“Middlesex County Landfill Improvements: Organic Waste Collection and Processing”

By Ethan Sinyavsky

The Undergraduate Research Writing Conference

• 2020 •

Rutgers, The State University of New Jersey

RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY

26 Carriage Place
Edison, NJ 08820

May 6, 2019

Charles Kenny
Chair of Infrastructure Management Committee
Infrastructure Management Office
75 Bayard Street, 2nd Floor
New Brunswick, NJ 08901

Re: Organic Waste Collection and Processing at the Middlesex County Landfill

Dear Mr. Kenny:

I would like to start by thanking you for attending my proposal presentation on April 8th. I am glad to have been able to share my idea for a better waste processing operation with you. Attached is the final proposal; this document explores several alternatives to traditional landfills and the less-than-ideally-efficient landfill-to-gas system that is currently at use at Middlesex County. My proposal is to implement a system of anaerobic digestion that feeds off of organic wastes collected by each municipality, while shrinking the size of the traditional landfill operation by 22% to handle only inorganic wastes.

Some of the merits of an anaerobic digestion system include the fact that the process occurs in closed chambers, which allows all gases and byproducts generated to stay contained, in effect reducing the impact of escaped landfill gases. Additionally, anaerobic digestion more thoroughly processes wet food wastes and cooking oils, something that aerobic composting and direct combustion cannot handle. As a result, the size of the landfill mound will decrease due to more complete digestion of the organics, as well as leading to a higher electricity yield per ton of material. The benefits will be passed onto the residents in surrounding areas, who should see an increase in property values thanks to improved living conditions. Residents further away in the rest of the county may see decreases in taxes, thanks to the extra revenue that is generated from the sales of the electricity and digestate.

Regarding financing the plan, the county should issue a municipal bond that will be paid back with the revenues from the digester over the course of three years. After the bond has been paid off, the county will have a profit of over $10,000,000, which can then be shared with municipalities to motivate them to collect the organics.

I would like to thank you again for your time and consideration of my proposal. Together, we can work to improve the quality of life for thousands of Middlesex County residents while reducing the social costs and impacts of the Middlesex County Landfill.

Sincerely,

Ethan Sinyavsky

Middlesex County Landfill Improvements: Organic Waste Collection and Processing

Submitted by Ethan Sinyavsky
Student, Rutgers Business School

Submitted to Charles Kenny
Chair of Infrastructure Management Committee
Infrastructure Management Office
75 Bayard Street, 2nd Floor
New Brunswick, NJ 08901

May 6, 2019

Prepared for Business Writing for the Professions 303
Professor Alex Saville

Abstract

The Middlesex County Landfill, the largest landfill in the state, does not currently process the organic waste that constitutes 22% of the waste stream. 35,000 residents in the surrounding area have a problem with the landfill gases that occur as a result of organic waste decomposing in the landfill, as well as with decreased property values that come as a consequence. The entire county also faces the problem of wasted materials, as new inputs have to be used to create necessities, such as electricity, that could otherwise be generated from the food waste. After exploring several alternative options, this proposal seeks to install and operate an anaerobic digester system that generates electricity and digestate from organic materials used as inputs. The county will operate the system and share profits with municipalities to motivate them to collect the organics from households and businesses. The aim is to reduce the social costs of the landfill, as measured by surveys distributed to households after the program begins operating.

Table of Contents

Table of Figures

Executive Summary

The Middlesex County Landfill, located in East Brunswick, New Jersey, is the largest landfill in the state. By accepting 500,000 tons of waste per year from 25 towns in Middlesex County, the landfill handles about 830,000 people's waste disposal needs. However, a major concern with the landfill is that 110,000 tons of the waste disposed, or 22%, is organic food waste, which presents the county with several problems and degrades residents' quality of life.

The first problem, environmental effects from the landfill operation, affects two different populations from Middlesex County in two different ways. The first subset of the problem, the environmental impact of landfill gases, affects 35,000 people in the area surrounding the landfill, up to a radius of 2 miles. People complain that the substances in the landfill gases burn their noses and throats, and that the smell also prevents them from sleeping at night. Additionally, the entire county suffers from the second subset of the environmental problem, which is the impact of wasted materials. Because food waste can be processed in different ways to form useful products, such as fertilizers and electricity, it is a waste for all residents in the county to dispose of their food waste without additional processing to realize these benefits. Consequently, all residents in the county end up paying higher taxes to finance an inefficient process; they also end up paying for new products to be produced from new materials, which contributes to additional pollution and depletion of natural resources.

The second problem is a decrease in the property values surrounding the landfill. As a result of the current landfill operations, especially the odor and unsightliness of the mound, property values in the immediate area decrease by 12.9%, or by a gradient of 5.9% per mile away from the landfill. For a home on Marion Street in East Brunswick, which is just 0.5 miles away, this translates into a loss of over $30,000; in the aggregate, all homeowners in the two-mile radius lose over $200,000,000 in equity due to the landfill, not considering any other property value deflators.

Landfills are still used because their operations costs are relatively low compared to other methods. Before a landfill-to-gas system was introduced at Middlesex, operating costs would have been about $4,200,000; the tipping fees would have allowed for a profit of over $32,000,000. Even after a landfill-to-gas system was installed, profits were still over $20,000,000. However, the county does not take into account social costs of over $200,000,000, as well as the impact of wasted materials, and consequently greater expenses for residents. As a result, the county continues operating the landfill in its current state because it is profitable.

