A02467
Composting Organic Waste at State and Municipal buildings in New York Bill

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Executive Summary

The waste sector, primarily consisting of solid organic waste, accounts for 11% of New York State's greenhouse gas emissions, making it the second-largest source of emissions after energy production (76%). Notably, organic waste makes up 7% of the state's greenhouse gas emissions. Organic waste is defined as any material derived from plants or animals that can be decomposed by microorganisms into simple organic molecules, or any remains, residues, or waste products from organisms.

State and local government employees in New York State produce approximately 1.69 million pounds of organic waste daily, which constitutes around 64% of the municipal solid waste. This waste is currently transported to landfills and waste to energy plants where it mixes with other waste streams. When it ends up in landfills it leads to methane production due to anaerobic decomposition in the oxygen-poor environments of landfills. Methane has a significantly higher global warming potential than carbon dioxide and is often released directly into the atmosphere by landfills, exacerbating environmental issues. Additionally, organic waste in landfills contributes to leachate production, which can contaminate groundwater and surrounding soils, and causes habitat degradation due to changes in land use and pollution.

Source: Celine Andriana

The Composting Organic Waste at State and Municipal Buildings in New York Bill (A02467), referred henceforth as "the Bill," seeks to address the portion of this organic waste generated by state and municipal agencies. Composting constitutes two alternative organic waste methods, namely composting and anaerobic digestion. By diverting this organic waste from landfills, the Bill aims to reduce methane emissions, enhance renewable energy through biogas production, and contribute to a more circular food waste stream.

The Bill specifies that compostable materials include food scraps, plant trimmings, food-soiled paper, certified compostables, and other organic recyclables. For this analysis, we focus on two types of organic waste: food and yard trimmings. These types of waste cannot be reused (limiting their options), are less processed than other organic waste, contain higher water content (50-80%), and decompose rapidly. They make up approximately 24% of the waste in municipal solid waste landfills.

Given that the Bill focuses exclusively on handling garbage after it is generated, and waste is produced by all state and municipal agencies, it mandates that municipal and state agencies implement an organic waste composting program in buildings under their purview, separating and processing them appropriately. The solutions implemented can vary since some public agencies may have the land needed to process food waste on site while others will need to transport the waste to an organic waste treatment or pre-treatment facility.

This report provides an overview of the scientific explanation of the environmental issues associated with organic waste and their potential impacts on ecosystems and humanity. It also explores two possible composting solutions for municipal and state agencies, detailing the requirements for each in terms of conditions, facilities, and some of the products and byproducts of these processes.

Additionally, this report addresses gaps of information regarding different methods of organic waste treatment. Finally, we discuss numerous indicators are that measure the success of the Bill in reducing environmental degradation.

Source: Robert K Chin/Alamy

Introduction

Organic waste, when landfilled, contributes to a significant portion of total greenhouse gas emissions in the United States. In New York State, this accounts for 7% of its greenhouse gas emissions in 2021 (Figure 1). When landfilled, organic waste decomposes to emit greenhouse gasses, mainly methane, directly to the atmosphere unless captured. Methane is 27 to 30 times more potent as a greenhouse gas than carbon dioxide (United States Environmental Protection Agency, EPA, 2024). The diversion of organic waste from landfills should be a key part of New York State's decarbonization strategy.

Organic wastes also contribute to the environmental impact of landfills. Organic wastes, especially food wastes, yield acidic content that reacts with other materials in the landfill such as heavy metals, that are drawn out through water content in the landfills, producing a liquid known as leachate. If landfill containment measures such as clay linings break, leachate can seep into groundwater, contaminating sources of drinking water (Civiletti, 2021). This can result in carcinogenic and other serious health impacts.

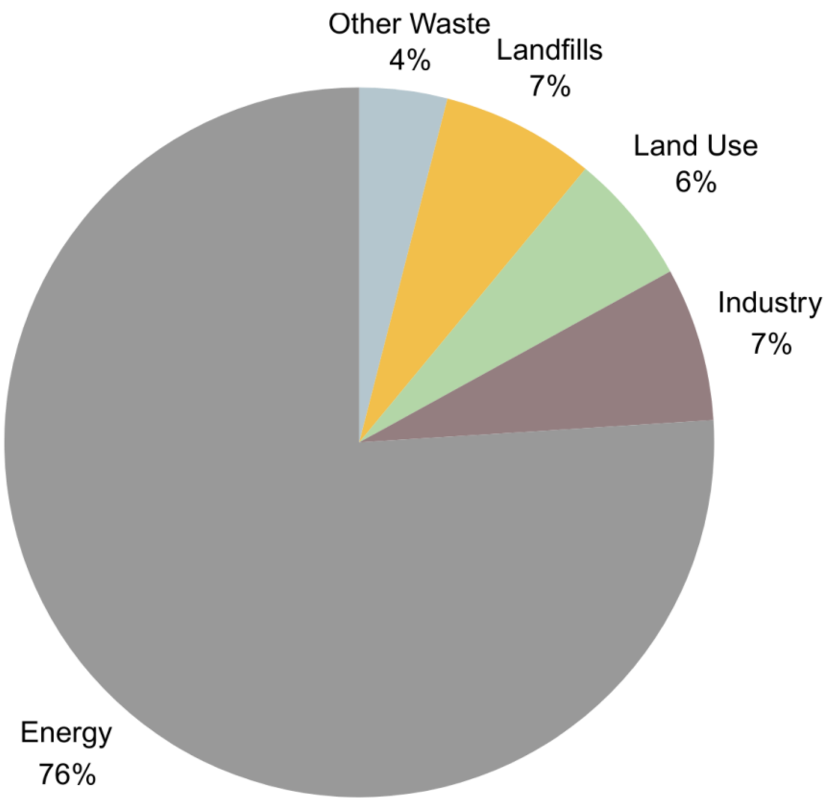


Figure 1 - New York State's Greenhouse Gas Emissions in 2021

Leachate and greenhouse gas emissions are two reasons why organic wastes specifically should be diverted from landfills; this diversion can also reduce the overall need for landfills, which contributes to landfill-driven forest clearing, and the degradation of habitats and their ecosystem services, such as natural water filtration.

New York State's 1.3 million state and local government employees produce approximately half a pound of organic waste per workday. Presently, municipalities and agencies are encouraged (through state-level grants and programs), but not required to include organic waste diversion in their solid waste management plans (New York State Department of Environmental Conservation, NYSDEC, 2024).

The proposed Bill A02067 mandates agencies, municipalities, in the buildings they own, manage, occupy to divert their organic waste from landfills to alternative processing methods such as composting or anaerobic digestion. Composting refers to recycling organic matter into soil amendments such as fertilizer, while anaerobic digestion refers to the production of biogas, and sometimes soil amendments through processing organic wastes. Though addressing households and businesses instead, various states such as Washington and California and New York City have programs in place to similarly divert organic waste from landfills.

