Council President, Ted Michaels, Wastdive.com journalist Cole Rosengran, Solid Waste Authority of Palm Beach County's Chief Operating Officer Mark Eyeington, and various members of the International Solid Waste Association. Attendance at other waste-related events, meetings and tours in New York City, as identified in this paper's introduction, enabled this time to reach a range of municipal, industry, facility, and community officials with expertise in New York City's MSW management.

Environmental, social and economic impacts of current practices were researched through a range of sources, while assessments were made by unpacking the different methodologies and identifying the metrics categorically left out of key waste streams. Only by characterizing the studies that capture similar streams, and prorating backwards to approximate hidden streams, could a final tally of waste management practices be made. Exact quantities sent to WTE or to landfills could only be captured by monitoring the waste throughput to waste transfer stations managing tonnage from New York City. GHG emissions needed to be treated separately because those metrics do not disaggregate New York City's publicly managed waste from the privately managed. Exact numbers on each specific stream were also not publically available. Several

sources were analyzed to approximate a range of emissions for each stream. **(See table in appendix NYC Waste Management System)**

5.1 The Missing Waste to Landfill

Upon reviewing the 2015 DSNY inventory of disposal sites for New York City's MSW, questions for the research team arose about which municipal residential waste streams were included in the data? If the OneNYC baseline for Zero Waste includes residential waste, is New York City's sanitary waste, or sewage sludge, included in that computation and aspirational goal?

What about the municipal solid waste, including recyclables and non-recyclables commonly referred to as "floatables" or "marine debris," that enter New York City's sewers through its nearly 150,000 catch basins? What about the inorganic waste, from grit and other sediments from our urban landscape including roadways and sidewalks, or other chemical pollution from the street that runs off into our sewers, mixes with human and animal waste, plus the food waste that goes down our drains mixing with our water and litter, all of which must be removed through an extraction process during wastewater treatment in order to be sent to a landfill?

With the help of the NYC Mayor's Office of Sustainability, we took another look at the Zero Waste baseline. We were able to confirm with the custodians of OneNYC that the Zero Waste baseline only contained waste collected by DSNY. This is further evident when looking at the Zero Waste to landfills by 2030 indicators in their most recent OneNYC 2016 Progress Report.

Goal: New York City will send zero waste to landfills by 2030

KEY PROGRESS

- **Expanded curbside organics collection to over 700,000 New Yorkers**
- **Launched the NYCHA recycling program in 850 public housing buildings**
- **Updated city regulations to make it easier for businesses to recycle**
- **Expanded e-waste collection to reach more than 500,000 residents**

INDICATORS	PREVIOUS	LATEST
Reduce volume of DSNY-collected refuse (excluding material collected for reuse/ recycling) by 90 percent relative to 2005 baseline of ~3.6M tons	11% reduction from 2005 to 2014 (3,193,800 tons collected in 2014)	**11.5% reduction from 2005 to 2015 (3,176,900 tons collected in 2015)**
Increase curbside and containerized diversion from a rate of 15.4 percent in 2014	15.4% 2014	**16% in 2015**
Increase citywide diversion rate (including all streams of waste: residential, commercial, construction and demolition, and fill) from current state of ~52 percent	52% in 2013	**No additional data available**

However, in that same recent report, the NYC Mayor's Office of Sustainability indicated that, in generating a longer term plan to reach the Zero Waste goal, city agencies including DSNY, MOS, NYCHA, BIC, NYC DOE, and NYC DEP have initiated their own plans for getting to zero waste, including incremental and broad changes in programs and operations. Two measurable co-benefits of these efforts to reach the zero waste objective include reducing greenhouse gas emissions, in line with the OneNYC 80X50 goal, and improving air quality.

DEP, in particular, is entering an RFP stage to retain a vendor to help them collect and understand the stratified data, and to write a plan for implementing it (DEP, 2016).

DEP Landfill-Destined Collections Illustrated



Catch basin collecting MSW (floatables or "marine debris") entering the combined sewer system with sanitary waste, marine debris and system.
Figure ___: Source: NYC Dept of Environmental Protection

Explaining the Missing DEP Residential Metric in Zero Waste Baseline

Confidential conversations with DEP officials have led to this team getting a better understanding of the challenges to this missing metric in the Zero Waste baseline. Ownership surrounding waste among city agencies is a historical problem, which is grounded in regulatory, labor and liability issues. Utilities tasked with sanitation are addressing a different set of priorities and challenges than the utilities that are tasked with water and sewer services.

In gaining a better understanding of this separation of responsibilities, this research group also learned that separate contracts for waste were being held by both agencies, and yet DSNY's contracts contained excess disposal capacity that would accommodate, at minimum, the 300/tons per day of bio solids (treated sanitary sludge) being transported to landfill at the cost of $35 million to NYC ratepayers, a redundant expense committed until 2019 through various contracts (Ellis, 2016). This cost, DEP states, is far less than the $100 million dollars that the agency was spending on contracts to land application of bio solids in Colorado and Texas, as well as pelletization in the Bronx. The most beneficial reuses for New York City's bio solids,

from a regulatory perspective, were not affordable for ratepayers post-recession (Ellis, 2016), and once that change was made, there was no going back.

When trying to obtain an inventory from DEP of its 2915 landfill tonnage similar to what was obtained through DSNY, this researcher team was told “to FOIL” for it (Freedom of Information Law). This convenient four-letter word meant that the team would have to request this information through a lengthy and complicated process (LaGrotta, 2016).

However, the team learned that, with landfills now turning biosolids away, DEP is looking at the range of disposal opportunities for its bio solids disposal, including WTE thermal technologies including pyrolysis, gasification, biochar, as well as energy generation through incineration, biogas production, pelletization and composting, mine reclamation and agriculture, soil amendment and other approaches (Ellis, 2016). These new approaches will be evaluated through the 80X50 lens and DEP’s own zero waste and GHG emissions reductions goals.

5.2 Assessing Potential Impacts on Disposal Site Communities

Environmental Impact

The impact of landfills on the health of the surrounding communities have been studied extensively. However, due to the indirect nature of the exposure to elements stemming from the landfill, findings are inconclusive (Vrijheid,2000). This problem is further compounded by the incredible variability in waste composition found from landfill to landfill, as well as within landfills over time (Chu, 1994). Additionally, despite this research, the health risk of most the organic chemicals produced in landfill gas and leachate are still unknown. According to one study, “These "non-conventional pollutants" include more than 95% of the organics in MSW leachate” (Lee, 1994). The EPA, which collects waste characterization reports from all over the country, only has statewide examples of such reports from 18 out of 50 states (EPA, 2016).

