Waste to Energy:

A Feasibility Study of Anaerobic Digestion of Food and Manure Waste in Saratoga Springs, NY

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1. INTRODUCTION

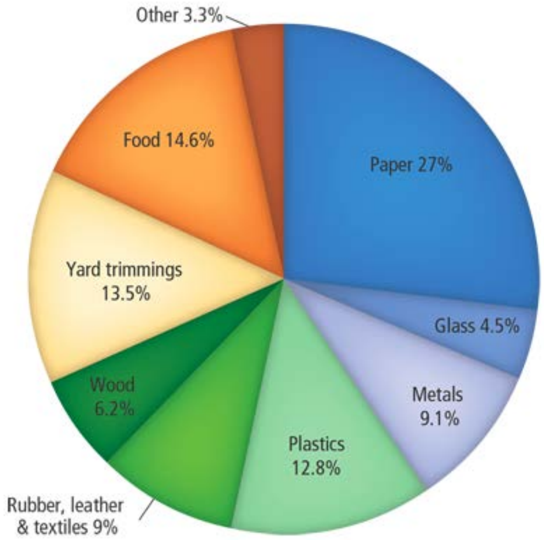
1.1 Food Waste Concerns

1.1.1 Environmental Concerns

The Environmental Protection Agency (EPA) estimates that food waste is the second largest component of municipal solid waste (MSW) going to landfills (See Figure 1). Currently, only 2.5% of organic food wastes are diverted from landfills annually, making landfills the third largest source of methane in the U.S. (USDA, 2014 & Moriarty, 2013). According to the US. EPA, landfills account for about almost 20% of all U.S. methane emissions (Fact Sheet: Landfill Methane, 2013). Methane is a highly potent greenhouse gas (GHG) that largely contributes to climate change and is twenty times more dangerous than carbon dioxide. According to the Intergovernmental Panel on Climate Change, methane is much more effective than carbon dioxide at trapping heat in the atmosphere; it warms the planet by 86 times more than carbon dioxide (Vaidyanathan, 2015). Diverting food waste from landfills through the use of anaerobic digestion will decrease the amount of GHG emissions released from landfills, as well as the amount of liquid sewage and leachate that leaks into the soil surrounding landfills.

On top of the methane emissions from decomposing food wastes, millions of acres of land are being used to grow food which is ultimately uneaten. As a nation, we grow and raise more than 590 billion pounds of food and we waste approximately 160 billion pounds of food each year (Bloom, 2011). We can estimate that each person throws away half a pound of food per day, adding up to an annual total of 197 pounds of food per person thrown away annually (Escobar and Kaslowski, 2015). Food waste uses a massive amount of natural resources; it contributes to useless overconsumption of water, and is responsible for 25% of freshwater usage in the United States (Hall, Guo, Dore and Chow, 2009). Additionally, the transportation of the wasted food accounts for 300 million barrels of oil in the U.S. (Hall, Guo, Dore and Chow, 2009).

Figure 1: Total Municipal Solid Waste Generation (by material), 2013



Source: EPA- Municipal Solid Waste (https://archive.epa.gov/epawaste/nonhaz/municipal/web/html/)

1.1.2 Economic Concerns

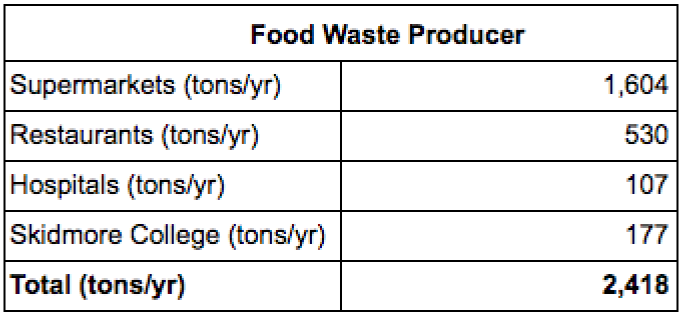
In addition to the environmental pollution associated with food waste, there is an economic impact as well. "Every year, billions of dollars are spent by producers, distributors, retailers, and consumers on food that will simply be sent to landfills" (Alvarez, Chang, Fennel, 2015). Producers waste money on labor, fertilizer, water, gas, land, and utilities when the food they produce is wasted (Alvarez, Chang, Fennel, 2015). Food waste is one of the biggest challenges that we see in the restaurant industry in the United States (Escobar and Kaslowski, 2015). Industries could save money on energy and be more environmentally conscious by diverting their food waste to a community anaerobic digester and using the energy that is generated.

Americans waste close to 25 percent of food that is purchased. It is wasted before being prepared because it spoils and after it preparation as American's tend to over prepare and serve themselves (Reducing Wasted Food From Households). Most of the wasted food ends up in a landfill and releases methane. Wasting food also means wasting resources - growing, packaging, transporting, and refrigerating food uses labor, water, and energy (Reducing Wasted Food From Households). It is important to think about the entire life cycle of food as a product.

1.1.3 Food Waste in Saratoga Springs

Within New York State, Saratoga Springs is 29 square miles and has an estimated residential population of about 27,765 people (U.S. Census Bureau: State and County Quick Facts, 2015). For our study, we analyzed areas of potential food waste in Saratoga Springs. We organized areas of potential food waste into the following categories: supermarkets, restaurants, hospitals and colleges/universities. Our food waste estimates are conservative estimates because we are not taking into account all the potential food waste generators in the area, such as residential food waste. With regards to supermarket food waste, we tried to get a comprehensive picture of all the supermarkets in Saratoga Springs, but due to lack of information we only collected data from the three Price Chopper stores in the area, Hannaford's, Fresh Market, Walmart, Target and the nine Stewart's Shops in the area. With regards to restaurant food waste, Saratoga Springs has approximately 102 restaurants that produce approximately 200 pounds of food waste weekly, leading to about 20,400 pounds of food waste per week, or 530 tons per year (Cooper, 2007 & Escobar and Kaslowski, 2015). The one hospital we considered for the study is the Saratoga Hospital, which we concluded produces approximately 107 tons of food waste per year. The one college we considered for the study is Skidmore College, which we concluded produces around 177 tons of food waste per year. Overall we concluded our conservative total food waste estimate from these sources is approximately 2,418 tons per year of food waste (See Table 1).