The Bill

In New York State, the obligation to conserve, improve, protect and prevent the detriment of natural resources is mandated by the Environmental Conservation Law (Chapter 43-b, Article 1, Title 1). The law regulates state waste management as part of the effort to protect public health, encourage urban growth, and the development of economically advantageous projects for collection, treatment and management (Article 27 "Collection, Treatment, and Disposal of Refuse and Other Solid Waste", Title 1). However, no specific regulation for composting organic waste is included in this law.

Consequently, considering that the New York State and local governments contribute significantly to the amounts of organic waste generated a law regulating this source of organic waste could result in significant reduction in environmental pollution. On January 26, 2023, the Democratic Party introduced in the New York State Assembly the "Composting Organic Waste at State and Municipal Buildings in New York Bill" (A02467)*. This bill amends the current Article 27 for state and municipal agencies to establish and implement a waste composting program one year after its effective date.

The purpose of the bill is to promote organic waste recycling among public agencies. The bill allows agencies to process this waste on-site, transport it to a treatment facility themselves or via an authorized private carter. It also enforces the monitoring and controlling of the effectiveness of the program developed.

The Bill establishes requirements to implement a system of mandatory recycling of all compostable waste produced by state and local governments in New York state.

Finally, the Bill obligates agencies to adhere to reporting requirements and compliance deadlines. The annual reports are to include the implementation and management costs, and collection rates. NYSDEC will be in charge of consolidating the program efficacy reports and produce an annual public report on the progress of the composting programs.


Source: USDA

The Problem

Problem Definition

What is Organic Waste?

By definition, organic waste has two properties: it is biodegradable and is derived directly from nature. Almost 68% of New York State's municipal solid waste stream is organic waste in 2018[New York State Department of Environmental Conservation. (2023). New York State Solid Waste Management Plan: Building the circular economy through sustainable materials management.

The Bill targets organic waste that are specifically unrecyclable through mechanical means and break down within a relatively shorter time of 6 months to 2 years, namely yard trimmings, food waste, and food-soiled papers. Together these three waste categories make up more than 24% of New York State's municipal solid waste volumes in 2018 (NYSDEC, 2023).

Where does the Organic Waste go?

New York State's current waste stream management system contributes toward the United State's waste generation problem. Only 19% of the State's municipal solid waste is recycled. About 39% of New York's municipal solid waste is landfilled in state, while 28% is exported out of state to incineration plants and landfill across the Eastern United States (NYSDEC, 2023).

How Does Organic Waste Pollute the Environment?

After organic waste enters a landfill, it enters the decomposition process, where a series of chemical reactions takes place. The decomposition process produces greenhouse gasses such as methane, which also pose a severe fire hazard to workers and nearby communities, and precursors to groundwater pollution through landfill leachate.

* Note: by the time this document is written the Bill has not been enacted yet] (NYSDEC, 2023).

Environmental Problems Arising from Landfilling Organic Waste

Environmental problems that arise from landfilling organic waste include methane production, landfill fires and leachate pollution (Figure 2).

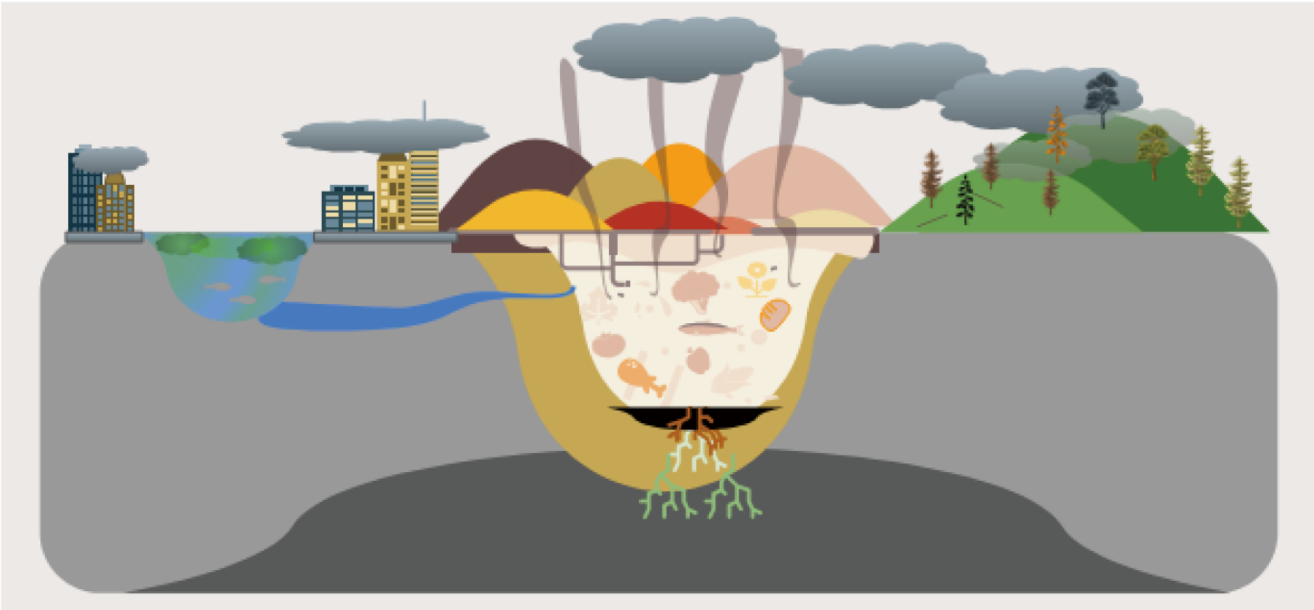


Figure 2 - Overview of environmental problems from landfilling organic waste

Methane Production

During the last phase of decomposition, the process of methane production occurs. Within the process of methanogenesis, microorganisms metabolize the waste and produce methane as a byproduct within landfills. Though measures such as gas collection systems are in place in modern landfills to prevent its emission into the atmosphere, these are limited to landfills with high biogas potential and economic considerations.

More notably, leaks in the gas collection and permeable landfill cover layer allow for atmospheric exchange and for methane to seep into the atmosphere. Methane is a potent greenhouse gas that can effectively trap heat within the atmosphere. Due to its molecular composition, it has a strong radiative-forcing abilities, it absorbs heat, and re-emits it back at the surface at 27-30 times more powerfully than carbon dioxide (Patricola et al., 2016; EPA, 2024). Greenhouse gas emissions induce rising global temperatures, which leads to climate change. This poses a credible threat towards, not only ecosystems, but also planet Earth, resulting in permanent habitat change due to rising temperatures and sea levels. Moreover, increased heat fluxes can drastically alter the climatology of Earth, changing normal convection currents, and intensifying evaporation, resulting in extreme weather conditions (Etminan et al., 2016).