The composition of NYC MSW contains approximately 3.4% more food waste than the national average (DSNY 2013) (EPA 2012). In a study where various components of waste were isolated and studied separately, only food waste was determined to have a leachate by product which was toxic (Eleazer, 1997). Therefore, it is reasonable to assume that landfills that accept NYC MSW are taking on a greater risk of instability in their landfills. This assumption would correlate with the problems being experienced at Atlantic Waste Disposal, a landfill in Waverly, VA. It is the single leading recipient by volume of NYC MSW, and has an extensive history of environmental problems related to leachate.

During the summer of 2011, Inspectors from the state Department of Environmental Quality noted "leachate seeps" and the unauthorized use of ditches and holes to catch the dirty garbage juice dribbling off the face of the earthen site, according to case records. In September of 2011, there was a 10 acre slope failure which resulted in 150,000 tons of waste being deposited into an unfinished cell of the landfill. This waste migrated out of the landfill, across a work access road and into a nearby pond. Residents complained about the strong odor that resulted from the

accident. During that same inspection, Virginia DEQ noticed inadequate landfill cover for the waste involved in the slide as well. These infractions resulted in a $56,400 fine. (Virginia, 2011)

In March of 2015, another leachate failure resulted in a "significant" amount being released into nearby wetlands, resulting in a civil charge of $26,000 and an enforcement action by the State Water Board of a further $8,000. (Campbell, 2016)

In December 2015, the DEQ issued an emergency order against the facility due to ongoing violations and specifically "excess heat within the landfill mass that has caused concerns about odor, instability of portions of the facility and increased leachate liquid production...That leachate, or landfill-waste-contaminated water, was seen flowing beyond the limits of the landfill's lined disposal area about 500 to 600 feet into nearby forested wetlands, impacting approximately 3.4 acres." (Campbell, 2016)

These violations resulted in numerous complaints by nearby residents: "The odor described by Virginia DEQ in their order has been a serious issue for residents of Sussex and neighboring Prince George County, where some residents say it forces them to stay indoors with the windows and doors closed and, for some, even that does not provide relief from the overpowering smell." Around the same time, sinkholes began forming on the main mass of the landfill that "appeared to be continuously emitting odor and steam," according to DEQ documents (Buettner, 2016).

Waste Management admitted that they do not know exactly what is causing the problem. The landfill admitted that it has also been dealing with gas management issues since 2014. This problem, along with the increased production of leachate, appear to be connected to the elevated temperatures in the waste mass.

According to the DEQ, the facility produces roughly 300,000 gallons of leachate a day, which is transported out of the facility by 55 trucks per day. "DEQ officials say there is 'An imminent risk of overflow and discharge of leachate at the Atlantic Landfill facility.'"
"In an effort to mitigate that risk, the Department of Environmental Quality and Waste Management have entered into an emergency order by consent, allowing the company to utilize the Passaic Valley Sewerage Commission treatment plant in Newark, New Jersey, as a facility to manage the leachate. The leachate is transported from the Sussex County Landfill to a double-hulled barge in Hampton Roads, where it is then taken to Passaic Valley's treatment facility in Newark Bay." (Campbell, 2016).

The DSNY tracks the amount of vehicle miles travelled to and from the landfill. Atlantic Waste Disposal is responsible for 3,457,744 rail miles travelled per year (DSNY, 2016). However, it does not take into account the miles that the resulting leachate might travel by barge. While the evidence is circumstantial, it is reasonable to assume that NYC MSW makes a significant, if not a principal, contribution to problems such as these. Based on the combination of data from DSNY and the Virginia DEQ, MSW from New York City accounts for approximately 2/3 of all waste that comes into Atlantic Waste Disposal (Table 3).

Socio-Economic Impacts

Large scale disposal sites can impact communities socio-economically in several ways. They include jobs, tax revenue, political influence and community engagement and services.

A major key to an economically successful landfill is having relatively low tipping fees. In an era where waste freely crosses state lines, finding a disposal site location where land is cheap can provide a key competitive advantage. Furthermore, Waste Management Inc. (WM) owns not only landfills, but manages the rail that moves waste from the transfer stations in New York City to its landfills in Fairport, NY and Waverly, VA. The same is true for Republic Services, which sends waste by rail from Staten Island to its landfill in Lee County, South Carolina.

WM offers this WasteByRail service to third parties, and through the use of intermodal containers and trucks can connect with places that do not have direct access to railroads. In 2015, 46.5% of New York City's residential MSW was transported by rail, accounting for 18,718,424 rail car miles travelled (DSNY, 2016).

Intermodal rail travel reduces costs, time, and greenhouse gas emissions caused by truck delivery. It thereby enables the transport of waste from places like New York City to Virginia and South Carolina, thousands of miles away. High Acres Landfill, located in Monroe County, NY, recently built a rail spur, to the encouragement of residents. In November 2016, the landfill received an "Environmental Excellence Award" from the New York State Department of Environmental Conservation, which hailed the "significant environmental benefits" of the facility's use of rail (Orr, 2016). About 40 miles away, in the town of Seneca Falls, residents fought fiercely to halt the construction of a rail spur that would have provided the exact same function for the Seneca Meadows landfill located there. Understanding these seemingly polar opposite reactions is important to shedding light on what the potential impacts of these disposal sites are.

Looking at Table 1, we can see some stark demographic differences between Monroe County, which houses High Acres, and Seneca County. Seneca County is significantly less populated, and poorer. High Acres lies just outside Rochester, one of the biggest cities in New York. Seneca Meadows lies in the rural Finger Lakes region of the State. The size of Seneca Meadows causes the landfill to dwarf its economy. Landfill fees make up more than half of the town's budget (Murphy, 2016). While this is a significant boon to the town's economy, landfills are a finite venture. They are predetermined to close at a certain point in the future. When this exactly comes to pass depends on how much waste the landfill brings in, and whether or not it is able to expand. Nevertheless, towns such as Seneca Meadows must prepare for the inevitable closure of the landfill, and subsequent loss of revenue and jobs. Whether this time comes sooner or later depends on the working relationship between the landfill and the community.