Table 1: Area Food Waste Estimates



Food Waste Producer	
Supermarkets (tons/yr)	1,604
Restaurants (tons/yr)	530
Hospitals (tons/yr)	107
Skidmore College (tons/yr)	177
Total (tons/yr)	**2,418**

1.2 Manure Waste Concerns

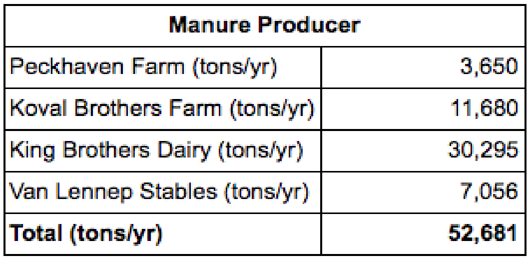
Agriculture is a major contributor to climate change. Along with fertilizer and pesticide run-off which pose separate environmental threats, farms produce large quantities of manure which poses an even greater environmental threat, in the form of methane emissions. It is expected that animal production activities in developed countries is going to intensify, which will lead to higher manure surplus, and therefore higher methane emissions if the manure is not properly disposes of (Holm-Nielsen, Seadi, Oleskowicz, 2009). The largest methane source emitter in the world is from livestock and manure emissions combined (Environmental Impact of Animal Production). The animal production sector is responsible for 18% GHG emissions (Holm-Nielsen, Seadi, Oleskowicz, 2009). Unmanaged animal manure is a substantial contributor to nonpoint source pollution (Animal Manure Management). Nonpoint source pollution is the primary contributor to water pollution, which leads to drinking water contamination and can affect wetland habitats (Animal Manure Management). Unmanaged manure also contributes nutrients, disease-causing microorganisms, and oxygen-demanding organics to the nation's waters (Animal Manure Management). Many farms apply their manure to their fields as a form of fertilizer. However, the over application of animal manure to the land can degrade soil quality and decrease crop yields (Animal Manure Management).

Air quality is also a concern associated with livestock manure. Odor pollution have historically been the main issue with livestock production, but recently ammonia and methane emissions are a major concern associated with manure. Ammonia volatilization contributes to elevated nitrogen levels in rainwater, which leads to excess nitrogen in water bodies and the acidification of soils, which affects the entire surrounding ecosystem (Animal Manure Management).

1.2.1 Manure Waste in Saratoga Springs

For the purpose of our study, we created a conservative estimate of the amount of manure waste in the area by focusing on three dairy farms located in Saratoga Springs, NY and calculating the amount of manure waste these farms produce per year. The three farms we selected were Peckhaven Farm, Koval Brothers Farm and King Brothers Dairy. Peckhaven Farm has 120 cows and produces 10 tons of manure per day for the entire herd; therefore, this farm produces 3,650 tons per year. Koval Brothers Farm has 385 cows and produces 32 tons of manure per day for the entire herd; therefore, producing 11,680 tons per year. Lastly, King Brothers Dairy has 1,000 cows and produces 83 tons of manure per day for the entire herd; therefore, producing 30,295 tons per year. These three farms alone produce 45,625 tons of manure per year; however, we also considered the manure waste produced at the Van Lennep Stables down the street from Skidmore College for our study because horse manure is more energy rich than dairy manure. We calculated that the Van Lennep stables produce 7,056 tons per year of manure (See Table 2). Considering Saratoga Springs is a big horse-racing town, we believe our study can be scaled up to include manure produced at the track during track season. The only issue with using this manure in the digester is that it is a very seasonal supply, and the for the digester to operate efficiently, it needs steady and reliable feedstock inputs.

Table 2: Manure Waste Estimates



Manure Producer	
Peckhaven Farm (tons/yr)	3,650
Koval Brothers Farm (tons/yr)	11,680
King Brothers Dairy (tons/yr)	30,295
Van Lennep Stables (tons/yr)	7,056
Total (tons/yr)	**52,681**

1.3 Renewable Energy Picture in New York

New York is making significant strides toward a more sustainable energy future. Wind, hydropower, solar, geothermal and sustainable biomass already provide about 11% of all the energy that New York uses for transportation, space heating, industrial processes and electric power (Renewable Energy). On average, energy costs a lot in New York, about 16 cents per kWh, which is 20 to 50 percent more than the national average (New York Solar Rebates and Incentives). That makes renewable energy power sources more attractive to homeowners because it can cut down their utility bill costs. New York state instituted its most comprehensive and ambitious clean energy goal in the state's history with its Clean Energy Standard (CES). The CES is designed to fight climate change, reduce harmful air pollution, and ensure a diverse and reliable low carbon energy supply (Clean Energy Standard). The CES seeks to achieve these goals by requiring that New York's electricity comes from 50% renewable energy by 2030.

The current Governor of New York, Governor Cuomo, has and continues to promote renewable energy as a solution. In April 2016 he announced $150 million in funding to support large-scale renewable energy projects across the state (Governor Cuomo Announces $150 Million Available for Renewable Energy Projects). This funding will help advance the Governor's Reforming the Energy Vision (REV) strategy and help the state meet its goal of generating 50% of electricity from renewable energy projects by 2030. REV is Governor Cuomo's strategy to battle climate change and grow New York's economy. Already, REV has driven 600% growth in the statewide solar market, helped over 100,000 low-income households cut their energy bills and created thousands of jobs in clean technology sectors (Governor Cuomo Announces $150 Million Available for Renewable Energy Projects). Therefore, with Governor Cuomo as the New York State Governor, there is a bright future for the economic feasibility of more renewable energy projects, such as anaerobic digestion in Saratoga County and the rest of New York State.

1.4 Anaerobic Digestion as a Solution

Anaerobic digestion represents one solution to the food and manure waste problem. The co-digestion of energy-rich food waste and manure waste can help communities manage waste more sustainably, generate renewable energy, and provide electricity services at affordable rates (Food Waste to Energy, 2014). Anaerobic digestion of manure is regularly practiced in the U.S.; however, the inclusion of food waste in anaerobic digester feedstock is still quite new (Feasibility Report for the Central Vermont Recovered Biomass Facility, 2012). Our feasibility study explores the many aspects and complexities of the technology and feedstock required, the energy produced, and the economics of implementing an anaerobic digester facility in Saratoga Springs.