Science of decomposition

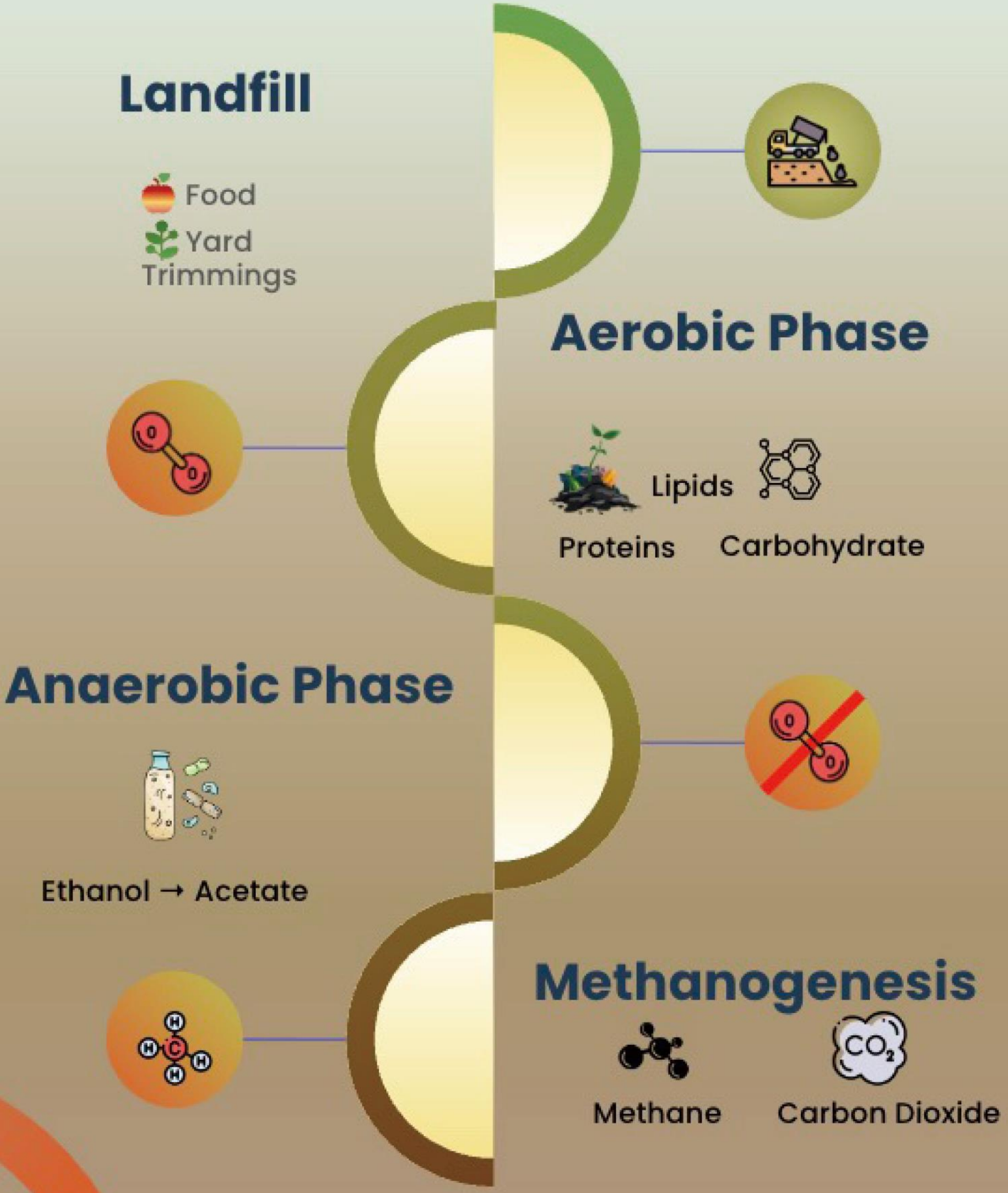


Figure 3 - Science of decomposition of organic materials

Landfill Fires

Methane production induces a secondary problem, landfill fires. Methane is a highly flammable gas, where in the US an average of 8300 landfill fires occur annually. Chemical reactions within the landfill release great amounts of heat that when combined with methane, can lead to spontaneous combustions within the landfill. Landfill fires release large amounts of toxic pollutants such as dioxins over long distances through its smoke, causing respiratory and cardiovascular health impacts, and potential neurological issues related to chronic carbon monoxide exposure (National Collaborating Centre for Environmental Health, 2015). Landfill fires also damage protective linings and cover materials potentially leading to direct contact of waste material with air.

Leachate Pollution

Landfill leachate is produced when water filters through the landfill contents, drawing out chemicals and pathogens. Water sources in landfills include the internal moisture of organic waste, predominantly from food waste, and rainfall. Compostable wastes are often composed of 50-80% moisture, as decomposition happens the moisture accumulates at the bottom of the landfill. Protective liners are put under the landfill to prevent the leachate from percolating and leaking into groundwater. However, these liners have the potential to break thus polluting aquifers.

The EPA estimates that between 0.1% to 0.4% of all groundwater is polluted by landfills and industrial reservoirs.The contaminated water can be released back into the surface through Earth's hydrologic cycle where aquifers and springs bring the contaminated water back onto the surface. Leachate can also be produced through the excess of rainwater percolation in the landfill. As rainwater infiltrates through the wastes moisture also accumulates within the landfill. If excess rainfall or flooding happens the leachate can have the potential to overflow into surrounding water bodies.

Leachate contains high concentrations of pathogenic microorganisms, nitrogenous compounds, heavy metals, and xenobiotic chemicals. Pathogenic microorganisms such as E.Coli are often associated with unsafe drinking water. Nitrogenous based compounds such as nitrate and ammonia could result in excessive nutrients within water bodies resulting in algal blooms. Algal bloom creates oxygen deficient "dead zones" where aquatic organism populations drastically decrease.

Lastly, leachate contains high amounts of heavy metals such as arsenic, cadmium, mercury, and lead. Heavy-metal pollutants, when released back into the environment, have adverse health effects on both organisms within the ecosystem and on human health. Levels of heavy metals bioaccumulate from prey to predators continuously causing high levels of toxins in predators, resulting in weakened immune systems, neurological system damage, impaired growth, and death.