Many residents of Seneca Falls saw attempts to buy land around the landfill and the construction of rail spurs as threatening to the livelihood of their town (Shaw, 2016). A group of concerned citizens filed a petition with the Department of Environmental Conservation to have the landfill's permit removed (Crocker, 2016).The rejection of the rail spur led to a $3.3 billion waste deal with New York City to fall through (Lambert, 2016). In December of 2016, a vote was called on Local Law 3, which would force the landfill to close by 2025. Residents complained of robo-calls and mailings which threatened tax hikes (Shaw, 2016). On December 6, the law passed with

majority approval. Without the NYC contract or the use of rail, the landfill may not be able to fill its capacity by 2025.

The loss of the $3.3 billion dollar Seneca Falls contract is a significant blow not only to the landfill, but to New York City's sustainability plans as well. The continued reliance of trucks to carry the 1500 tons of MSW a day from NYC to Monroe County will impact not only the city's waste management plan but also its GHG emission reduction plans. The genesis of this problem was an antagonistic relationship between a community and disposal site, which was affected by an adverse socio-economic relationship. This example should be a call for the city to take more initiative in studying the relationship its MSW has with the communities where it ends up, instead of relying on waste management companies to broker for them on its behalf.

5.3 Sustainability Assessment of Landfill and WTE practices

In order to effectively assess the impact of our current waste management system we will need to incorporate three distinct lenses for sustainability: Environmental, Financial, and Social. The complex interaction between these three spheres of influence paint a clearer picture of both our sustainability goals and strategies towards Zero Waste and Reduced GHG Emissions.

By assessing the impact of current Zero Waste policy measures, we can see a reduction in the quantity of waste sent to landfill from the 3.6 million tons baseline in 2005 to 3,193,800 tons in 2015. (NYC MOS Progress report 2015) This means our waste diversion from the baseline is approximately 10-15%, if you also account for increases due to population growth. If we continue at this rate of diversion (10-15% from 2005 to 2015), it would take until almost to 2075 to reach New York City's goals. The rate of diversion must increase.

$$\text{Diversion Rate} = \frac{\text{Quantity of recycling (organics, paper, metal, glass and plastic collected)}}{\text{Quantity of all waste collected}}$$

Factors taken into account for assessing the impact of this diversion are included in the subsequent GHG emissions calculations. There has been a .17 increase in emissions due to population increase but a -.70 decrease due to a reduction in the amount of waste generated per person. There were also significant decreases in emissions from advancements in technological means to process Wastewater. From this we can see that the dynamics of categorizing impact is a complex because there are so many factors evolving at the same time. (See figure 23)

Impacts of Waste Management on the Environment

New York City's residents, workers, and visitors generate more than 20,000 tons of solid waste and use more than 1 billion gallons of water each day. The management of this solid waste and treatment of wastewater was responsible for 2.66 $MtCO_2e$ of fugitive CO_2, methane (CH_4), and nitrous oxide (N_2O) in 2014. Approximately 86% of that emissions is in the form of methane and predominantly originates from landfilling. Only 5 % of the emissions is the result of Waste to Energy conversion and in the form of Carbon Dioxide. The remaining emissions are a result of wastewater and biological treatment. (NYC Mayor's Office of Sustainability, NYC GHG Emissions Report 2014) Because of the scaled impact of Methane release compared to carbon

dioxide, the disparity in environmental impact is exponential. Most reports scale the impact to the ozone layer for methane at no less than 25-30 times that of carbon dioxide (USEPA). If you take the portion of greenhouse gas emissions from each practice and weight it to the impact on the ozone, landfilling is approximately 425 times worse for the Earth's ozone layer and global warming than WTE incineration at rate of current practice. This does not take into account the differences in the lifespan of the two materials, studies show that Methane is not only more potent but takes much longer to disintegrate and change form so it stays in the atmosphere longer.(USEPA) When you take that factor into account you see that the release of Methane is not only exponentially more destructive now but has the potential to be a factor for many years to come.

e=emissions quantity
i=impact on global warming

5% WTE : 86% Landfill = 17 times more emissions (e)
17e * 25i = 425ei or impact of emissions on global warming

Financial Challenges of Waste Management

There is, however, research that questions the economic feasibility and financial benefits of many of our current policies. The Citizens Budget Commission has been very active in assessing current and projected policies in waste management, and how it affects both the environmental and economic indicators of progress. In their most current policy paper titled "A Better Way to Pay For Solid Waste Management," they did an analysis of the capacity to collect and process organics, and found that if the stated goals were reached in organics collection, it would drive the current cost up from $170 million to $250 million, or an increase of $80 million. (CBC Facts about DSNY 2015). In fact, everything New York City does in relation to waste has a high price tag, which is not totally surprising. New York City, through its sanitation agency, spends about $1.5 billion annually for maintenance and operations. In 2012, an estimated $1.1 billion of that spending was associated with DSNY and collection of residential and public waste only. The remaining budget, $400 million, was spent in the disposal of municipal waste and the collection and disposal of all the commercial private sector combined.

NYC spends more to manage its waste than any other state. The most significant costs come from the collection of municipal solid waste. DSNY spends $433 per ton for handling both recyclable and non-recyclable wastes, with about $307 million for collection and $126 million for disposal.(CBC 2014) Recycling can offset the cost of the disposal side of the equation, but only to the extent that the market can support the value of the recycled material. At peak market value, it can subsidize approximately $25/ton, but the real cost is still heavily weighted toward the collection side. The cost for private haulers to operate is less than half of DSNY's spending, at approximately $185/ton.

New York City pays the highest cost per ton to manage its waste, and is the only city to completely fund their waste management through tax dollars as well. This disconnection between the large pool of services rendered through the city's budget, and inefficiencies of the waste system, leave little incentive for waste producers to change their behaviors for the better.

San Antonio and Los Angeles charge a flat monthly or annual fee, typically collected through building water bills. Some cities charge based on how many bins or bags the household sets out for pick-up. This structure is commonly called pay-as-you-throw or PAYT. This incentive or disincentive creates a downward pressure on the producer side to generate less waste, while the level of incentive varies. Some cities have policies that allow residents to choose the size of their waste bin with appropriate rates. For example, in Houston, you are afforded one size bin and are charged for extra bins or bags.(City of Houston) The good news is that OneNYC's Zero Waste initiatives include exploring a Pay-As-You-Throw program, however it is recognized as a challenge unlike any other metropolis given its high density of high rises in a small footprint (Garcia, Megacities). The current understanding is that the Department of Sanitation is actively researching and developing a plan for a Pay-As-You-Throw pilot, however no information is publicly available on the timeframe, parameters or location of its launch.