Anaerobic digestion is a biological process where bacteria breaks down biomass in the absence of oxygen. Anaerobic digesters have been used in the United States for over 30 years. They are most commonly used at wastewater treatment facilities (WWTF) and livestock operations; however, AD can process almost any organic material. Potential feedstocks for the digesters include agricultural waste, food waste, manure, yard wastes, etc. The process creates two outputs: a solid digestate and biogas. The solid digestate is high in nutrient content, making it possible to refine this product into an organic fertilizer, which can be sold to local farms for profit. This organic fertilizer will reduce the need for artificial fertilizers, which are harmful to the environment (Adelman and Gill-Austern, 2011). Biogas, the second output, is composed of 60%-70% methane (CH4), 30%-40% carbon dioxide (CO2) and water and can be used to produced renewable energy (Moriarty, 2013).

Anaerobic digesters pose a solution to the issue of manure waste because they reduce the presence of methane, nitrous oxide and synthetic fertilizers on farms. The combustion of the biogas produced in by the digester reduces emissions of the potent GHG, methane, released during conventional farm management practices (Feasibility Report for the Central Vermont Recovered Biomass Facility, 2012). Additionally, when manure waste is diverted from the farm and is sent to the digester, it gets rid of the odor pollution that is associated with manure on a farm. We chose to digest horse and dairy manure because anaerobic digestion systems work better with dairy and cattle manure rather than poultry and swine manure because they present more of a challenge due to their higher nitrogen levels (Manure Management. According to Dr. Joan Richmond-Hall, a professor at Vermont Tech Community College, it is important to maintain accurate carbon to nitrogen ratios because it increases the percentage of methane in the biogas and the overall efficiency of the digester.

As previously mentioned, organic waste, such as food waste, is often sent to landfills where it breaks down and releases methane gas. Some landfills who do not have an anaerobic digester capture the naturally emitted methane emissions and use it as a form of energy. For example, methane emitted from the now decommissioned landfill on Weibel Avenue in Saratoga Springs used to be captured and was used to power the generators to create ice at the Vernon Ice Rink, also on Weibel Avenue. Capturing the methane emitted from landfills creates a usable form of energy while also limiting the amount of methane released into the atmosphere (Adelman and Gill-Austern, 2011). There are currently more than 630 landfill gas energy projects in place across the U.S. with more than 2,000 MW of installed capacity for electricity generation (USDA, 2014). Due to the similarities in project development and the technologies, the landfill gas energy industry allows us to apply what has worked and what hasn't worked to the anaerobic digestion industry (USDA, 2014). One issue with the process of capturing methane from landfills is that the methane captured is not always a consistent, high-quality, reliable volume. Alternatively, some landfills flare their methane to prevent it from going into the atmosphere, but this method ruins a huge potential for viable energy and economic revenue. However, the majority of landfills do not engage in methane capture; thus when food waste is deposited in landfills, it breaks down and the methane gas is released into the atmosphere.

On the other hand, anaerobic digestion aids to speed up the decomposition process and consistently produces high quality biogas that can ultimately be used as renewable energy. Biogas can be used to generate electricity with minimal treatment and can be used as a renewable substitute for natural gas in homes and businesses (Food Waste). Natural gas, or pure methane, has a heat energy content of approximately 1,020 British Thermal Units (BTU) per cubic foot, usually varying from 950 to 1,050 BTUs per cubic foot (Chapter 1: External Combustion

Sources). Due to the fact that biogas is composed of 60% methane and 40% carbon dioxide, it contains 60% of the heat energy content of methane. Therefore, for the purpose of our study, we are assuming natural gas has a heat energy content of 1,000 BTUs per cubic foot, which means our biogas contains 60% of the heat energy content of natural gas, meaning 1 cubic foot of biogas will have a heating value of 600 BTUs. Biogas from the anaerobic digester is capable of operating in nearly all devices intended for natural gas (Moriarty, 2013).

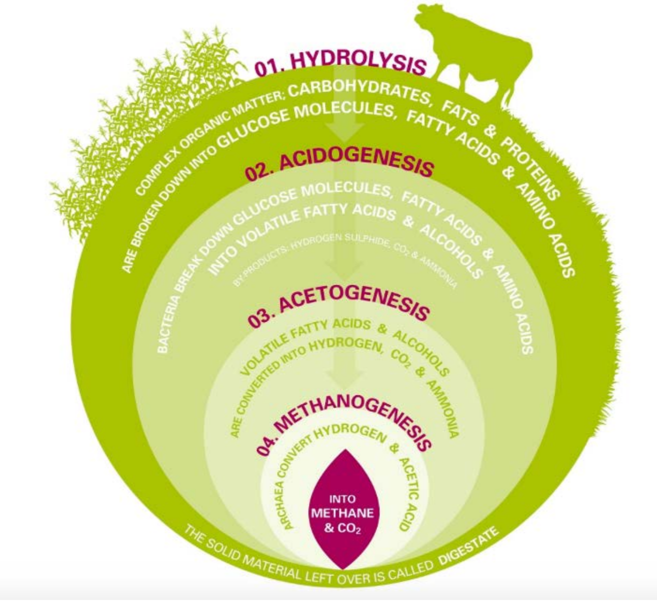
There are many benefits from anaerobic digestion such as renewable energy generation, GHG emissions reductions, diversion of organic wastes sent to landfills, reduced water pollution, low sludge production, and potential economic revenue in the form of fertilizer and/or electricity (Moriarty, 2013 & Chen, Cheng, Creamer 2008). Since the production of biogas from manure and other organic wastes requires the growth of plant feedstock, the use of biogas as a renewable energy resource is considered to be nearly carbon neutral because the carbon dioxide produced by combustion of the biogas will enter the carbon cycle and be used to produce plant feedstock (Feasibility Report for the Central Vermont Recovered Biomass Facility, 2012). Digesters represent a step closer to achieving the triple bottom line by solving an environmental problem, while at the same time turning a waste product into an economic asset.

1.4.1 The Science of Anaerobic Digestion

Anaerobic decomposition is a biological process that occurs in natural environments, and in landfills, as organic materials decompose over time and emit methane gas. Anaerobic digestion essentially mimics this natural anaerobic decomposition, but the organic matter is digested in an enclosed anoxic chamber “where critical environmental conditions such as moisture content, temperature, and pH levels can be controlled to maximize microbe generation, gas generation, and waste decomposition rates” (Waste not- Want Not, 2010).