Habitat Destruction

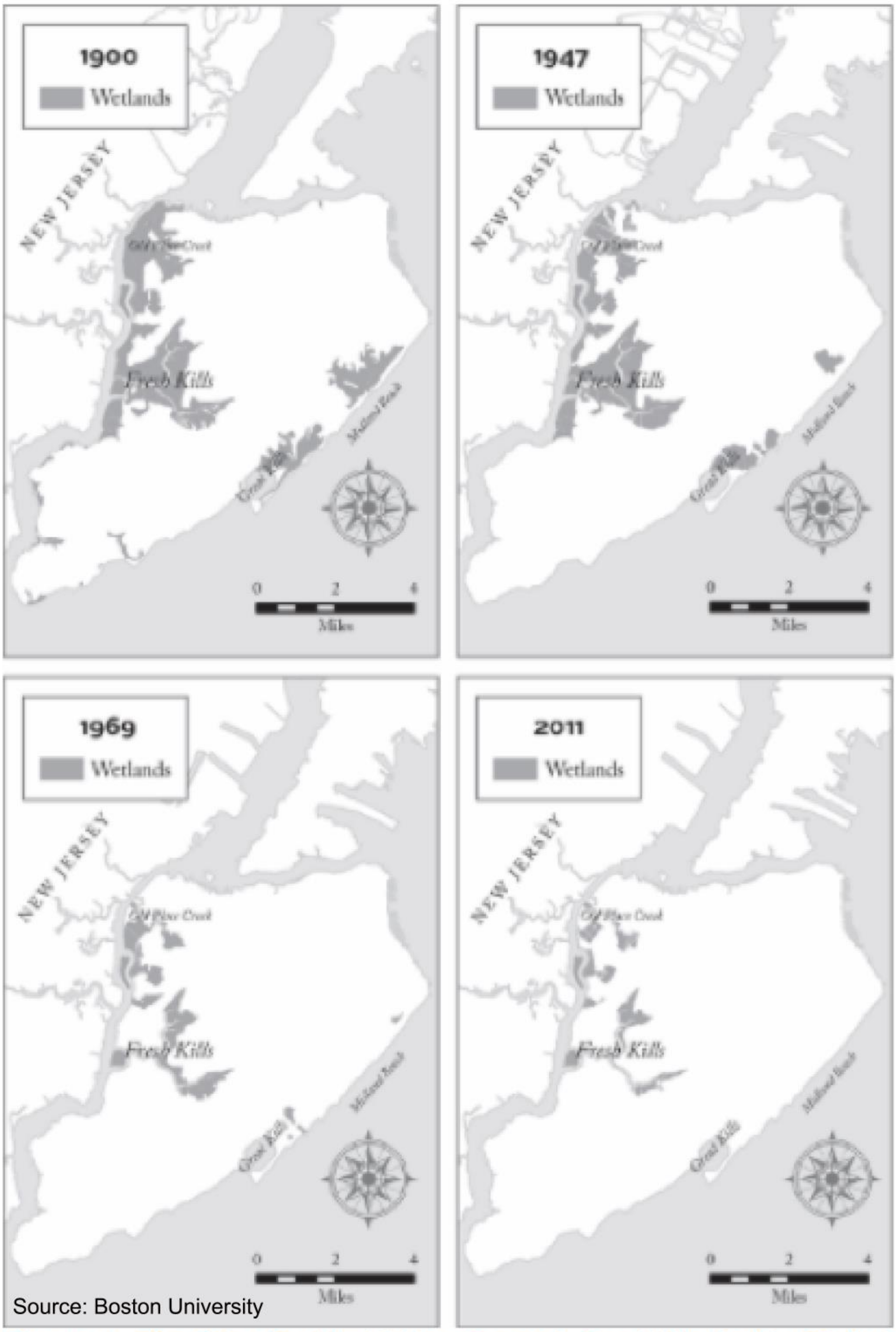
Within the US, the average landfill size of 600 acres results in large amounts of land utilized for waste disposal, resulting in an array of habitat destruction and degradation issues (Vasarhelyi, 2021). Landfill induced habitat destruction results in the loss of between 30-300 species per 100 acres (EPA, 2022).

On the other hand, decomposition results in the production of odorous gasses such as VOCs (volatile organic compounds), ammonia, and hydrogen sulfides. These odors escape through the landfill cap and are carried to neighboring communities by air transmission and wind creating odor nuisances. Elevated odorous gas concentrations have shown to be linked to elevated risks for respiratory diseases.

Source: Tharmapalan Tilaxan

Case Study: Fresh Kills Landfill

Located on Staten Island, right in New York City, Fresh Kills Landfill covers 2,200 acres of tidal marshland and estuaries, making it the largest landfill in the world (New York City Department of City Planning, n.d.). In 1946, the local government purchased the wetlands on Staten Island as a temporary solution for the transition of the city's waste management from incineration to landfilling (Ibid.) However, at its point of closure, it had turned into four massive mounds (Figure 4), ranging from 30-70 meters above sea level, holding 150 million tons of waste (New York City Department of Health and Mental Hygiene, 2020).



Source: Boston University

STATEN ISLAND MARSHLANDS 1900-2011

Figure 4 - The Grim Reality Hidden Beneath Freshkills Park's Bright Facade

Fresh Kills has created a myriad of environmental problems in the area. The landfill is located on a salt marsh, an ecologically diverse and crucial part of the local ecosystem, which serves as a nesting ground for a variety of avian species and harbors different native plant species. As the vegetation was uprooted, significant habitat degradation occurred, leading to deoxygenated waters, making the area less attractive to waterfowl. Consequently, there has been a significant decrease in bird species such as the great egret, marsh wren, and American black duck. Additionally, habitat destruction wiped out local vegetation species such as switchgrass and bugbane, replacing them with more resistant species like the common reed. The landfill attracts various animals that are not supposed to be there, such as rats, dogs, and herring gulls that scavenge through the waste. The effects of the landfill on humans are also evident. Elevated risks of asthma, cancer, and birth defects have been reported. A study conducted by the New York Health Department showed that adults living in the area around Fresh Kills have a statistically significant elevation in bladder, breast, kidney, non-Hodgkin lymphoma, and thyroid cancers compared to residents in other parts of Staten Island.

The Solution

The bill proposes that one year effective from the passing of this bill, all state and municipal agencies must establish a composting program in buildings owned, operated, or occupied by theseagencies. The aim is to ensure that all (certified and uncertified) organic compostable waste and other recyclables are separated and placed in designated containers, transported to appropriate facilities or processed onsite. The proper collection, transportation, and processing of waste via anaerobic digestion or composting methods enables the waste to become beneficial resources, i.e, biogas and fertilizer/compost respectively. The process of converting organic waste into these resources is illustrated in Figure 5.