Societal Challenges of Waste Management

In many ways these are the most important but harder to quantify. The increased organics collection will take more collaboration amongst stakeholders including the real estate management community, the NYC Department of Buildings, the NYC Department of Environmental Protection, NYC Housing Authority and others to fully explore the challenges of this initiative for a city made up of primarily renters. Larger agencies like the NYC Department of Education have had their own challenges in implementing Zero Waste. Longstanding behavioral changes and lack of trust in the system to support the changes, leave many parts of the administration frustrated on lack of return on investment in training initiatives. As waste touches more people's routines and ultimately their pockets, there will be differing opinions on how initiatives like Pay as you throw will be adopted and successfully implemented in a city which has had such a contemptuous history of dealing with their waste

6.0 Analysis and Conclusions

With a system as large and layered as the waste management in New York City there are many opportunities for political and operational breakdowns but also a great deal of potential for improvement and innovation. The following section will summarize points made throughout the paper and set a modest list of recommendations on how New York City can move further along in its goals towards Zero Waste.

With respect to the contention between the two communities "Zero Waste" and "Energy Recovery" there seems to be an underlying theme. Both parties battle it out with their research and statistics, but the real danger lies in the passive acceptance of landfilling as the go to option for our cities waste after the closure of Fresh Kills in 2001. This reactionary policy and lack of foresight has led to a greater expansion of landfilling practices. Not only did we increase on a normal rate of expansion to send more waste to landfills but the locations of landfills started to extend further and further from the city, which drastically increased its true cost in dollars and emissions. Landfilling a ton of waste leads to 30 times more greenhouse gas emissions than does recycling a ton of waste.(Tellus Institute and ALIGN) Our research shows the actual impact of WTE energy on its surrounding communities and the environment is significantly less than landfilling. We also show that the current practice of WTE conversion is displacing as much as

30M tons of CO2 equivalent into the atmosphere that would be released if it was landfilled. The current policies of OneNYC are not incongruent with WTE policies and there can be more than one application of recovering energy through thermal processes which can both support New York City in achieving Zero Waste in the interim as a progressive step, as well as, a part of a long term solution for dealing with residual waste streams.

Ideas like extended consumer responsibility have a real bearing on practice even landfilling practice. The European Union is piloting a version of a type of certification for source and destination communities of waste that verifies the impact that said waste will have on its consumer. Looking at waste in America protected under the Interstate Commerce Clause we can see that there is a basis for this type of social responsibility especially in places that have experienced significant negative impact. New York City's management of waste has without a doubt left a negative environmental impact on many communities. In light of its impact, NYC as part of its goal to send zero waste to landfill, should provide support and guidance for communities who depend on these landfills as their main economic engine. NYC can support the development of sustainable and environmentally friendly economic development in affected areas.

The accountability measures for OneNYC should be pervasive across all actors that the initiative seeks to affect. In order to do this research methodologies and metrics must be uniform and transparent. The obscure nature of the current metrics and the lack of accountability for many waste streams makes it very difficult to get a full picture on both the management of our waste but more important its real impact on us and the environment.

The perceptions of waste to energy and the reality of the practice needs to be reconciled in a public forum. Our current landfilling and recycling practice are far from ideal. We need the best information and innovations on the table to create solutions that bridge the gaps between ideal and our current context. If feasible, new sites should be considered for both WTE plants and anaerobic digesters. These decisions should be made with careful scrutiny not to undermine our larger objectives to reduce waste in all parts of the system. For this reason it is crucial for all parts of the system to collaborate to ensure that the systems and businesses that support our sustainability agendas are dealt with fairly and kept in the forefront of decision making in a way that meets collective goals.

The commercial waste sector needs clearer standards and policies on diversion goals. There should be significant improvements in their trucking technologies to reduce emissions. Smarter routing and possible franchising options can make the collection of waste in the private sector much more efficient and reduce miles traveled. The DSNY residential waste pick up system costs twice as much as it does for private haulers on a per ton basis but is 15x more efficient in its route efficiency. (table 10) This type of coordination and development needs to be evaluated and best practices should be shared across public and private contracts

Incorporating Pay as you Throw within New York City is not a small task but one that is crucial to the success of many of the City's Zero Waste Initiatives. The current costs of waste management is increasing drastically and the financial burden cannot rest solely on the city via tax dollars. The burden of managing waste must be dispersed not only to make it fiscally

feasible but also to elicit cooperation and buy in. All programs must respect the diverse financial and political landscape of New Yorkers as to not be prejudicial or oppressive.

It is also crucial for cities like New York to collaborate and coordinate their respect Waste management practices so that they can support each other's sustainability goals instead of externalizing costs that are not convenient to take ownership of politically. WTE can maintain a viable business model by working in a comprehensive waste management structure in which not only do states think about their waste streams as intertwines but agencies and actors within municipalities working together on contracts and coordinating extraction.

7. Areas for Future Research

We think more information and study can be done in the following areas:

- A Study on the residuals of DSNY Waste and potential to be utilized in WTE processes.
- The potential for a common rubric to be utilized by all NYC waste transporters on tonnage, transport, and emissions
- Could NYC use collective contracts with other states to solve Waste management issues
- What the Potential GHG reductions with combined collections (DSNY transport app to reduce mileage); Sivan to gls)raph GHG of MSW + biosolids landfill practices (will not include other WWT landfill-bound residua
- Add all waste streams including DEP and DSNY redefine a revised OneNYC Zero Waste baseline
- What would an equitable Save as you throw program look like in NYC and what impact would it have on sustainable waste management
- Is there an interim strategy for Zero waste that includes WTE technologies and what would that quantitative analysis look like

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8. Appendix

Figure: 1

Table 1
Demographic Profiles of Landfill Communities

Name	County	Method of Waste Transport	Population (2015 est.)	Median Household Income	Ton Waste/Person/Year	% Persons in Poverty	% college educated	Land area (sq.miles)	Ton Waste/Sq.mile/Year
Lee County	Lee, SC	Rail	17,896	$30,954	23.96	28.3	10.7	410.18	1,045.37
Atlantic Waste Disposal	Sussex, VA	Rail	11,715	$39,194	104.45	22.1	9.6	490.22	2,496.01
High Acres	Monroe, NY	Rail	749,600	$52,553	0.68	14.8	36.2	657.21	771.57
Grows North/Tullytown/Fairless	Bucks, PA	Truck	627,367	$77,568	10.67	6.3	37.4	604.31	11,073.03
Bethlehem	Northampton, PA	Truck	300,813	$60,972	1.67	8.8	27.2	369.67	1,357.63
Blue Ridge	Franklin, PA	Truck	153,638	$53,916	4.04	9.4	19	772.22	803.53
Seneca Meadows	Seneca, NY	Truck	34,833	$49,292	58.86	14.1	20.2	323.71	6,333.69
Keystone	Lackawanna, PA	Truck	211,917	$46,271	12.49	15.3	25.9	459.08	5,764.25
Cumberland County	Cumberland, PA	Truck	246,338	$61,820	3.70	7.3	32.7	545.46	1,672.90
		U.S. Average		$51,939	-	13.5	33	-	-