Anaerobic digestion, the simple, natural breakdown of organic matter into carbon dioxide, methane and water, is broken down into 4 basic steps as shown in Figure 2: (1) in the hydrolysis stage, complex organic matter such as carbohydrates, fats and proteins are broken down into simple sugars, fatty acids and amino acids; (2) in the acidogenesis stage, simple sugars, fatty acids and amino acids are broken down into volatile fatty acids and alcohols; (3) in the acetogenesis stage, the volatile fatty acids and alcohols are converted into hydrogen, carbon dioxide and acetic acid; (4) in the methanogenesis stage, the remaining hydrogen and acetic acid are converted into methane and more carbon dioxide, known as biogas (The AD Cycle).

Figure 2: Stages of Anaerobic Digestion



Source: Anaerobic Digestion and Bioresources Association (http://adbioresources.org/about-ad/what-is-ad/ *)*

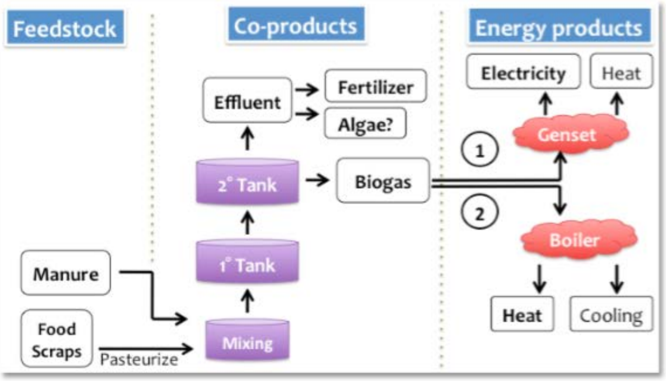
1.4.2 Digester Types

There are single-stage and two-stage systems. Two-stage systems increase construction and material costs but they have been proven to lead to higher biogas yields; however, single-stage systems are more common due to lower capital costs (Moriarty, 2013). Anaerobic digestion systems are typically designed to operate in one of two temperature ranges: mesophilic and thermophilic. Mesophilic digesters operate between 95 degrees Fahrenheit and 105 degrees Fahrenheit and thermophilic between 125 degrees Fahrenheit and 140 degrees Fahrenheit (Moriarty, 2013). Although thermophilic digesters produce more energy, they are more difficult to operate; therefore, mesophilic digesters are more common due to lower capital costs and ease of operation (Moriarty, 2013).

There are two methods for introducing feedstock into the digester: batch or continuous (Moriarty, 2013). In the batch method, digester tanks are filled with feedstock and then closed during digestion. All four stages of the AD process occur in the same singular tank. When the digestion is complete, the remaining material is removed and the tank is refilled for another round of digestion (Feasibility Report for the Central Vermont Recovered Biomass Facility, 2012). Although batch digesters are less expensive to construct and operate, they are less efficient than other designs and offer a lower biogas output (Feasibility Report for the Central Vermont Recovered Biomass Facility, 2012). Continuous digestion is the more common method where feedstock is frequently added to the digester (Moriarty, 2013). Continuous digesters constantly take in small amounts of feedstock and release small amounts of digested material to the secondary tanks (Feasibility Report for the Central Vermont Recovered Biomass Facility, 2012). The continuous digesters are typically more efficient than batch digesters but they are more expensive to construct and operate (Feasibility Report for the Central Vermont Recovered Biomass Facility, 2012).

There are many small but significant variations of anaerobic digestion processes to produce biogas and energy. The digester type we think best suits our project is a two-stage continuously stirred-tank reactor (CSTR) for combined heat and power (CHP). The CSTR design can either use one or two tanks for the digestion process. We chose the two-stage options because this separation of the anaerobic digestion process maximizes the growth of bacteria and increases biogas yield (Feasibility Report for the Central Vermont Recovered Biomass Facility, 2012). CSTR continuously accepts feedstock and releases digested material. CSTRs are stirred to mix substrate and maintain a homogenous environment and constant temperature for the greatest bacterial growth (Feasibility Report for the Central Vermont Recovered Biomass Facility, 2012). This type of digester results in more complete digestion of high-energy feedstock and higher yields of biogas (Feasibility Report for the Central Vermont Recovered Biomass Facility, 2012). Figure 3 is a diagram that depicts both CHP and straight combustion (heat-only configuration) that we considered for this project. We chose to do CHP configuration over the heat-only configuration because we believe the ability to sell the electricity produced will create a profit for the town.

Figure 3: Depiction of Combined Heat and Power and Heat-only Configurations



1. Combined heat and power configuration produces both electricity and heat.
2. Heat-only configuration burns biogas in to produce heat, but not electricity.