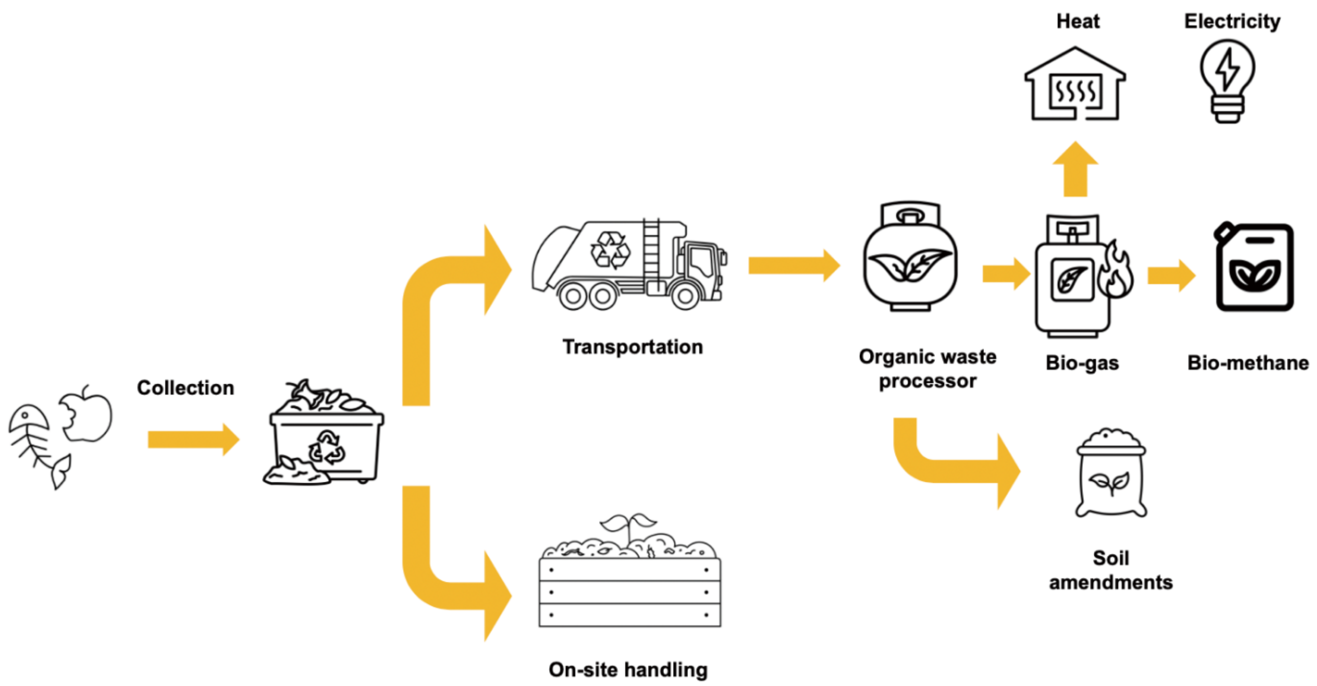


Figure 5 - Organic waste alternative pathways and outputs

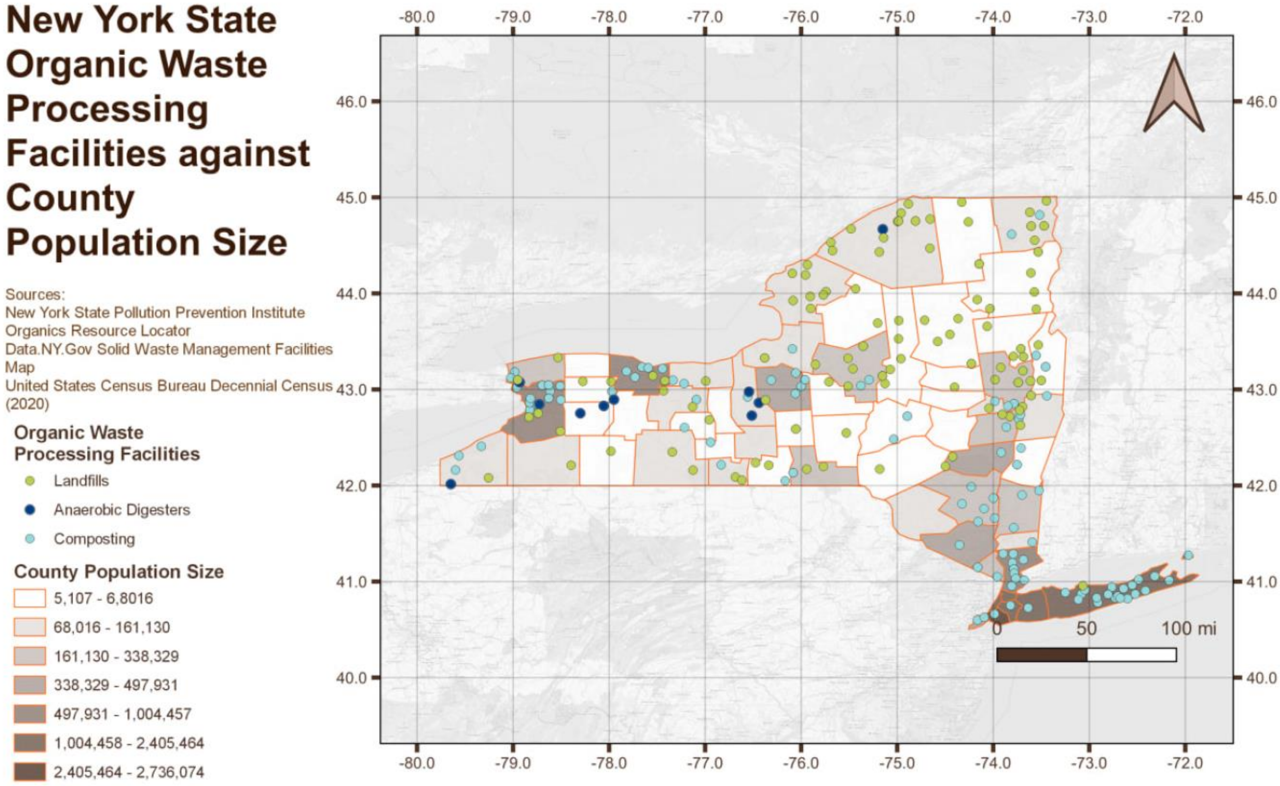


Figure 6 - This map shows the population of New York counties with marked out organic waste management facilities (composting, landfills, anaerobic digesters). Facilities that do not accept food waste, yard trimmings or other plant-based garden waste are excluded.

The technologies for converting waste into resources are typically available off-the-shelf. New York State has 10 anaerobic digestion and 158 composting facilities which process food waste and yard trimmings. As shown in Figure 6, these are located closer to the regions with higher population as compared to landfills, indicating higher accessibility to regions generating high waste volumes by virtue of a larger population.

Composting

Composting involves the decomposition, or breakdown of organic matter to produce carbon dioxide, water, heat, and humus (a stable, organic end product). Under optimal conditions, composting involves three phases: mesophilic or moderate-temperature phase, thermophilic or high-temperature phase, and finally the cooling or maturation phase (Trautmann & Olynciw, 2024). Initial decomposition is carried out by mesophilic microorganisms, which rapidly break down the soluble, readily degradable compounds and release high heat during the process. As the temperature rises above about 40°C, thermophilic or heat-loving.

microorganisms replace the mesophilic ones. High temperatures destroy plant pathogens, producing a clean, stable product. During the maturation phase, mesophilic microorganisms once again take over for the final phase of curing of the remaining organic matter.