Source: Census.gov, Table 3

Figure: 2

Table 3
Landfill information for sites which accept over 150 tpd from NYC

Name	Location	Owner/Operator	Transport Meth	Tons/Day (NYC2015)	Total tons (NYC2015)	Total tons annual (All)	Existing annual permit limits	total remaining existing capacity	Closure	NYCMSW as % of adv
Lee County	Lee County, SC	Republic	Rail	576	210459	428789	1944938	16183465	N/A	49.08
Atlantic Waste Disposal	Waverly, VA	WM	Rail	2262	825630	1223596	N/A	47533179	2113	67.48
High Acres	Fairport, NY	WM	Rail	900	328500	507086	1074500	46104000	2020	64.78
Grows North/Tullytown/Fairless*	Bucks County, PA	WM	Truck	1262	460630	6691545	7300000	N/A	2019	6.88
Bethlehem	Bethlehem, PA	Waste Connections	Truck	195	71175	501875	657000	N/A	N/A	14.18
Blue Ridge	Scotland, PA	Progressive	Truck	258	94170	620500	730000	N/A	N/A	15.18
Seneca Meadows	Waterloo, NY	Progressive	Truck	1503	548595	2050280	2190000	24032014	2025	26.76
Keystone	Dunmore, PA	Keystone Sanitatior	Truck	356	129940	2646250	2737500	N/A	N/A	4.91
Cumberland County	Shippensburg, PA	Advanced Disposal	Truck	338	123370	912500	1076750	N/A	N/A	13.52
			Totals	7650	2792469	15582421				17.92

Sources:
New York disposal site info: DSNY, (2016). Disposal Sites for DSNY Waste CY '15. Unpublished raw data., And New York Department of Environmental Conservation. (2013). *2013 Capacity Chart*. Retrieved from http://www.dec.ny.gov/docs/materials_minerals_pdf/capchart.pdf
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Figure: 3

Table 4
NYC WTE Disposal Sites

Name	Location	Owner/Operator	Tons/Day (NYC 2015) (	Total Tons (NYC2015)	Total Tons annual	Existing annual permit limits	NYCMSW as % of adv
Westchester Resco	Peekskill, NY	Wheelabrator	132	48180	676380	71000	7.12
Wheelabrator Falls	Morrisville, PA	Wheelabrator	2	730	2800	N/A	26.07
Covanta Essex	Essex, NJ	PANYNJ/Covanta	1135	414275	N/A	N/A	
Covanta Delaware County	Chester, PA	Covanta	669	244185	1731925	2080500	14.10
Covanta Hempstead	Westbury, NY	Covanta	148	54020	986591	1040250	5.48
Covanta Union	Rahway, NJ	Covanta	15	5475	N/A	N/A	
Covanta Niagara	Niagara Falls,NY	Covanta	163	59495	749596	821250	7.94
		Totals	2264	826360	4147292	4013000	

Sources:
New York disposal site info: DSNY, (2016). Disposal Sites for DSNY Waste CY '15. Unpublished raw data., And New York Department of Environmental Conservation. (2013). *2013 Capacity Chart*. Retrieved from http://www.dec.ny.gov/docs/materials_minerals_pdf/capchart.pdf
Pennsylvania disposal site info: Pennsylvania Department of Environmental Protection. (2015). *MUNICIPAL WASTE LANDFILLS AND RESOURCE RECOVERY FACILITIES*. Retrieved from http://www.dep.pa.gov/Business/Land/Waste/SolidWaste/MunicipalWaste/MunicipalWastePermitting/Pages/MW-Landfills-and-Resource-Recovery-Facilities.aspx