It is true that Middlesex County currently operates a landfill-to-gas system. A landfill to gas system captures the methane and other gases from the landfill mound and turns them into electricity by burning the methane. Although this process does reduce the quantity of odors released, it does not help reduce the size of the landfill mound, as organic wastes break down slowly and inefficiently in the pile. Consequently, it is not possible to generate as much electricity from methane as from other methods, leading to residents paying for a system that is not handling their waste, and also leading to higher social costs of CO_2 from burning for a lower payoff to residents (in the form of reduced taxes from extra electricity generation and sales).

Another method that could be used to handle food waste is direct combustion. Here, the waste is burned and used to generate electricity by way of the heat and steam. Bottom ash that results from

materials not burning completely can also be sold for road paving purposes. However, this process also produces CO_2, and does not handle wet food wastes as efficiently as other methods, resulting again in excessive CO_2 pollution relative to the benefits to residents, and undigested materials that would have to be landfilled. Bottom ash is also not a profitable source of income.

Aerobic composting was also considered as a method. In this method, the waste breaks down under open piles, in effect yielding a nutrient-rich fertilizer that could be sold. However, like direct combustion, the process does not handle wet food waste as efficiently, in effect causing the process to not completely digest the waste. This results in a lower payoff for the operations costs, as well as a lower payoff for the social cost of CO_2 that is produced. Because there will be leftover materials, the landfill pile is not likely to shrink.

Finally, anaerobic digestion was considered to process the organic wastes. This process happens in closed chambers by way of bacteria that digest the food waste and turn it into methane and digestate, which can be used for electricity production and as a fertilizer, respectively. The benefit of this process is that all organic waste is contained to inside the chambers, preventing odors from escaping and ensuring that the maximum amount of methane is captured. Also, the process digests wet food wastes and cooking oils more thoroughly, allowing for a higher yield of electricity and digestate per ton of waste, which offsets the CO_2 social costs of burning the methane offsite. As a result of this process, the size of the landfill pile should decease, and the amount of landfill gas escaping into the area should also decrease. Consequently, property values should rise as a result of improved expectations of conditions around the landfill.

In order to implement the plan, the county will need to vote on issuing a municipal bond to finance the project. The anaerobic digester will then be constructed next to the existing landfill site and will be ready to accept waste. In cooperation with municipalities, who will be responsible for collecting the organic waste separately, bins (paid for by the county) will be placed by the municipalities at households and businesses and collect their organic waste using an additional seven truckloads per week, on average.

The operating costs for the program will be $8,800,000 for the first three years; this number includes the yearly payments for the construction costs. After year three, the costs will drop to $3,960,000; given the revenues from the sales of electricity and digestate, the county will have a profit of $10,901,000, which allows the county to give each town $436,040 per year as compensation for their pickup efforts.

Over time, to see that the program is working, residents will be surveyed regarding how they feel about landfill characteristics such as odor and attractiveness; if these values increase, property values and quality of life are likely to increase, leading to the success of the program of an anaerobic digester at Middlesex County.

Introduction

The Middlesex County Landfill, located in East Brunswick, New Jersey, is the largest landfill in the state. The landfill has an area of 233 acres (NJDEP) and accepts 500,000 tons of solid waste per year from 25 towns, with food waste making up 110,000 tons, or 22% of the total waste stream (U.S. EPA). The continued operation of the landfill with such a high content of organic material yields two distinct problems, each affecting a certain portion of the 830,000 residents in Middlesex County (U.S. Census Bureau).

Population

The continued operation of the landfill yields two problems, or social costs, each affecting a certain segment of the Middlesex County population. Table 1 shows the problems and affected populations:

Table 1: Problems and Affected Populations

Problem	**Area Impacted**	**Number of People Impacted**
1. **Environmental impact** of operating a landfill: a. Landfill gases b. Physical waste	a. Gases: Portions of Sayreville, East Brunswick, and South River that are within 2 miles of the landfill b. Waste: Entire County	a. Gases: About About 35,000 (datausa.io) b. Waste: About 830,000 (U.S. Census Bureau)
2. **Economic losses** due to landfill proximity to homes and subsequent fall in property values	Portions of Sayreville, East Brunswick, and South River that are within 2 miles of the landfill	About 35,000 (datausa.io)

The table above lists the problems and affected populations. The environmental problems are immediately clear and cause residents of the affected areas to speak out. In fact, as reported in a local newspaper, one resident resorted to sleeping with a "surgical style filter over [her] mouth and nose" (Loyer). Several complaints of a "rotten egg smell" also consistently come from residents close to the landfill (Middlesex County Utility Authority). The economic losses from reduced property values require specific background knowledge and are therefore not well-known to the public; in other words, newspaper articles regarding the landfill emphasize the unpleasant odor without going deeper into the economic impacts.

Environmental Impact of Landfill Gases and General Landfill Operations

One of the effects of operating a landfill is the odor that is generated by decomposing trash. Landfills bury waste under a growing mound, causing it to decompose and produce landfill gas (LFG), consisting of about 50% methane and 50% carbon dioxide (U.S. EPA 29); the trace amounts of hydrogen sulfide and ammonia in LFG are responsible for unpleasant odors (New York

State Department of Health); these gases occur during anaerobic digestion that happens deep inside landfill piles (U.S. EPA). The smell generated from gases directly impacts residents living near the landfill, with most complaints originating from residents on Marion Street in East Brunswick, whose neighborhood is only 0.5 miles from the landfill (Middlesex County Utility Authority). The health impacts on these residents include "coughing, irritation of the eyes, nose, and throat, headache, nausea, and breathing difficulties" (New York State Department of Health) caused by hydrogen sulfide. There is even the potentially deadly loss of oxygen if carbon dioxide and methane enter homes (New York State Department of Health). The landfill is within a 0.5 to 2-mile radius of major towns, including Sayreville, South River, and East Brunswick. If residents can detect a smell from their homes, there is potential for health impacts on them as well.