Methods for composting include windrow, static pile and in-vessel composting. The former two methods occur in open environments, while the latter occurs in enclosed settings. In the windrow method, organic waste is piled in long rows, i.e. windrows, which are periodically turned to aerate the material. In the static pile method, organic waste is stacked in piles with ventilation pipes or forced air systems to provide oxygen without turning the pile. IVC, however, contains the composting process in a drum or silo, where the environmental conditions can be controlled for efficient decomposition of organic matter. Of these three methods, IVC is the most suitable for suburban urban areas, as it takes up the least space and minimizes odors (U.S. EPA, 2000). IVCs provide an added benefit of preventing runoff of compost into water bodies, thus reducing the risk of ecological impacts through the creation of algal blooms. Hence, IVCs are most feasible for use in densely populated regions of New York State, where public agencies are located and likely to contribute organic waste.

Anaerobic Digestion

An alternative to composting is anaerobic digestion, to produce fertilizer and biogas, i.e. renewable resource-produced and methane-based fuel.

During anaerobic digestion, bacteria break down solid organic waste in an oxygen-restricted environment. The process is composed of four metabolic phases: hydrolysis, acidogenesis, acetogenesis and methanogenesis.

In the initial hydrolysis phase, complex organic compounds like carbohydrates, fatty acids and proteins break down to form soluble molecular compounds such as simple sugars and amino acids. This is followed by acidogenesis, which converts the products of hydrolysis into alcohols, volatile fatty acids and inorganic compounds such as hydrogen sulfide, carbon dioxide, ammonia and hydrogen gas. The third phase (acetogenesis) produces carbon dioxide, acetate, and hydrogen from compounds obtained from the acidogenesis step. In the final phase, methanogens i.e. bacteria produce methane, a major component of biogas. All leftover products from the four processes form a wet, nutrient rich mixture called digestate. Biogas from anaerobic digestion can be harnessed to generate electricity or further refined into biomethane to fuel vehicles. The digestate can be processed to produce fertilizer for crops (U.S. EPA, 2000) (Figure 7).

Anaerobic digestion for biogas production takes place in sealed vessels called reactors. Some reactor designs enable co-digestion in which multiple organic materials including food waste, crop residues or manure can be combined in one digester. Co-digestion can increase biogas production from organic waste inputs that result in low yields or are difficult to digest.

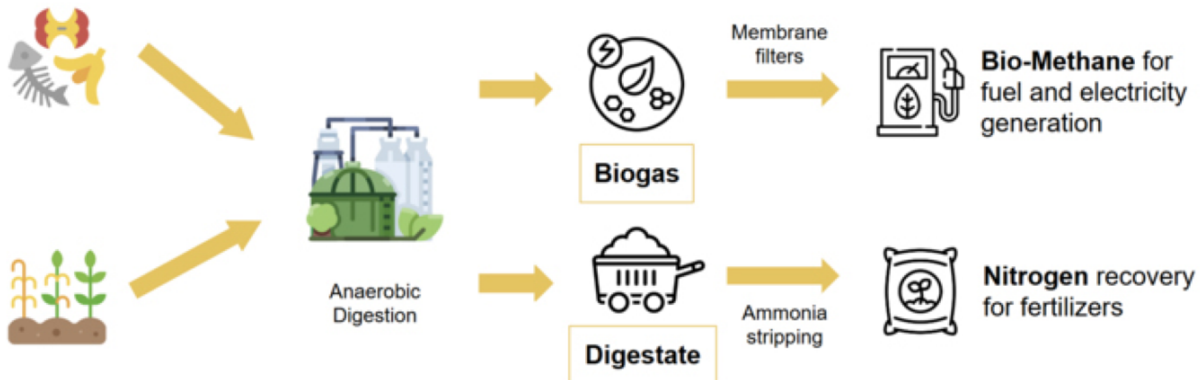


Figure 7 - Process and Byproducts of Anaerobic Digestion

Transportation of Waste

State and municipal agencies are likely to find that transportation forms a significant portion of associated greenhouse gas emissions. Transporting organic waste with conventional diesel trucks causes emissions of around 1.84 kilograms of carbon dioxide per kilometer (Peña, Dorronsoro, & Ruiz, 2024), or 7.6 times the emissions per kilometer for an average gasoline powered passenger vehicle (U.S. EPA, 2000).

These emissions can be reduced by transporting organic wastes with electric vehicles (EVs). Considering New York State's energy makeup (New York State Energy Research and Development, NYSERDA, 2023), one kilometer of transport with battery-operated, medium-weight trucks emits around 1.26 kilograms of carbon dioxide (Better Energy, 2024). EVs also offer the added benefit of emitting lesser pollutants, thus enhancing air quality and lowering public health costs from respiratory and pollution-related illnesses. However, currently the supply of electric medium-weight vehicles (i.e. garbage trucks) is low, given limited market demand and high capital costs.

Case Study: California Senate Bill SB1383

A similar bill to A02467 was enacted in California in 2021 that required cities and counties to reduce their organic waste disposal by 75% by 2025. The legislation has a wider scope compared to New York State Bill A02467, as it goes beyond public agencies to include California residents, businesses, and multifamily complexes.

Source: Town of Los Gatos California

It also mandates certain measures regarding generated food waste and repurposing. It requires these stakeholders to separate organic waste into designated organic carts (WM Intellectual Property Holdings, LLC, 2021). These designated waste carts are to be made available by all towns, cities and counties. State jurisdictions will then be responsible for collecting and processing the collected organic waste.

California State agencies under SB1383, similar to what is mandated by New York's Bill A02067 must do the following:

For collection: All state agencies will provide informative signs on what to sort into the organic waste carts to limit cross contamination. These labels have to meet specific requirements under SB1383 and correspond to the correct colors of the organic waste (and other recycling) containers. Moreover, employees are required to properly sort their organic waste into the correct containers.

For transportation and processing: State agencies must either,
i. Subscribe to the transportation service the jurisdiction provides,
ii. Organize transportation and handling of through an independent private charter,
iii. Process the collected waste on-site through an appropriate composting facility, or other program/activity.
For reporting: Under SB1383 jurisdictions must also provide an annual report covering organic waste collection, procurement, compliance, and monitoring, amongst other data points.

In 2023, SB1383 was amended giving jurisdictions the right to implement a fine if organic waste is collected and processed incorrectly (Heffernan, 2024). The California Department of Resources Recycling and Recovery (CalRecycle) estimates that the implementation of this state-wide composting program will contribute an extra 5.5 million tons of compost to be produced and that this compost will be primarily recycled into soil amendments, and energy.