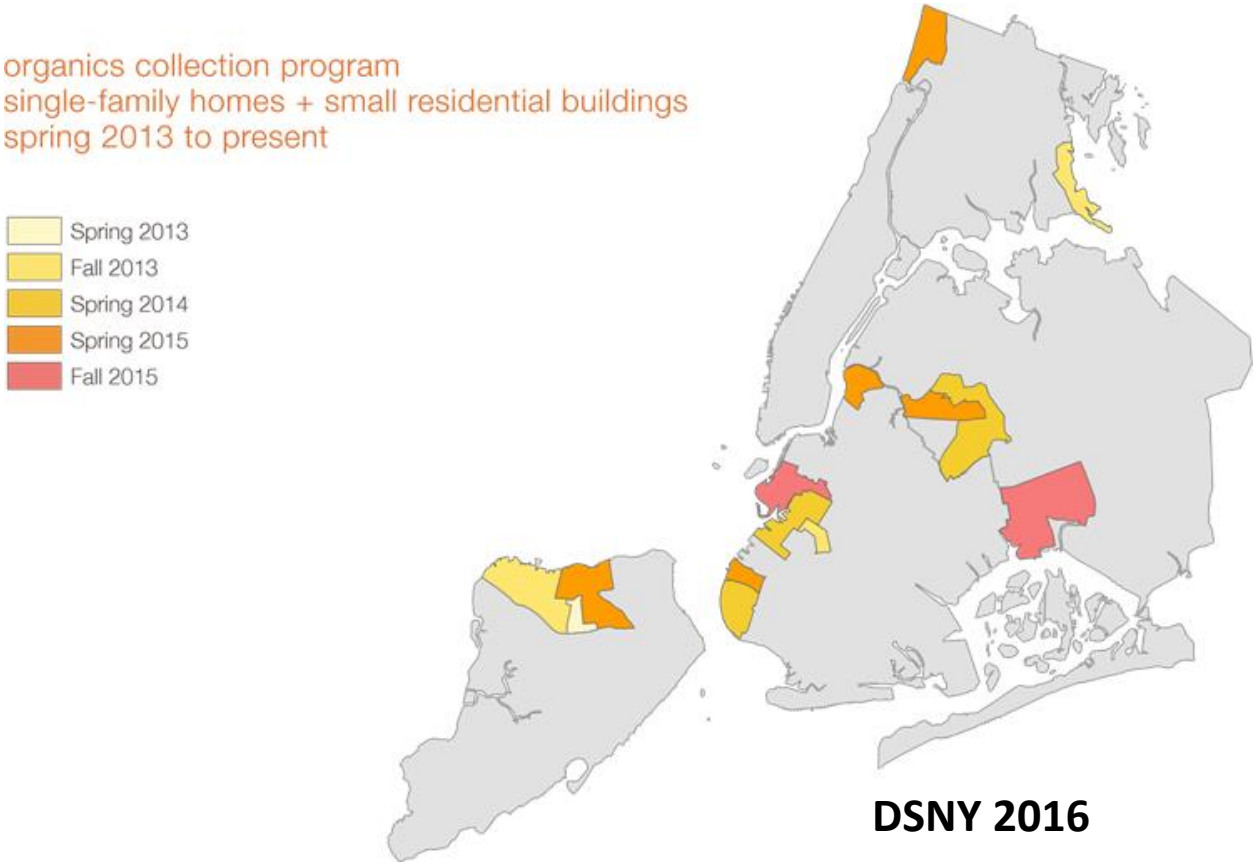
Figure: 4

Map of NYC MSW Destinations



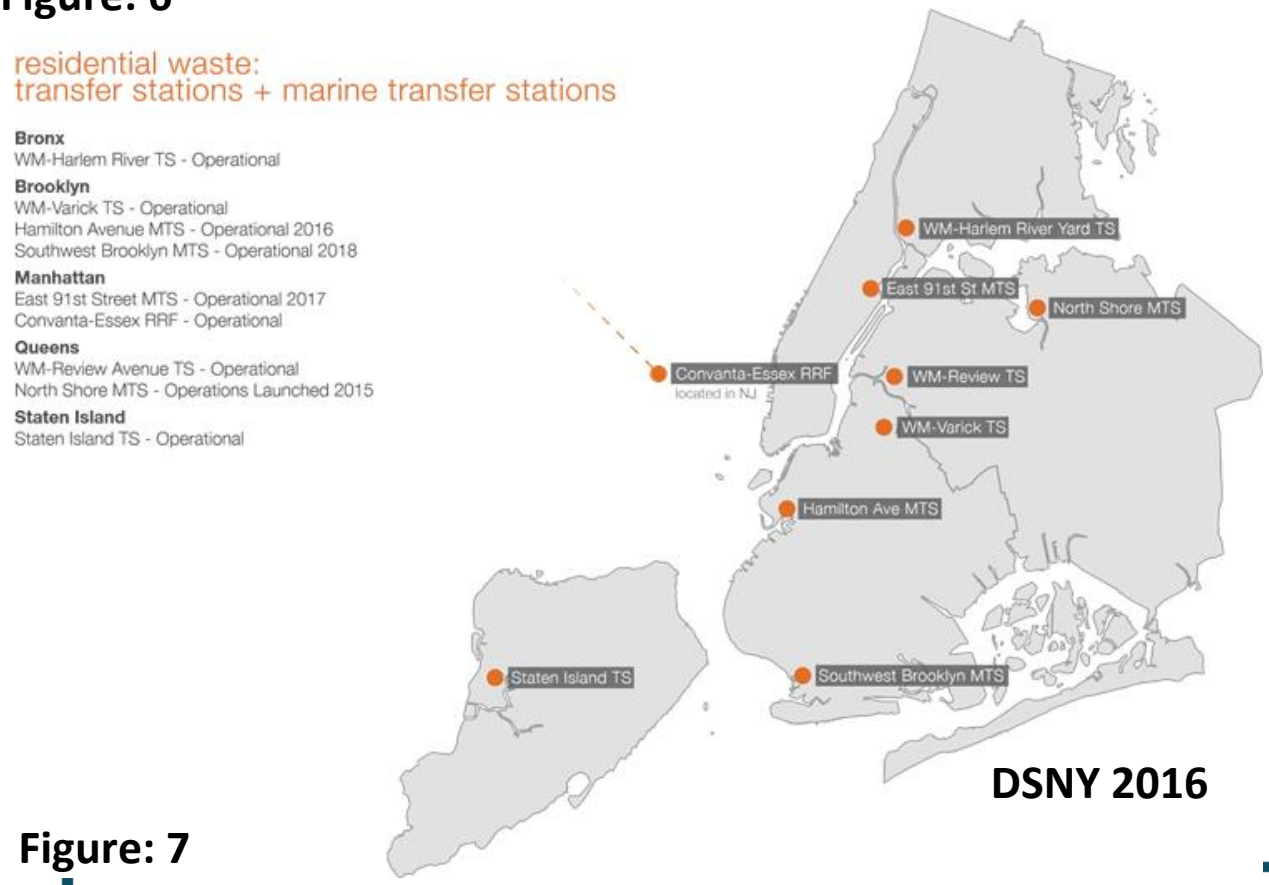
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Figure: 5