Environmental Impact of Wasted Materials

The sustained operation of the landfill is also a waste of usable materials that would otherwise be reused or recycled. First, 22% of the waste stored in a typical American landfill is biodegradable (European Commission) food waste (U.S. EPA); this is the ` component of landfills, despite the existence of alternatives such as composting. Given that Middlesex accepts 500,000 tons of waste per year (Middlesex County Utility Authority), this translates into about 110,000 tons of food waste accepted per year. Storing food scraps in a landfill is a waste because organic material has potential to be reused for electricity generation and can also be used to produce digestate[1] if anaerobic digestion is used. Generating these byproducts is more productive than storing the waste because of the potential for additional revenue if the county sells them (Hochman et. al). Additionally, glass, metals, and plastic also end up in landfills, despite the availability of recycling programs. In fact, one of the smallest components of landfills was true inorganic waste that could otherwise not be recycled (U.S. EPA); as a result, the entire county suffers from the depletion of natural resources from manufacturing brand new materials instead of using recycled materials.

Economic Impact of Lower Property Values

Not only are there environmental effects, but there are also less obvious economic effects due to a potential loss in property values in surrounding homes. The main causes of decreases in property values include "increased traffic, noise, unpleasant [odors], and aesthetic degradation" (Lim & Missios). Although no data exists for Middlesex County in particular, a study conducted by Ready on a large landfill—similar in size to the Middlesex County landfill—asserts that property values around a large landfill were depressed by 12.9% right next to the landfill, with the impact decreasing by a gradient of 5.9% per mile away (Ready). The table below shows the estimated losses in property values in Middlesex County based on the study, with significant towns and neighborhoods highlighted.

[1] Digestate is a byproduct of anaerobic digestion that can be sold as a fertilizer (Hochman et. al).

Table 2: Impact of Landfill on Middlesex County Property Values, based on Ready's study in Pennsylvania

Middlesex County Area Affected	**Distance from landfill**	**Mean Home Price in Area**	**Percentage Loss**	**Dollar Value Loss**	**Net Home Value**
East Brunswick: Marion Street Neighborhood	0.5 miles	$321,433 (Zillow)	9.95%	$31,983	$289,450
Edges of South River and Sayreville; East Brunswick just east of Rt. 18	1 mile	$321,433 (Zillow)	5.9%	$18,965	$302,468
Centers of South River and Sayreville; East Brunswick just north of Tices Lane (Google)	2 miles	$321,433 (Zillow)	1.1%	$3,536	$317,987
Total loss in equity for 11,667 households (Middlesex County), given a mean dollar value loss of $18,161					**$211,884,387**

As shown by the table, the farther the home is from the landfill, the smaller the impact on the property values. Homes very close to the landfill in the Marion Street neighborhood, which is also a common origin for odor complaints (Middlesex County Utility Authority), are most seriously affected, with property values dropping by 9.95%. The edges of South River, Sayreville, and East Brunswick homes just east of Rt. 18 see values dropping by 5.9%, a reduced but still serious impact. Finally, at 2 miles away, the centers of South River, Sayreville, and homes in East Brunswick just north of Tices Lane see a 1.1% drop in property values. As a result, on average, homeowners within the entire two-mile circle lose $18,161 per home, which translates into a loss of $211,888,276 in equity when multiplied by the approximate number of households in the area. If homeowners decide to sell in the future, they will be worse off than if they had owned a home in another location, as their home values are depressed automatically by the landfill, not considering any other home devaluators.

Literature Review

Why Landfills Are Still Used

Despite the fact that there are costs to society, as shown by the effects of landfill gases, physical waste, and economic losses on both property values and lost digestate sales, waste disposal facilities still opt for landfills because they are relatively inexpensive to operate after initial construction costs have been covered (U.S. EPA 2-18). A new landfill, with safety technologies such as landfill covers (Middlesex County Utility Authority), landfill gas collection systems (U.S. EPA 2-15), and bottom liners (Taylor), costs about $555,000 per acre to construct, with 37% of the costs coming from excavation on average (U.S. EPA). Additionally, buildings and structures are needed, totalling $1,467,500 on average (U.S. EPA). To put this into perspective, building a 233-acre landfill similar to Middlesex would cost $130,782,500 today. However, once construction costs are completed, the recurring costs total about $4,200,000 per year, with "[o]perations [...] [,] [l]eachate collection and treatment [...][,] [e]nvironmental sampling and monitoring [...] [,] [and] [e]ngineering services" (U.S. EPA) as components. Admittedly, the county operates a landfill-to-gas system, which adds $12,000,000 to operating costs per year (Hochman et. al), but the county still manages to make a profit of $20,425,000. The county generates this revenue by charging a $73.25 tipping fee per ton (Middlesex County Utility Authority). From these calculations, especially because the county does not pay the social cost of lost property values of $211,888,276, it is an attractive option for the county.

Why Not Increase Tipping Fees?

Another possible argument is attempting to increase tipping fees in order to discourage waste contractors, and ultimately communities from disposing of too much waste, including food waste, because of the increased costs of disposal. However, raising tipping fees would be ineffective against curbing excessive waste generation because landfill contractors have the option of going to a private landfill. Private landfills are designed to achieve scale effects (U.S. EPA 2-12) by attracting a larger volume of waste disposal. Strategies to do this include setting tipping fees lower and collecting waste that is delivered from a "large geographic area" (U.S. EPA 2-12), including by train or truck. Although New Jersey has only two small (NJDEP) private landfills (NJDEP), this does not prevent contractors in the area from disposing of waste out-of-state; neighboring New York City, for example, sends all of its waste out of state to large landfills, sometimes going as far as 600 miles away (Galka), as the last landfill in New York City closed in 2001 (Jacobs).