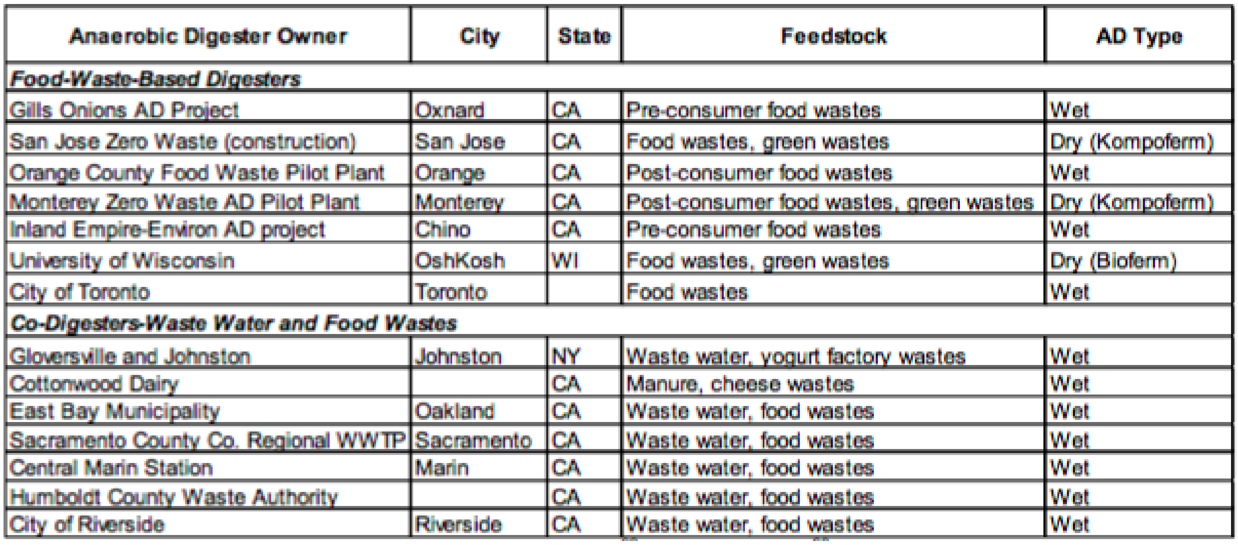
Source: Vermont Tech Feasibility Study

1.4.3 Anaerobic Digestion in the United States

Market conditions are looking increasingly favorable for the growth of the anaerobic digestion industry in the U.S. (Business Analysis of Anaerobic Digestion in the USA, 2013). The feasibility of anaerobic digestion projects varies state-to-state, but advances in technology and legislation in favor of anaerobic digestion development are creating growth in the anaerobic digestion market (Business Analysis of Anaerobic Digestion in the USA, 2013). As previously mentioned, anaerobic digestion systems were exclusively used in agriculture and wastewater processes; however anaerobic digestion systems are growing in favor as a method of managing and extracting value from food wastes. According to the American Biogas Council, there are 1,500 digesters at wastewater treatment plants (Business Analysis of Anaerobic Digestion in the USA, 2013). The majority of these digesters are increasingly introducing food waste to be co-digested with the agricultural and wastewater because the high energy content of the food waste boosts the biogas production of these facilities (Business Analysis of Anaerobic Digestion in the USA, 2013). Table 3 shows existing U.S. food waste AD projects. Nearly all AD projects are owned and operated by municipalities, and many partner with private waste haulers to deliver food waste feedstock to the facility.

Several communities have and are planning food waste digesters. Cottonwood Dairy in California installed an AD to digest manure and waste from a cheese plant; the electricity and heat produced is used on site and the excess electricity is sold to the grid (Moriarty, 2013). This is similar to the Vermont Tech Community Anaerobic Digester that is located on the Vermont Tech Community College campus. It collects and digests food waste from the community and manure from the farm on campus.

Table 3: Existing U.S. Food Waste AD Projects



Anaerobic Digester Owner	City	State	Feedstock	AD Type
Food-Waste-Based Digesters				
Gills Onions AD Project	Oxnard	CA	Pre-consumer food wastes	Wet
San Jose Zero Waste (construction)	San Jose	CA	Food wastes, green wastes	Dry (Kompoferm)
Orange County Food Waste Pilot Plant	Orange	CA	Post-consumer food wastes	Wet
Monterey Zero Waste AD Pilot Plant	Monterey	CA	Post-consumer food wastes, green wastes	Dry (Kompoferm)
Inland Empire-Environ AD project	Chino	CA	Pre-consumer food wastes	Wet
University of Wisconsin	OshKosh	WI	Food wastes, green wastes	Dry (Bioferm)
City of Toronto	Toronto		Food wastes	Wet
Co-Digesters-Waste Water and Food Wastes				
Gloversville and Johnston	Johnston	NY	Waste water, yogurt factory wastes	Wet
Cottonwood Dairy		CA	Manure, cheese wastes	Wet
East Bay Municipality	Oakland	CA	Waste water, food wastes	Wet
Sacramento County Co. Regional WWTP	Sacramento	CA	Waste water, food wastes	Wet
Central Marin Station	Marin	CA	Waste water, food wastes	Wet
Humboldt County Waste Authority		CA	Waste water, food wastes	Wet
City of Riverside	Riverside	CA	Waste water, food wastes	Wet

Source: Louisiana Feasibility Study (http://www.nrel.gov/docs/fy13osti/57082.pdf *)*

1.4.4 Anaerobic Digestion in New York

Anaerobic digestion and biogas combustion is not new to New York. The use of biogas in New York to create electricity has been increasing since 2007. Currently, 2.5 million tons of waste are sent to Waste-To-Energy (WTE) facilities (How New York Uses Renewable Energy). In 2010, of the 157 estimated digester projects operating on a commercial scale nationwide, 22 were located in New York (Newbold, 2013). This makes New York the second leading state in operating digesters in the country (Newbold, 2013).

Locally, located just 35 miles from Saratoga Springs, in the towns of Gloversville and Johnston, New York, there is a wastewater treatment facility (WWTF) that utilizes an anaerobic digester to co-digest wastewater and yogurt wastes from the nearby yogurt manufacturer Fage Yogurt. Additionally, the town of North Elba, New York is in the beginning stages of building a small-scale anaerobic digester unit designed for source-separated municipal food and organic wastes. This will be the very first of its kind in the United States (Beadle, 2015). The project is expected to receive approximately 900 tons of organic waste that is currently sent to landfills each year and in turn generate about 290,500 kilowatt-hours of renewable electricity per year (Beadle, 2015). In addition, this digester will create green jobs in the bioenergy field and become a model for other communities to follow.

2. Research Goal

Considering the environmental and economic impacts of food and manure waste, our capstone research goal focuses on anaerobic digestion as one possible solution for waste reduction in Saratoga Springs. Our study embodies a conceptual analysis of the feasibility of an anaerobic digester in Saratoga Springs. We will do so by first conservatively estimating the amount of food and manure waste in Saratoga Springs and then studying the energy content of food and manure waste. We will use this data to examine whether an anaerobic digestion system will be feasible based on expected payback period and social incentives to participate. We will show different scenarios of waste collection, potential energy content, favorable policy changes and potential funding to show ranges of payback periods and to show how complex the whole process is.

3. Methods

The majority of our research was collected by reading through previous literature published on our topic in combination with primary source informal interviews. For background information on the process and technology of anaerobic digestion, we read through multiple articles published on the subject to help us better understand the science behind anaerobic digestion as a renewable energy option. To get a better understanding of the role anaerobic digestion plays in New York, we contacted Steven Hoyt, a project manager at NYSERDA. We had an initial informal phone interview with him in November 2016. We followed up with him via email throughout the duration of the project to get more information regarding potential grants, funding and biogas output information.

After speaking with Hoyt, Karen Kellogg, an Associate Professor in the Environmental Studies and Sciences Department at Skidmore College and Bob Turner, an Assistant Professor in the Environmental Studies and Science Department at Skidmore College, we had been referred to multiple anaerobic digestion feasibility studies that we used to base our study off of. The most successful applicable studies, in our opinion, were “Feasibility Study of Anaerobic Digestion of Food Waste in St. Bernard, Louisiana” by Kristi Moriarty and the “Feasibility Report for the Vermont Recovered Biomass Facility”, which is also known as the Vermont Tech Community Anaerobic Digester. We had an informal phone interview with Dr. Joan Richmond-Hall, Associate Professor of Science at Vermont Tech College, she was directly involved with the digester project under the title “Feedstock Support”. Using interviews as our method of data collection allowed us to gain perspectives on the hurdles faced in installation and operation of the digester. Our initial interview with Dr. Richmond-Hall took place in February 2017 over the phone. They were informal, informational interviews and the interviewees preferred not to be recorded so we took thorough notes through the conversation.