DSNY 2016

Figure: 6



DSNY 2016

Figure: 7

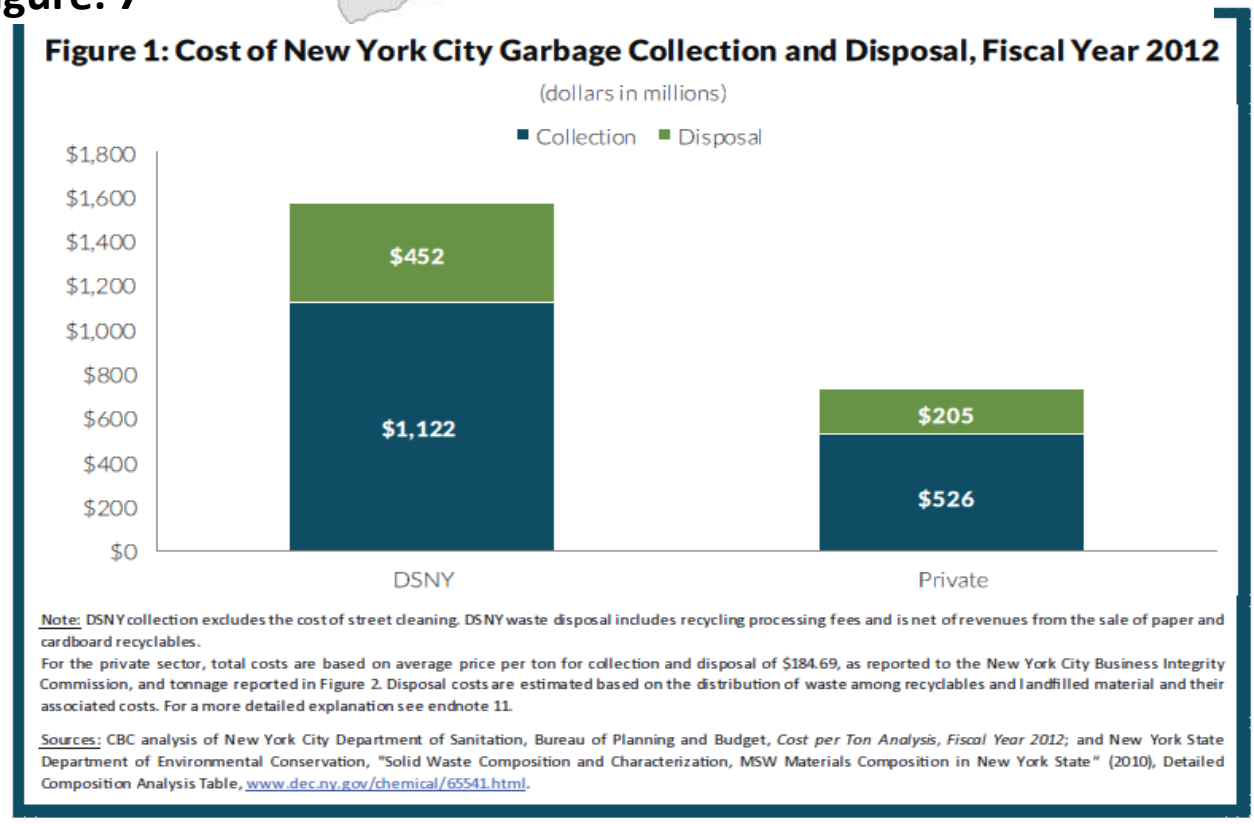


Figure: 9

Table II 2-4 (continued)
FY 2015 Projected Generated Tonnage

FY 2015 Projected Generated Tonnage	Total	
	Tonnage	TPD
Other Recycled Wastes		
Derelict vehicle recycling	9,266	31
Auto tire recycling	1,591	5
Lot cleaning bulk metal recycling and dirt reuse	749	2
DOT asphalt recycling[2]	187,574	621
DOT millings recycling[2]	128,294	425
Interagency clean fill reuse[2]	315,619	1,045
Interagency road material reuse[2]	249,444	826
Total "Other Recycled Wastes"	**892,538**	**2,955**
Total Recycling, Composting and Reuse	**2,141,711**	**7,092**
Grand Totals and Diversion Rates		
A. Total DSNY-Managed Curbside/Containerized Recycling	**1,249,173**	**4,136**
B. Total DSNY-Managed Curbside/Containerized Refuse Collection & Recycling[3]	**4,415,933**	**14,622**
Curbside/Containerized Diversion[4]	**28.3%**	
C. Total Recycling, Composting and Reuse	**2,141,711**	**7,092**
D. Total (DSNY-Managed Waste for Export, Recycling, Compost and Reuse) Generation[5]	**5,504,760**	**18,228**
Total DSNY-Managed Diversion[6]	**38.9%**	

Notes:

(1) New programs may include those targeting waste prevention, other plastics recycling, or other streams.
(2) See Exhibit 1 at end of this section for a discussion of changes in the future status of these materials.
(3) "Total DSNY-managed Curbside/Containerized Refuse Collection & Recycling" is the sum of "Total DSNY Curbside/Containerized Refuse Collection" and "Total DSNY-managed Curbside/Containerized Recycling"
(4) Curbside/Containerized Diversion is calculated as "Total DSNY-managed Curbside/Containerized Recycling" divided by "Total DSNY-managed Curbside/Containerized Refuse Collection and Recycling" (line A ÷ line B)
(5) "Total (DSNY-managed Waste for Export, Recycling, Compost and Reuse) Generation" is the sum of "Total DSNY-managed Waste for Export" and "Total Recycling, Composting and Reuse"
(6) "Total DSNY-managed Diversion" is calculated as "Total Recycling, Composting and Reuse" divided by "Total (DSNY-managed Waste for Export, Recycling, Compost and Reuse) Generation" (line C ÷ line D)

DSNY

Figure: 10

RESIDENTIAL WASTE COLLECTION IN NEW YORK CITY IS 5 TIMES MORE EFFICIENT THAN COMMERCIAL WASTE COLLECTION

	COMMERCIAL	RESIDENTIAL
Volume of waste	3.2 million tons[16]	3.9 million tons[17]
Number of trucks	4,000[18]	1,640[19]
Miles travelled per truck per year	11,665 miles[20]	6,900-9,000 miles[21]
Total truck miles travelled in a year	47 million miles	12 million miles
Ratio of truck mile to waste ton	15:1	3:1

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Figure: 11

THE RECYCLING JOB POTENTIAL IN NYC'S COMMERCIAL SOLID WASTE

		RECYCLING PROCESSING		+	RECYCLING-RELIANT INDUSTRY		=	TOTAL
Material	2011 Tonnage[65]	Jobs per 1,000 tons[66]	# Jobs		Jobs per 1,000 tons[67]	# Jobs		# Jobs
Metal	148,708	2	297		4 to 17	595 to 2,528		892 to 2,825
Glass	120,232	2	240		8	962		1,202
Plastic	253,120	2	506		10	2,531		3,037
Paper	1,771,840	2	3,544		4	7,087		10,631
TOTAL JOB POTENTIAL:			4,588	+		11,175 to 13,108	=	15,763 to 17,696

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Figure: 12

Waste Handling Process	Jobs per 10,000 Tons of Waste per Year
Landfilling/ Incineration	1
Composting	5
Recycling Sorting	20