Landfill-to-Gas

One of the supplements to traditional landfill operations is a landfill-to-gas system, which collects the methane gas to generate electricity (Hochman et. al). This system is already in use at Middlesex County (Middlesex County Utility Authority) and involves a system of pipes that are drilled into the landfill pile, harnessing the gas that is generated as a result of the oxygen-free environment of the depths of the landfill (U.S. EPA). This system helps mitigate the release of methane, a greenhouse gas (U.S. EPA) into the atmosphere, with a capital cost of $24.36/ton and an operations cost of $20/ ton on average (Hochman et. al), which is quite affordable relative to other systems, such as direct combustion, aerobic composting, and anaerobic digestion. However, this method does require space to operate; to generate more gas, more landfill content, and therefore area is needed (Hochman et. al), which does not align with the goal of reducing the size of the landfill

mound. This method is also a waste of materials, as the organic materials do not decompose as efficiently in a landfill pile as they do in other systems (Capital Regional District), leading to lower payoffs for the same social costs of continuing to operate the landfill.

Direct Combustion

One of the simplest methods of processing organic food waste, and thereby reducing a landfill's size is by burning it. The process, in summary, involves combustion of waste at a temperature of 850 ℃ (1562 °F), and produces "carbon dioxide, vapor, and non-combustible incinerator bottom ash" (Hochman et. al). The carbon dioxide cannot be used, as it is a byproduct of combustion (U.S. EPA), and has to be discarded into the atmosphere. Therefore, using direct combustion implies an increased amount of carbon dioxide, a greenhouse gas, released into the atmosphere (U.S. EPA). The vapor, or steam, can be used for electricity production by driving turbines, which is a new potential revenue source for a landfill. Finally, the bottom ash, which is any organic material that cannot be combusted further (Hochman et. al), can be sold for use in asphalt at approximately $3 per ton (Hochman et. al). Regarding operations costs, direct combustion costs approximately $80-$120 per ton to operate (Hochman et. al); for 110,000 tons of food waste yearly, this translates into an average of $11,000,000 per year; capital costs to build the equipment are about $50 per ton, or $5,500,000 for the amount of food waste generated at Middlesex. Despite the potential for revenues from electricity generation, the efficiency of the process is only maximized when the inputs are dried; because food waste is about 75% moisture, it takes additional energy in the form of fossil fuels to dry them (Hochman et. al), further contributing to the operations costs and social costs in the form of additional CO_2 production. As a result, direct combustion is not viable for Middlesex because it does not help reduce the social costs of environmental pollution from CO_2, and economic effects, as higher taxes to finance increased operations costs will be passed onto homeowners, in effect lowering their net home value.

Aerobic Composting

Another alternative to landfilling organic food waste is aerobic composting, where food waste breaks down with the help of oxygen, either under open piles, or in closed systems, which range from small bins to large metal containers, tunnels, or drums (Baltrėnaitė and Baltrėnas 268). The process produces carbon dioxide, water, heat, and compost material (Hochman et. al); it is not possible to reuse or sell the CO_2 or water produced, but it is possible to use the heat generated to heat water and homes (Hochman et. al). It is also possible to sell the nutrient-rich compost material for $80/ton in New Jersey (Hochman et. al), allowing for a significant revenue source. Initial startup costs are low compared to other methods, at $13.60/ ton, and operating costs are also low, at $30-$60/ ton (Hochman et. al). Therefore, a facility that processes 110,000 tons of food waste would cost about $6,446,000 from construction through the end of the first year. Although a well-maintained compost pile does not smell (Cornell), and also does not produce methane, both of which could help improve surrounding property values, a drawback to using composting is that there is carbon dioxide produced. Because food-based inputs have a high moisture content and also have cooking oils, the efficiency of the composting process is also reduced (Hochman et. al). As a result, less sellable compost material is produced for the same carbon dioxide social cost to society, especially when more efficient methods are available.

Anaerobic Digestion

Anaerobic digestion is a process that involves breaking down food wastes by way of methanogens, which are bacteria that convert carbon dioxide into methane (Google) "in the absence of oxygen" (Hochman et. al). In comparison to other organic waste processing methods, anaerobic digestion has several merits. First, because the process takes place in closed chambers (Baltrėnaitė and Baltrėnas 88), there is no leakage of methane into the atmosphere, and 25% to 67% less CO_2 emitted from the process than aerobic composting (Hochman et. al), resulting in reduced greenhouse gas emissions. Additionally, any odors caused by anaerobic conditions (Cornell) will be contained to the chambers, thereby preventing odors from escaping into the surrounding area and bothering residents. As a result, property values in the area may increase. Also, despite the fact that startup and operations costs are higher relative to other methods, at $50/ton and $80/ton on average (Hochman et. al), respectively, there is potential to generate sellable byproducts at a smaller social cost than other methods. As mentioned before, anaerobic digestion produces methane; this methane can be harnessed and burned offsite to generate electricity. In fact, because Middlesex County already has a landfill-to-gas system in place (Middlesex County Utility Authority), the existing pipe system and substation can be reused for methane from the digesters. Also, the process produces digestate, which can be sold for use as a fertilizer. However, the main source of revenue is likely to be electricity sales, as the fertilizer produced is not as nutrient-rich as the compost produced during aerobic composting (Hochman et. al). Just as is true when burning any material, burning the methane offsite for electricity purposes produces CO_2 (Ophardt); however, the social costs are worth the payoff in this scenario, as the moist food materials and cooking oils used as inputs are processed better (Hochman et. al), and converted into either methane or digestate, with minimal additional byproducts that would have to be landfilled, as might be the case with aerobic composting, where moist food wastes and cooking oils are not broken down completely. Consequently, this method reduces the size of the landfill mound more effectively, and also allows more electricity to be generated per ton of CO_2 emitted, as opposed to other methods.