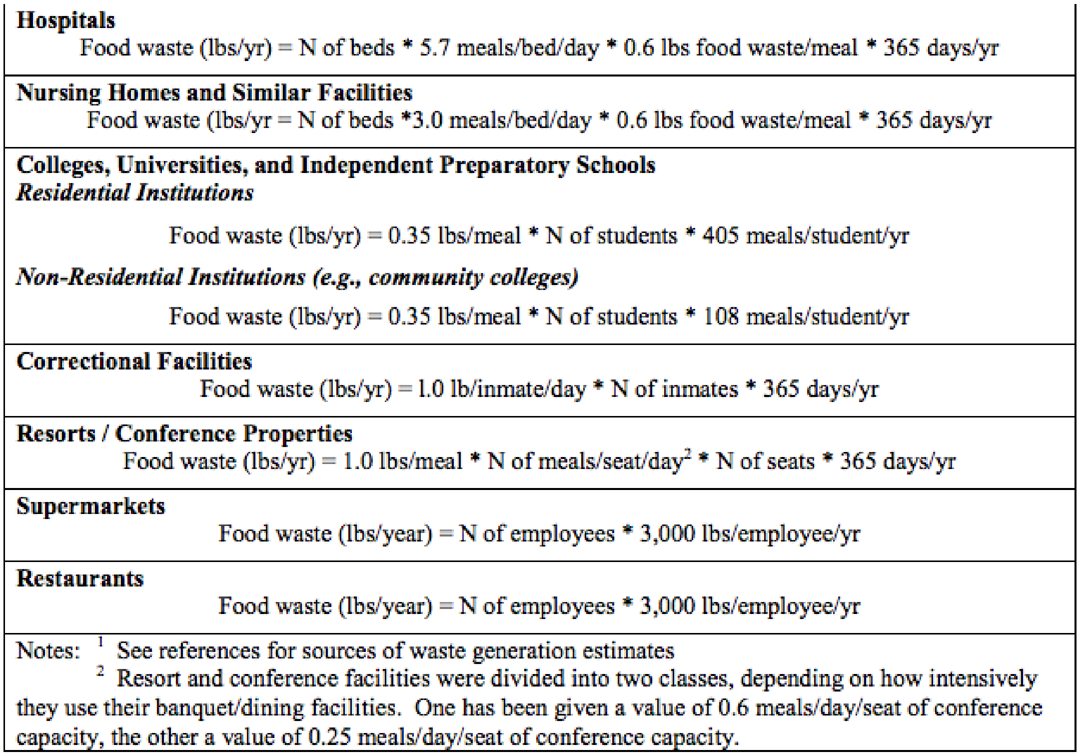
From this conversation, we identified that food waste has the greatest energy potential, but manure, was essential because it helps to neutralize the pH levels of the food waste thus allowing as much food waste as possible to be a part of the feedstock. The food waste sources we identified included supermarkets, restaurants, the hospital in town and Skidmore College. In order to calculate the total amount of food waste from supermarkets, the hospital and Skidmore College, we used equations taken from Drapper/Lennon, 2002 (See Figure 4). Restaurant waste in Saratoga Springs was previously measured in a prior Environmental Studies and Sciences capstone project by Raquel Escobar and Melissa Kaslowski in 2015. This gave us a general idea of the amount of potential food waste in the area; however, this number is very conservative because it does not account for other sources of food waste, such as residential food waste.

In order to calculate the total amount of manure waste in the area, we reached out to a few different farms to understand how they currently discard or utilize their manure and tried to gauge their interest level with our project. We ended up selecting three local farms, Peckhaven Farm, Koval Brothers Farm and King Brothers Dairy Farm, as well as, the Van Lennep Stables near Skidmore College. Again, these numbers for manure waste can greatly vary depending on the willingness to participate and the amount of waste that is actually collectable.

In order to calculate the potential energy output of the digester, we obtained biogas output ranges from Steven Hoyt at NYSERDA (See Table 4). We multiplied the average biogas output range for both food and manure by the amount of waste we expect to have of each. We created a few different scenarios with varying amounts of waste and other factors to give us a rough estimate of the potential energy output of the digester under a few different circumstances.

We measured the economic feasibility of the project by the amount of time it would take for the project to pay itself back. We analyzed several different scenarios, changing the amount of waste available, the addition of favorable policy changes, the amount of electricity sold and changes in potential grants and funding opportunities to give us an idea of the range of the payback period and what factors are the most important in speeding up this period.

Figure 4: Food Waste Generation Estimates by Generator Category



Hospitals
Food waste (lbs/yr) = N of beds * 5.7 meals/bed/day * 0.6 lbs food waste/meal * 365 days/yr

Nursing Homes and Similar Facilities
Food waste (lbs/yr = N of beds *3.0 meals/bed/day * 0.6 lbs food waste/meal * 365 days/yr

Colleges, Universities, and Independent Preparatory Schools
Residential Institutions

Food waste (lbs/yr) = 0.35 lbs/meal * N of students * 405 meals/student/yr

Non-Residential Institutions (e.g., community colleges)

Food waste (lbs/yr) = 0.35 lbs/meal * N of students * 108 meals/student/yr

Correctional Facilities
Food waste (lbs/yr) = 1.0 lb/inmate/day * N of inmates * 365 days/yr

Resorts / Conference Properties
Food waste (lbs/yr) = 1.0 lbs/meal * N of meals/seat/day[2] * N of seats * 365 days/yr

Supermarkets
Food waste (lbs/year) = N of employees * 3,000 lbs/employee/yr

Restaurants
Food waste (lbs/year) = N of employees * 3,000 lbs/employee/yr

Notes: [1] See references for sources of waste generation estimates
[2] Resort and conference facilities were divided into two classes, depending on how intensively they use their banquet/dining facilities. One has been given a value of 0.6 meals/day/seat of conference capacity, the other a value of 0.25 meals/day/seat of conference capacity.

Source: Drapper/Lennon, 2002.