SB1383 has already shown results in the diversion of waste from landfills. In 2022, CalRecycle found that 75% of the region's jurisdictions have successfully implemented the composting program and that 11.2 million tons of organic waste has been diverted from landfills, an 13% increase from 2021 (Taxin, 2024).

Concluding Notes on the Solution

Through the above analysis, diverting organic waste to composting and anaerobic digestion have been found to credibly reduce associated pollutive and global warming impacts. Composting technologies are commercially available, and similar programs have met with success. Furthermore, prior to processing in composting and anaerobic digestion facilities, organic waste can undergo pretreatment, to eventually produce higher quality compost and biogas. Notably, pre-treatment equipment such as pulpers and dehydrators may add to the overall emissions of processing organic waste due to their high energy usage.


Source: Grow NYC

Research Gaps

From the literature reviewed, it is evident that composting and anaerobic digestion greatly reduce the negative environmental impacts caused when landfilling organic waste instead. However, this understanding can be further refined by addressing some issues and research gaps, to refine the implementation of such solutions.

Heightened Risk of Compost and Fertilizer Contamination

Unlike the traditional waste treatment method of landfilling, composting has the end goal of its digestate for being used as fertilizers, thus introducing a new risk of circulating contaminants from organic waste back into the environment.

Microplastics

Source: Canva

If separation of waste stream is not done correctly plastics are prone to be found in compost. With the high heat and pressure from decomposition plastics are prone to break into smaller particles. Microplastic could be harmful to the environment as particles are small enough for uptake by plants through root hairs, and alter soil topographical conditions leading to increased erosion rates.

Pesticides

Source: Reaseheath Business Hub

Yard trimmings and food waste might contain residual pesticides sprayed on them. The effect of pesticides found within compost is uncertaindue to a lack of research. Although most pesticides become harmless, as they decay into simpler molecules and form bonds with other compounds, some specific pesticides persist within compost.

Pathogens

Heavy Metals


Source: Your Self Series

Compost leachates are characterized by high levels of heavy metals such as cadmium, nickel and chromium posing possible risk of bioaccumulation in humans if such contaminated compost is applied to food crops (Farrell & Jones, 2009). Further, heavy metals tend to concentrate in the sludge during anaerobic digestion and thus making the disposal of metal-laden digestate an environmental hazard (Montusiewicz et al., 2020).

Stains of bacteria such E. coli and Salmonella enterica, which are often associated with food waste and sewage sludge have been shown to survive in premature composts and could be revitalized via rehydration due to improper storage of compost.

There is a significant information gap on how these contaminants within digestates impact on soil and vegetation health, with minimal research conducted on its concentration and transference into compost and soil.


Source: Dreamstime

Lack of Compositional Data

A persistent issue in New York State’s current waste management system is the lack of information on the composition of municipal solid wasteFactors such as variation across districts and counties, seasonal changes, and municipality functions have significant implications on volume and content of waste. State agencies in New York State operate various buildings and facilities, including administrative offices, courthouses, public safety buildings, schools, state-owned parks, and health facilities. As a result, studies on the composition, processing method and environmental impact of organic waste should be collected in representative public buildings before or in early stages of the bill implementation to help agencies to decide the appropriate process to process organic waste: on-site or via facility.

Lack of Data on Emissions from Alternative

Although there is a scientific consensus that greenhouse gas and pollutant emissions from composting are substantially lower than that of landfilling, these gasses are equally prone to escape from composting sites. Composting creates problematic gaseous emissions through both aerobic and anaerobic chemical reaction processes that result in greenhouse gas emissions and odor nuisances (Table 1). Composition has a defining effect on emissions produced by composting.

	Greenhouse Gas	**Results in Respiratory Disease**	**Odorous Gases**
Ammonia (NH_3)		✓	✓
Nitrous Oxides (N_2O)	✓		
Carbon Dioxide (CO_2)	✓		
Methane (CH_4)	✓		✓
Volatile Sulfur Compounds (VSC)		✓	✓

Figure 8: Greenhouse gas and pollutants emitted from composting and anaerobic digestion

Factors such as particle size, moisture levels, amount of food matter and green waste affects pH levels and aeration rates which create fluxes within the emissions produced. There is limited data and research that measure compost emissions in relations with composition of waste.

Lack of Data on Digestates

Generally, there is limited data evaluating the impact of digestates from both anaerobic digestion and composting. The composition of waste from New York State's public agencies is expected to change daily, affecting the predictability and quality of the final digestate and its effectiveness as a fertilizer. While there is conclusive information on the benefits of anaerobic digestion for managing organic waste, there is insufficient evidence to balance greenhouse gas emissions, energy use, and pollution from this method. Additional research is needed in the US to assess secondary environmental effects, including chemical reactions and health, social, and economic impacts, to ensure the efficacy and proper adjustment of anaerobic digestion solutions.

Moreover, the effects of biogas and fertilizers in life cycle analyses (LCAs) remain undetermined. Although the benefits of using anaerobic digestion for biogas and fertilizer production are well-documented, there is a lack of comprehensive data on their inclusion in LCAs due to limitations in system boundaries, allocation methods, and impact assessment categories. Consequently, there is uncertainty about the impact of biogas and fertilizer production in anaerobic digestion processes.

Lacking Data on Transportation of Organic Waste

There are numerous data gaps on the greenhouse gas and other air pollution impacts from the transport of organic wastes, whether to landfills or to composting or anaerobic digestion facilities. Vehicles emit greenhouse gasses directly, especially if they are hybrid or diesel trucks. Optimizing the transportation route and frequency according to the organic waste generation rate of each area or building can reduce associated greenhouse gas emissions. For optimization to occur, data on each building's organic waste generation rate should be collected to inform the appropriate frequency of routes. Using this data to advise a central collection service may dwarf the associated emissions from allowing each entity to truck their own wastes to a facility, as CalRecycle has done, presumably from a similar lack of waste generation rates (CalRecycle, 2012).

Additionally, more information on the organic waste collection fleet can allow for optimization of transport routes to minimize associated emissions and pollutants. Characteristics such as the mileage, type of fuel used can be used to model the amount of greenhouse gas emissions and associated pollutants. The vehicles can even be equipped with GPS trackers with Internet of Things (IoT) integration to advise routes in real-time, based on traffic conditions or collection demand.

Performance Metrics

Key Scientific Indicators for Measuring

Understanding the key indicators that will determine the success of this bill is crucial. By distilling the evaluation down to a few essential metrics, we can conveniently and effectively measure the bill's success.

Therefore, from various perspectives and metrics of similar bills (namely California's Senate Bill SB1383, Washington State's Organics Management Law (RCW 70A.205.140)-ESS HB 1799, and Italy's Legislative Decree No. 152/2006), we have identified five scientific indicators to measure the success of this bill (Table 2). These metrics were chosen to ensure feasibility and cost-effectiveness while providing simple, direct, and efficient scientific indicators that thoroughly inform us about the bill's progress at each stage. The five factors provide a comprehensive view of the bill's success, from the initial separation of organic waste to the reduction of environmental pollutants like leachate, the production of beneficial by-products, and the overall reduction in greenhouse gas emissions. Additionally, stakeholders and organizations must adhere to the reporting and maintenance procedures to fully implement and benefit from the bill.