Model of Success: LIPOR Aerobic Composting Project in Portugal

A successful program of organic materials collection and large-scale composting was implemented in northwest Portugal in 2000. The project deployment area was very similar to Middlesex County in terms of population and area, covering 1,000,000 people and about 240 square miles, respectively (European Commission). By comparison, Middlesex County has a population of about 830,000 (U.S. Census Bureau), and an area of about 309 square miles (U.S. Census Bureau). The goal of the project was to "encourage waste separation [...] [and] [divert] waste from the traditional landfill disposal route" (European Commission). The organizers accomplished this separation through the use of dedicated bins for biodegradable material, which were placed at homes and businesses throughout the area. Dedicated trucks came by three times a week to collect the waste and delivered it to a facility for composting. Later on, the compost was sold for a price of 25 Euros/ton, or $40/ton in 2019 dollars. What is particularly notable is that the project area had a participation rate of 90%, as compared to an overall 5% participation rate in Portugal (European Commission) (the rest of Portugal could be considered the control group because no composting programs existed there). Although the project used aerobic composting instead of anaerobic digestion (European Commission), the latter of which would likely be more productive for Middlesex County because of the lower social cost in terms of CO_2 production and more complete

digestion of biodegradable material (less wasted materials), the project serves as a good example of how residents are willing to sort compostable materials if they are provided the opportunity to do so (at no cost to them), in effect completing the first necessary step to reducing odors at the landfill, as the odors are caused by the presence of the biodegradable materials in the landfill.

Ensuring that Property Values Will Increase

As mentioned in the introduction, the project aims to improve surrounding property values. Based on a study of homeowners near a landfill in Cleveland, Ohio, the most common complaints from residents living near a landfill are odors, with 25.7% of residents indicating that odors are a major problem, and unattractiveness, with 22.5% of residents indicating that unattractiveness is a problem (Reichert et. al). Based on these issues, which would also disturb future homeowners should they purchase a home near the landfill, a project that uses anaerobic digestion would eliminate the two most common complaints, in effect increasing property values because of improved future expectations of quality of life (Nelson); the odors would be eliminated through treatment of the gases, and the height of the 200-foot landfill pile (Kratovil) would be reduced by 22% to approximately 156 feet, making the landfill appear more compact. Quantitative evidence is limited, but one study of property values after a landfill closed suggested an increase of 10.8% (Kinnaman) in surrounding property values, although the results were inconclusive. Nonetheless, because housing prices are based on consumer sentiment (Fannie Mae), price improvements are likely because the common complaints are addressed, thereby making homes more attractive than they were previously.

Obtaining Funding Through a Municipal Bond Issue

Several options were explored to help fund this project. First, an EPA grant that was related to environmental engineering was explored. The grant was to be awarded to proposals that helped "prevent or minimize solid, liquid, and gaseous discharges of pollution to soil, water, and air" (National Science Foundation); however, the grant was only available for research purposes, with a maximum award amount of $140,000 (National Science Foundation), making it unsuitable for funding a project of this scope. A Bloomberg Philanthropies "Smart Cities Challenge" Grant was also considered, as the project aligned with Bloomberg's mission of reducing long-term impacts to the environment and improving quality of life (Bloomberg Philanthropies). However, the concern with this grant was that the award amount is approximately $2 million (Bloomberg Philanthropies), which is not enough to cover the startup costs of this project. Therefore, the project has to be financed by a municipal bond issue, which would help cover the initial operations and startup costs. Municipal bonds in particular are used for infrastructure projects, such as roads and schools (investor.gov); landfills also fit into this category. In fact, Middlesex County has previously issued bonds in the tens of millions of dollars for projects such as open space preservation, golf courses, and capital equipment (Middlesex County). In general, a municipal bond is issued by hiring a financing team after the plans for the project have been finalized; creating a financing plan; marketing the bond offer to investors; pricing the bond; and closing the transaction (MSRB Education Center). The bonds can either be repaid either by collecting taxes, or by revenues from the project operations (investor.gov). In the case of landfill improvements at Middlesex through the addition of an anaerobic digester, the revenues will be sufficient to cover the costs, as will be explored in the costs and revenues section.

Plan of Action

In order to reduce the amount of biodegradable materials (especially food waste) being landfilled at Middlesex, a program that collects food waste separately from homes and businesses, delivers them to the landfill site, and processes them by way of anaerobic digestion should be implemented. Any other inorganic materials will still be collected and processed the traditional way and landfilled; however, as a result of the collection of 110,00 tons of food waste, the original landfill mound will shrink by 22% to a volume of 390,000 tons. As a result of the program, Middlesex County residents will benefit from less waste of materials, fewer landfill gases and contaminants being released into the air, and consequently higher property values in the vicinity of the landfill. The anaerobic digester, thanks to the byproducts of electricity and digestate, will be able to pay for itself, as detailed in the Costs and Revenues section. Table 3 outlines the necessary steps that the county should take to install an anaerobic digestion system:

Table 3: Plan of Action

Step	**Explanation**
1. Finalize the details of the plan and vote on the bond issue	The Board of Chosen Freeholders, especially Charles Kenny and the infrastructure management committee, considers the proposal and votes on a municipal bond issue. A financing team (MSRB Education Center), hired by the county, helps close the transaction.
2. Notify municipalities of the creation of the plan and requesting their cooperation	Because municipalities handle recycling collection in Middlesex County (Middlesex County), the municipalities will also be responsible for pickup of organics materials and have will have a share of the revenues from the sales of electricity and digestate to help cover their costs. As a result, it is important to notify each of the 25 towns and send a detailed copy of the plan to each one's Public Works Department. Without the help of the municipalities, there will be no organics collection, and consequently no inputs for the anaerobic digester.
3. Advertise the creation of an anaerobic digestion/food waste processing facility to residents	The County sends text messages, emails, and newsletters to residents in the area to inform them of the new facility. This helps generate awareness and prepare residents for the start of the program.
4. Construct the anaerobic digester on the existing landfill site and integrating the digester with the existing methane collection system	Two anaerobic digesters, each with an 80,000-ton capacity (City of Perris), together capable of processing 160,000 tons of food waste per year, are installed. The anaerobic bacteria will take time to cultivate (Spuhler). The digester is also linked to the existing landfill-to-gas system, which runs to an electricity generation station in Sayreville (Middlesex County Utility Authority).

5. Distribute special brown organic materials collection bins to households and businesses, along with instructions	Each household and business in Middlesex County receives a wheeled brown recycling bin (Home Depot) (or several, depending on the size of the business), along with an instruction brochure, similar what is used in New York City (DSNY), that details which materials are acceptable to put into the organics bin. The municipalities will pick up the bins from the waste processing facility site and distribute them to residents. The county covers the cost of the bins.
6. Begin collection of organic waste materials from households by municipalities	Given that each of the 25 municipalities produces about 84 tons of food waste per week, and one truck can hold about 13 tons of waste (S.C. Department of Health), each municipality will need to have seven (7) additional truckloads per week, or one truckload (1) per day, to handle the additional organic waste. The waste will be delivered to the waste processing facility in East Brunswick for processing.
7. Load organic wastes into anaerobic digesters and generate revenues from electricity sales and digestate production	As the organic waste breaks down, it will generate methane gas that can be used for electricity production. This methane will be contained, along with any other gases, to the closed chambers. Digestate will also be produced. As a result, the county will be able to recover the costs of building and operating the plant over time, as well as being able to share revenues with municipalities to motivate them to continue pickups.
8. Benefit from reduced odors, waste, and increased property values	In the long term, thanks to the closed nature of the anaerobic system, residents in the surrounding areas should see a decrease in odors, and consequently an increase in surrounding property values. The entire county will also benefit from reduced taxes, as the organic material that was formerly wasted by being landfilled is now being used to generate revenues for all municipalities.

Budget

Costs

Although initial costs and operations costs of an anaerobic digester are higher than other methods, as seen in the Literature Review, there are significant benefits in terms of reduced social costs, as well as the ability of the digester and collection system to pay itself off, that make the costs worthwhile. The following tables explore both construction and operations costs of an anaerobic digester system at Middlesex County. These costs do not include the existing landfill operations.

Table 4: Breakdown of construction costs of an anaerobic digester system, based on a total construction cost of $50/ ton (Hochman et. al), or $13,800,000 total for the Middlesex system

Element (Moser et. al)	**Dollar Amount**
Lift station/mix tank	$165,000
Engineering	$550,000
Digester	$2,750,000
Miscellaneous	$165,000
Gas/hot water piping	$110,000
Gas pump, meter	$165,000
Used engine-generators	$1,100,000
Electrical	$275,000
Engine-generator building	$110,000
Startup	$110,000
Organics collection bins	$8,300,000 (Home Depot)
	Total: $13,800,000

Regarding the construction (or capital) costs, the largest element is the cost of the bins, which need to be purchased and distributed by municipalities. The next largest component is the digester, which is the heart of the anaerobic digestion process. Finally, the third largest element is the engine-generator, which will generate electricity by using the methane as a fuel. The rest of the costs involve engineering, piping, pumps, and other work that is necessary to operate an anaerobic digester.

Table 5: Estimated operations costs for Year 1 through 3 of an anaerobic digester system, including construction costs, assuming about 100,000 tons of waste collected per year

Element (Whyte and Perry)	**Percent of Total Cost**	**Dollar Amount**
Construction/capital (will not be included after year three based on revenue streams)	55% (Whyte and Perry); Hochman et. al estimates this percentage to be 62%	$4,840,000 (based on Whyte and Perry)

Plant Operations & Maint. (incl. labor)	15%	$1,320,000
Residue Disposal	17%	$1,496,000
Aerobic Curing	15%	$1,320,000
Year 1 through 3 Total: $8,800,000; after year 3 = $3,960,000		

The majority of operating costs come from the cost of repaying the construction costs back to the creditors, which is typically done in the amount listed above per year. The rest of the costs are associated with standard plant operations, including labor, maintenance of machinery and disposal of residues that cannot be otherwise processed. Aerobic curing is the process that the digestate has to go through before it can be sold as a fertilizer (Whyte and Perry); in order to make revenues from digestate sales, this process is necessary. Additionally, operating costs of the electricity generation system are assumed to be covered by the landfill's tipping fees, as is currently the case, as the existing landfill-to-gas infrastructure will be used to generate electricity.