Table 4: Biogas Output Range

Substrate	Biogas output low range (m3/ton) [1]	Biogas output high range (m3/ton)	Biogas output midpoint (m3/ton)
Food Waste	55	529	292
Manure	22	33	28

1. Numbers were originally in m3/m.ton and were converted in m3/ton

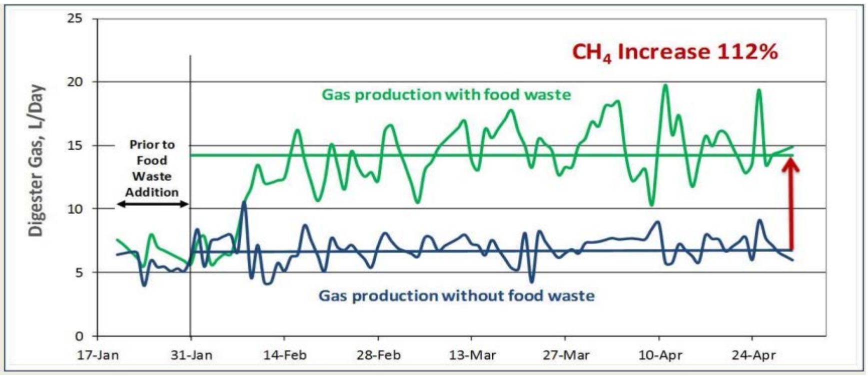
Source: NYSERDA

4. Conceptual Analysis

4.1 Potential Feedstocks

We evaluated what types of feedstock would be best for producing the most efficient and energy rich biogas through our review of the literature and through our informal interview with Dr. Joan Richmond-Hall. We selected to co-digest food and manure waste because food waste is extremely energy rich and produces energy rich biogas. As you can see in Figure 5, the introduction of food waste into a digester increases the methane production. The higher the methane content of the biogas, the more energy can be produced. Although manure is not nearly as energy rich, the addition of manure is an advantage for the project because of its other useful qualities and will only help increase biogas production. Horse manure is slightly more energy rich than cow manure, but it is extremely dry and will need extra water added to it before it is digested. Cow manure, while less energy rich than horse manure, is easier to transport and is pumpable, which creates less work for introducing it into the digester. If our digester was exclusively a food waste digester, the pH in the digester will drop and the microbes that make biogas wouldn't be able to continue doing so. However, manure is a good buffering agent for pH. Co-digestion manure with any amount of food will keep the pH stable, allowing for the microbes to keep creating biogas.

Figure 5: Increase of Methane with Additional Food Waste



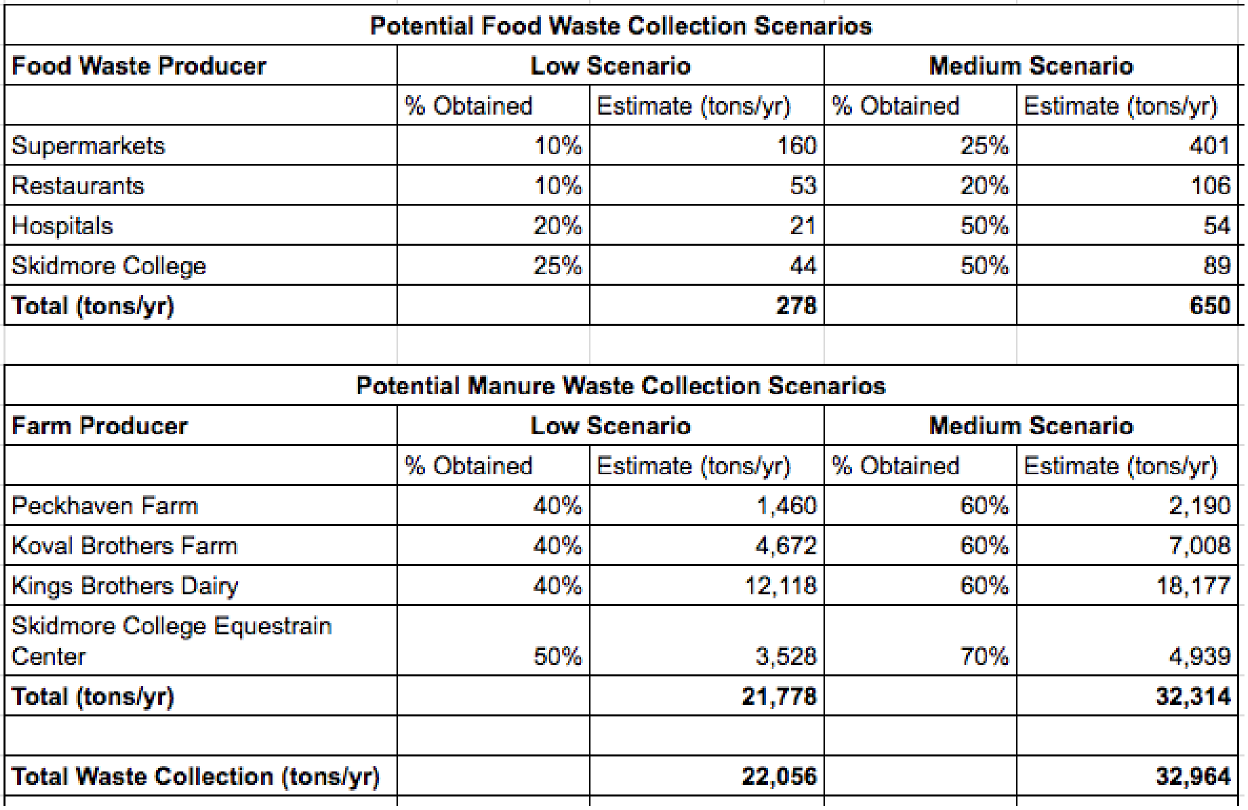
Source: NACWA Energy Workgroup (http://www.nacwa.org/docs/default-source/resources---public/2017-01-27schmidtlacsd.pdf?sfvrsn=4)

4.1.1 Food Wastes

Food wastes are an excellent candidate for anaerobic digestion due to the high moisture and organic content (Moriarty, 2013). In Saratoga Springs, there is ample food waste that we can utilize in our digester. A study funded by The Massachusetts Department of Environmental Protection, found food manufacturers, restaurants, and supermarkets produce the highest volumes of waste. Therefore, for our study we estimated the amount of food waste that would be generated at the Saratoga Springs Hospital, Skidmore College, and various restaurants and supermarkets located in Saratoga Springs. After our informal interview with Whitney Beadle from BIOFerm Energy Systems, she informed us that pre-consumer food waste (waste from supermarkets) is the best type of food waste because it has much less of the potential to cause contamination. Post-consumer food waste has a much greater potential for contamination because delivered feedstock may contain silverware, metals, rocks, and other non-desirable feedstock components (Moriarty, 2013). Therefore, food waste may likely require preprocessing to remove these contaminates from the food waste before entering the digester. However, food waste separation and other diversion processes can be costly (Moriarty, 2013).