Figure 9: Scientific Indicators of Success for Bill A02067

Indicators	Impact	Entity Responsible for Measurement
1. Mass of organic waste diverted from landfills (kg)	The more organic waste sep arated at the source for composting, the more efficient the program, resulting in less organic matter in landfills.	All public bodies in the jurisdiction of the bill
2. Reduction in leachate (m3)	Reducing organic waste in landfills lessens landfill burden, decreases the need for new landfills, and lowers leachate production, a soil and groundwater contaminant. This reduction results from improved waste management practices and better landfill lining.[https://apps.ecology.wa.gov/publications/documents/1207072.pdf]	NYS DEC
3. Amount of compost produced (kg)	The amount of compost produced directly indicates program success, showing that organic waste is being effectively processed into beneficial end products like fertilizers.	Composting plant in coordination with NYS DEC
4. Amount of Biogas Production (m3)	Similarly, the biogas production can be easily measured and can directly indicate how effective the bill is.	Anaerobic Digestion plant in coordination with NYS DEC
5. Reduction in Greenhouse Gas Emissions (MTXe) (e is the equivalent of gas and X is the gas, MT being metric tonnes)	The bill aims to reduce greenhouse gas emissions. Measuring this reduction is crucial for assessing its overall success.	US EPA

Limitations in Measuring Success

The methods for measuring the amount of organic waste separatedand the amount of compost and biogas produced, is done through obtaining measurements of waste mass and volume . However, finding the net reduction in leachates and the reduction in greenhouse gas emissions attributed to landfills is a more difficult to measure.

Greenhouse gas emissions through landfills

Landfills are the third-largest methane source in the U.S., with many leaks underestimated by current models. Persistent methane emissions can go undetected for years, therefore advanced technologies such as drones and satellites are crucial for identifying these leaks. Regular monitoring, timely repairs, and improved gas control are other essential factors to be considered to reduce emissions. Studies have found that methane measurement methods in landfills are inadequate, where methane is emitted even in areas and structures of the landfill where gas emissions are not expected.

Reduction in groundwater pollution as a proxy for leachate reduction

Measuring leachate production is a complex and resource-intensive process (52% of the landfills studied had point source emissions, the other 48% had no detectable point sources), so we use reduction in pollution of groundwater as a proxy to measure reduction in leachate by comparing the contaminants of groundwater and landfills.

Case Study - California's Senate Bill SB1383

California's Senate Bill (SB 1383) differs from New York State's Composting Organic Waste at State and Municipal Buildings Bill A02467 in timeline and implementation scale. While California's bill targets all entities, New York's focus solely on municipal and state-owned (public) entities is unique. Table 3 shows the key scientific indicators SB1383 used, compared to the five indicators we propose for the Bill.

Indicators for California's SB1383	Proposed Indicators for New York's State Bill A02467
1. Reduction in Organic Waste Landfilled 2. Methane Emission Reductions 3.Increased Organics Recycling and Composting Rates	1. Mass of Organic Waste Diverted from Landfills (kg) 2. Reduction in Leachate (m3) 3. Amount of Compost Produced (kg) 4. Amount of Biogas Production (m3) 5. Reduction in Greenhouse Gas Emissions (MTXe)

Figure 10: Comparison of Key Scientific Indicators

SB1383's implementation demonstrates successes that New York State should emulate, namely its systematic and comprehensive involvement of different sectors in its composting program, and clear, target-based approaches. SB1383 outlines a specific goal to reduce statewide emissions of methane by 40%, hydrofluorocarbon gasses by 40% and anthropogenic black carbon by 50% below 2013 levels by 2030, which reinforces a strong quantitative definition of the success of the program for its agencies and stakeholders.

What New York Should Do Differently

The Bill outlines the objective to mitigate climate change, improve public health outcomes while achieving co-benefits such as the production of compost and biogas. These are where our five proposed indicators differ from those of SB1383. We adapt CalRecycle's approach to measuring organics and composting rates to the mass of organic waste separated at sources for composting for ease of measurement. With regard to greenhouse gas emissions, while more studies are required, there are greenhouse gasses other than methane that should be taken into account to provide a comprehensive picture of the true carbon footprint of organic waste treatment methods.

New York State can enhance its composting program by adopting California's strategies with improvements. Focusing on localized solutions, according to the function of certain types of public building can boost efficiency and compliance. Adaptive and flexible systems with adjustable targets based on feedback can address unforeseen challenges. Utilizing new technologies will improve measurement and data collection of key indicators, such as leachate production and greenhouse gas emissions. Bridging gaps in data collection and processing by overcoming measurement limitations and technological deficiencies is also essential.

By integrating California's proven strategies with localized, flexible approaches and advanced technologies, New York can create a more all-inclusive picture and enhance its waste management initiatives.

Conclusion

In New York State, organic waste from state and municipal facilities contribute significantly to environmental pollution including methane emissions, leachate contamination, and habitat destruction. By creating regulations for the processing, transportation, and segregation of organic waste produced by government agencies, the Bill seeks to address these problems. Rather than addressing more comprehensive issues that contribute to the state's high level of organic waste, for instance, cultural practices leading to wasted food the law focuses exclusively on handling garbage once it is formed and waste produced by government workers and other affiliates engaging in activities in government buildings.

Notwithstanding these drawbacks, the measure is a significant first step in creating circular economy principles and paving the way for future regulations that may be implemented in both public and private sectors. It can provide a basis for the program to be expanded to upstate residential and industrial areas in the future. New York City is already committed to recycling organic residential and commercial waste, and New York State can aim to follow suit.

The project also has the added benefit of potentially generating revenue. The captured methane can be used to produce biogas and generate electricity, generating profits for the public service. New York state and municipal agencies produce 1.69 million tonnes of organic waste, which can generate an estimated $4.225 million annually in revenue based on a wholesale electricity price of $.04 per kWh. Additionally, the slurry from biogas plants can be sold to landscapers and farmers as fertilizers rich in plant macronutrients.

Moreover, we conclude that the main issue that is transversal to all the sections is the existing data gap that needs to be addressed. We consider that the solution to this is increasing funding to interdisciplinary research on the aforementioned environmental impacts. Finally, after an integral analysis of the environmental impacts of the problem and the solutions, we reckon that, with the available data, the “Composting Organic Waste at State and Municipal Buildings in New York Bill” (A02467) is a key addition to the Environmental Conservation Law to tackle waste management in New York State.

* Adapted from New York City's Independent Budget Office’s estimations on revenue from production of biogas from residential waste streams]

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