Revenues

The anaerobic digester and electricity generation system will be able to pay for itself within three year as a result of the revenues from digestate and electricity sales. The revenues for the system at Middlesex are listed below:

Table 6: Yearly revenue streams for an anaerobic digestion system

Item	**Expected Revenue**
Sales of electricity, assuming a sale price of $0.15 per kwh (U.S. EIA) and 110,000 tons of wet food waste	$8,085,000 (Ontario Government)
Sales of digestate, assuming a 77% input-to-output ratio (City of Perris) and a sale price of $80/ton (Hochman et. al)	$6,776,000
Total yearly revenues: $14,861,000	

Cost and Revenue Analysis

As a result of the revenues generated, the capital costs, which are also factored into the first-year operating costs, will be paid off by the end of the third year the system is in operation. As a result, the county will have $6,061,000 in profits, for the first three years which can be shared with the 25 municipalities to motivate them to continue organics collection. For the first three years, the 25

municipalities will get $242,440 each. After the third year, when capital costs have been paid off and only operating costs remain, the county will have $10,901,000 in profits, which then increases the share paid to each town to $436,040 per year. As a result of the electricity and digestate sales, the towns will be motivated to continue pickups of organics, and the county will be able to cover all costs without necessitating tax increases or tipping fee increases. In fact, because of the extra revenues, which do not necessarily have to be used on waste collection, each municipality can pass on the benefits to residents in the form of lower taxes.

Discussion

Monitoring the Plan's Success

In order to measure the success of the plan, the county should monitor the frequency of odor complaints posted to the Middlesex County Utility Authority website. A reduced frequency of complaints should logically point to the plan's success. In order to ensure that residents feel that their property values are increasing, surveys similar to the one conducted by Reichert should be sent out, preferably online ones for ease of data collection. The surveys will contain questions that ask how significant they feel various factors from the waste processing facility are, including odors, attractiveness, and discounts on taxes. The county should listen to residents' opinions and make appropriate adjustments to the plan, including frequency of collection and hours of facility operation.

Conclusion

Middlesex County currently faces an environmental problem of wasted materials and landfill gases, as well as economic impacts from decreased property values as a result of the landfill's continued operation. The landfill gases impact people in the surrounding area, totaling about 35,000; the entire county of 830,000 suffers from the waste of materials in the form of resource depletion and manufacturing new materials, whose costs are consequently passed onto the residents. By capturing the gases in a more efficient way than a landfill-to-gas system, an anaerobic digester allows more complete digestion of the organic materials in a closed system, leading to fewer released gases and more revenues generated from electricity sales. These benefits are passed onto homeowners in all municipalities, as they can benefit from reduced taxes thanks to profit-sharing by the county. Additionally, as a result of more optimistic price expectations of homes by the landfill because of a reduced landfill mound size and reduced odors, the effects of a landfill on surrounding property values will be undone. By implementing an anaerobic digestion system, all residents in the county can benefit from increased quality of life and enjoy a smaller environmental impact from a more efficient and profitable organic waste disposal system.

Works Cited

Baltrėnas, Pranas, and Edita Baltrėnaitė. Small Bioreactors for Management of Biodegradable Waste. Springer, Cham, Switzerland, 2018, doi:10.1007/978-3-319-78211-9.

Bloomberg Philanthropies. "Environment | Bloomberg Philanthropies.", 2019, https://www.bloomberg.org/program/environment/#intro.

Capital Regional District. WHAT HAPPENS IN A LANDFILL?.

City of Perris, and CR&R. The Largest Anaerobic Digester in the United States Sets the Green Pace in Perris, California. , 2017.

Cornell University. "Agricultural Composting: A Feasibility Study for New York Farms.", 1993, http://compost.css.cornell.edu/feas.study.html.

Cornell University. "Odor Management.", 1996, http://compost.css.cornell.edu/odors/odor.html.

DSNY. "Organics Curbside Collection.", 2018, https://materials.bwprronline.org/system/tdf/org-coll-brochure-2018-ocb-en-18.pdf.

European Commission. "Biodegradable Waste.", 2016, http://ec.europa.eu/environment/waste/compost/index.htm.

European Commission. Success Stories on Composting and Separate Collection. Office for Official Publications of the European Communities, Luxembourg, 2000.

Fannie Mae. "Housing Sentiment Surges just in Time for Spring Homebuying Season.", March, 2019.

Galka, Max. "What does New York do with all its Trash? One City's Waste – in Numbers.", 27 October, 2016, https://www.theguardian.com/cities/2016/oct/27/new-york-rubbish-all-that-trash-city-waste-in-numbers.

Google. "Define Methanogen - Google Search.", 2019, https://www.google.com/search?q=define+methanogen&oq=define+methanogen&aqs=chrome..69i57j0l5.2839j1j7&sourceid=chrome&ie=UTF-8.

Google Maps. Middlesex County Utility.

Hensher, David A., and Kenneth J. Button. Handbook of Transport and the Environment. Emerald Group Publishing, 2003.

Hochman, Gal, et al. "Cost of Organic Waste Technologies: A Case Study for New Jersey." AIMS Energy, vol. 3, no. 3, 2015, pp. 450-462, doi:10.3934/energy.2015.3.450.

Home Depot. "Organic Wheeled Brown Indoor/Outdoor Recycling Bin.", 2019, https://www.homedepot.com/p/Orbis-Organic-Wheeled-Brown-Indoor-Outdoor-Recycling-Bin-NPL280A/304473558.

Investor.gov. "Municipal Bonds.", https://www.investor.gov/introduction-investing/basics/investment-products/municipal-bonds.

Jacobs, Karrie. "How the World's Largest Landfill Became New York's Biggest New Park.", 13 September 2016, https://ny.curbed.com/2016/9/13/12891320/freshkills-park-nyc-staten-island-engineering-design.

Kinnaman, John. "Landfill Closure and Housing Values." Contemporary Economic Policy, 2009, pp. 380-389, https://digitalcommons.bucknell.edu/cgi/viewcontent.cgi?article=1708&context=fac_journ.

Kratovil, Charlie. "As County Piles Garbage Higher, More Residents Say Middlesex Stinks.", January 19, 2019, https://newbrunswicktoday.com/article/county-piles-garbage-higher-more-residents-say-middlesex-stinks.