ALIGN REPORT

Figure: 13

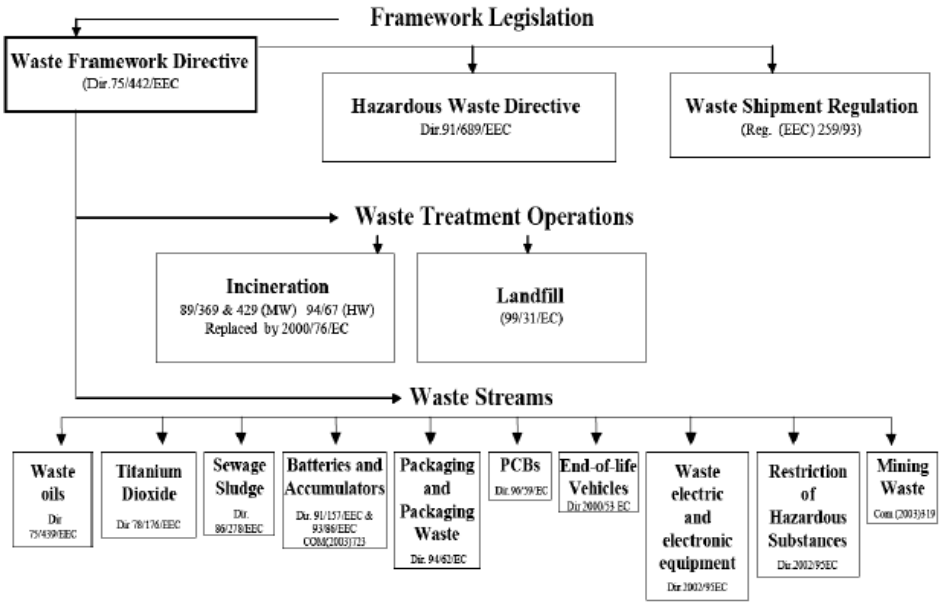
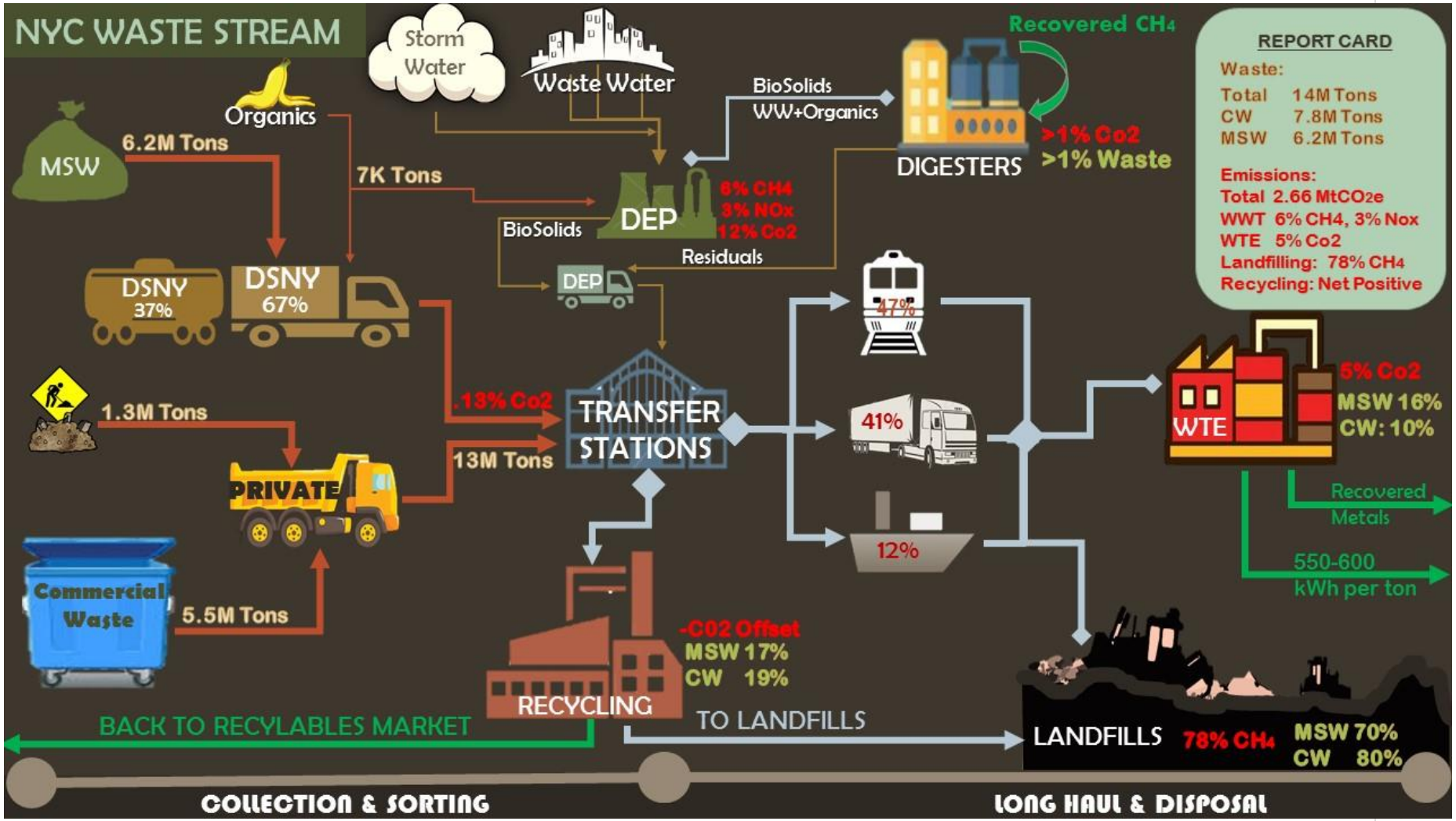


Fig. 5.: EU Waste legislation


NYC WASTE STREAM
Storm Water
Waste Water
Organics
MSW
6.2M Tons
7K Tons
BioSolids
WW+Organics
Recovered CH4
DIGESTERS
>1% Co2
>1% Waste
REPORT CARD
Waste:
Total 14M Tons
CW 7.8M Tons
MSW 6.2M Tons
Emissions:
Total 2.66 MtCO2e
WWT 6% CH4, 3% Nox
WTE 5% Co2
Landfilling: 78% CH4
Recycling: Net Positive
DEP
6% CH4
3% NOx
12% Co2
BioSolids
Residuals
DEP
DSNY 37%
DSNY 67%
47%
1.3M Tons
13% Co2
TRANSFER STATIONS
41%
WTE
5% Co2
MSW 16%
CW: 10%
PRIVATE
13M Tons
Recovered Metals
550-600 kWh per ton
Commercial Waste
5.5M Tons
12%
-C02 Offset
MSW 17%
CW 19%
RECYCLING
BACK TO RECYLABLES MARKET
TO LANDFILLS
LANDFILLS 78% CH4
MSW 70%
CW 80%
COLLECTION & SORTING
LONG HAUL & DISPOSAL