Lim, Jong S., and Paul Missios. "Does Size really Matter? Landfill Scale Impacts on Property Values.", 2007, https://www.tandfonline.com/doi/pdf/10.1080/13504850600592531?needAccess=true.

Loyer, Susan. "Joseph Cryan: Rotten Egg Odor at Edgeboro Road Landfill is Byproduct of Emissions from Trash." My Central Jersey, January 17, 2019, https://www.mycentraljersey.com/story/news/local/middlesex-county/2019/01/17/rotten-egg-odor-middlesex-county-landfill-byproduct-emissions-trash/2601553002/.

Loyer, Susan. "Middlesex County Landfill Odor to be Addressed at East Brunswick Meeting.", January 19, 2019, https://www.mycentraljersey.com/story/news/local/middlesex-county/2019/01/10/middlesex-county-landfill-odor-addressed-east-brunswick-meeting/2516042002/.

Middlesex County Utilities Authority. "About the Division.", 2018, http://www.mcua.com/solid-waste-division/.

Middlesex County Utilities Authority. "Odor Reports.", 2019, http://www.mcua.com/odor-reports/.

Middlesex County. "Freeholder Charles Kenny.", 2014, http://www.middlesexcountynj.gov/Government/ElectedOfficials/Pages/Freeholder-Kenny.aspx.

Middlesex County. "Middlesex County's Recycling and Solid Waste Guide.", March 2014, http://sj-site-persistent-prod.s3.amazonaws.com/fileadmin/cicbase/documents/2014/9/2/14096229890465.pdf.

Middlesex County. Middlesex County, New Jersey County-Guaranteed Bonds Issued by Mcia., 2013.

Middlesex County. "Statistics and Demographics.", 2015, http://www.middlesexcountynj.gov/about/statisticsdemographics/Pages/default.aspx.

Moser, Mark, et al. Benefits, Costs and Operating Experience at Seven New Agricultural Anaerobic Digesters., 1998.

MSRB Education Center. "The Underwriting Process.", https://www.msrb.org/EducationCenter/Municipal-Market/Lifecycle/Primary/Underwriting-Process.aspx.

National Science Foundation. "Environmental Engineering.", August 16, 2018, https://nsf.gov/funding/pgm_summ.jsp?pims_id=505551.

Nelson, Arthur C., John Genereux, and Michelle Genereux. "Price Effects of Landfills on House Values." Land Economics, no. Vol. 68, No. 4, 1992, pp. 359-365.

New York State Department of Health. "Important Things to Know about Landfill Gas ", August, 2012, https://www.health.ny.gov/environmental/outdoors/air/landfill_gas.htm.

NJDEP. "Njdep Approved Operating Private Sanitary Landfills.", June 13, 2018, https://www.nj.gov/dep/dshw/lrm/aopsl.htm.

NJDEP. New Jersey Landfill List, 2014.

Ontario Government. "Energy Yields from a Farm-Based Anaerobic Digestion System.", 4 January, 2016, http://www.omafra.gov.on.ca/english/engineer/facts/enyields.htm.

Ophardt, Charles. " Combustion of Fossil Fuels.", 2003, http://chemistry.elmhurst.edu/vchembook/511natgascombust.html.

Reichert, Alan K., Michael Small, and Sunil Mohanty. The Impact of Landfills on Residential Property Values. vol. 7, , 1992.

Richard Ready. "Do Landfills always Depress Nearby Property Values? ", 2005, https://aese.psu.edu/nercrd/publications/rdp/rdp27.pdf.

S.C. Department of Health and Environmental Control. "Landfill Gases.", 2018, https://www.dhec.sc.gov/sites/default/files/Library/OR-1197.pdf.

S.C. Department of Health. "How Landfills Work.", 2018, https://scdhec.gov/environment/your-land/landfills-overview/how-landfills-work.

Spuhler, Dorothee. "Anaerobic Digestion (Large-Scale).", 23 November, 2018, https://sswm.info/humanitarian-crises/urban-settings/sanitation/semi-centralised-treatment/anaerobic-digestion-%28large-scale%29.

U.S. Census Bureau. "Quickfacts.", https://www.census.gov/quickfacts/fact/table/atlantacitygeorgia,cincinnaticityohio,stlouiscitymissouri,charlottecitynorthcarolina,middlesexcountynewjersey/PST045218.

U.S. Census Bureau. "QuickFacts Middlesex County, New Jersey.", 2018, https://www.census.gov/quickfacts/middlesexcountynewjersey.

U.S. Energy Information Administration (U.S. EIA). "How Much Electricity does an American Home use?", October 26, 2018, https://www.eia.gov/tools/faqs/faq.php?id=97&t=3.

U.S. Environmental Protection Agency. "Municipal Solid Waste Landfills.", 2014, https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials#NationalPicture.

U.S. EPA. "Basic Information about Landfill Gas.", 9 April, 2019, https://www.epa.gov/lmop/basic-information-about-landfill-gas.

U.S. EPA. "Direct Emissions from Stationary Combustion Sources ", 2016, https://www.epa.gov/sites/production/files/2016-03/documents/stationaryemissions_3_2016.pdf.

U.S. EPA. Municipal Solid Waste Landfills - Economic Impact Analysis for the Proposed New Subpart to the New Source Performance Standards , 2014.

Whyte, Rob, and Guy Perry. "A Rough Guide to Anaerobic Digestion Costs and MSW Diversion." BioCycle, 2001, pp. 30-33, https://search-proquest-com.proxy.libraries.rutgers.edu/docview/236909776?accountid=13626.

Zillow. "Sayreville Home Prices and Values.", 2019, https://www.zillow.com/sayreville-nj/home-values/.