Food waste estimations were based off an equation for food waste generation estimates from the study Drapper/Lennon, 2002 we estimated the amount of waste generated at the hospital, Skidmore College, and the local supermarkets (See Figure 4). We obtained waste generation estimates for local restaurants from a previous capstone, “Feeding Mouths, Not Landfills: An Analysis of Food Recovery Efforts in Saratoga Springs” by Melvin Alvarez, Jordan Chang, and Rebecca Fennel. We estimated our total food waste potential to be 2,418 tons per year (See Table 1). We then posed two potential scenarios for our food waste feedstock, a low scenario and a medium scenario. These scenarios depict the percentage of food waste we expect to obtain and then we estimated our new total food waste in tons per year. The percentages of food obtained were taken from the study “Feasibility Study of Anaerobic Digestion of Food Waste in St. Bernard, Louisiana” by Krisit Moriarty. Our low scenario estimates that we will obtain 278 tons of food waste per year and our medium scenario estimates that we will obtain 650 tons of food waste per year (See Table 5).

Table 5: Potential Food and Manure Waste Collection Scenarios



Potential Food Waste Collection Scenarios				
Food Waste Producer	**Low Scenario**		**Medium Scenario**	
	% Obtained	Estimate (tons/yr)	% Obtained	Estimate (tons/yr)
Supermarkets	10%	160	25%	401
Restaurants	10%	53	20%	106
Hospitals	20%	21	50%	54
Skidmore College	25%	44	50%	89
Total (tons/yr)		**278**		**650**

Potential Manure Waste Collection Scenarios				
Farm Producer	**Low Scenario**		**Medium Scenario**	
	% Obtained	Estimate (tons/yr)	% Obtained	Estimate (tons/yr)
Peckhaven Farm	40%	1,460	60%	2,190
Koval Brothers Farm	40%	4,672	60%	7,008
Kings Brothers Dairy	40%	12,118	60%	18,177
Skidmore College Equestrain Center	50%	3,528	70%	4,939
Total (tons/yr)		**21,778**		**32,314**
Total Waste Collection (tons/yr)		**22,056**		**32,964**

4.1.2 Manure Waste

For the purpose of our study we are estimating that we will receive manure waste from three local dairy farms and from the Van Lennep Stables, which house the Skidmore College equestrian team’s horses. The three farms we are focusing on are Peckhaven Farm, Koval Brothers Farm and Kings Brothers Dairy. Based on estimates of manure produced obtained from informal interviews with the farmers, we estimated that Peckhaven Farm, with 120 cows, produces 3,650 tons of manure per year; Koval Brothers Farm, with 385 cows, produces 11,680 tons of manure per year; King Brothers Dairy, with 1,000 cows, produces 30,395 tons of manure per year. Based on conversations with waste haulers, we estimated that The Van Lennep Stables produce 7,056 tons of manure per year. We estimated our total manure waste potential to be

52,681 tons of manure per year (See Table 2). We again posed two potential scenarios for our manure waste feedstock, a low scenario and a medium scenario. These scenarios depict the percentage of recoverable manure waste we expect to collect. Recoverable manure waste is defined as the amount of manure waste that can be feasibly collected and utilized (USDA). The percentages of manure waste obtained were estimated by us under the assumption that in a best case scenario only 90-95% of manure can be collected (USDA); therefore, we assumed that for the farms, in a low scenario, we would obtain 40% of overall manure and in a medium scenario, we would obtain 60% of overall manure. After speaking to Cindy Ford, head riding coach at Skidmore College, we estimated that in a low scenario we would collect 50% of manure waste and in a medium scenario we would collect 70% of manure waste. These numbers differ from the farm collection percentages because the stables already have a manure management plan in existence; therefore, we assume we will be able to collect more of their waste. Our low scenario estimates that we will obtain 21,778 tons of manure waste per year and our medium scenario estimates that we will obtain 32,314 tons of manure waste per year (See Table 5). Table 5 also shows our total low and medium waste collection scenarios.

4.1.3 Digester Outputs

We will get two outputs: a digestate and biogas. The digestate can be further refined to create an organic fertilizer, which could potentially be sold to increase the project's revenues. However, in our analysis of the economic feasibility of the project, we don't take into account potential digestate revenue, we only focus on potential revenue from selling the energy produced to the grid as well as the potential revenue from a tipping fee. Biogas outputs vary depending on the type and amount of feedstock put into the digester. Of the total biogas produced, 10% will go back and be used to generate and run the anaerobic digester facility itself. The remaining biogas, will create heat and power, due to our CHP system. The CHP is only 60% efficient so only 60% of the biogas will become heat and power.

4.2 Site Considerations

In order for our anaerobic digestion facility to be successful, it needs to be located near the feedstock and required utilities. The site we chose is located at the Saratoga County Transfer Station on Weibel Avenue in Saratoga Springs. This is a good site for the location of our digester because it is not near the center of town, but closer to the highway as a major concern people have against digesters is the way they look and the slight odor that is emitted.

Proximity to communities is also an important factor to consider because of the increased traffic volume to deliver feedstock and potential odor. The site is located in an area with multiple wholesale stores around and little no residences. Being located at the Transfer Station, we don’t predict any increased disturbance with feedstock delivery because traffic is already coming and going to the Transfer Station.

4.3 Collection and Transportation

The local landfill is located in the town of Colonie, NY; therefore, the benefit of locating our digester at the transfer station in Saratoga Springs cuts down the travel distance of waste haulers, cutting emissions while also reducing money spent on gas.

Efficient and economical supply of the large volumes of food waste is required because collection must focus on large commercial generators rather than small commercial generators or residential generators. The focus on large scale generators allows haulers to create routes with fewer stops and collect larger volumes at each stop (Moriarty, 2013). We are assuming for the purpose of our study that food waste generators will separate their organic waste and local haulers will pick it up and deliver it to our facility. The feasibility of this actually happening is low unless an organics law is put in place to mandate separation, collection and delivery of the waste.

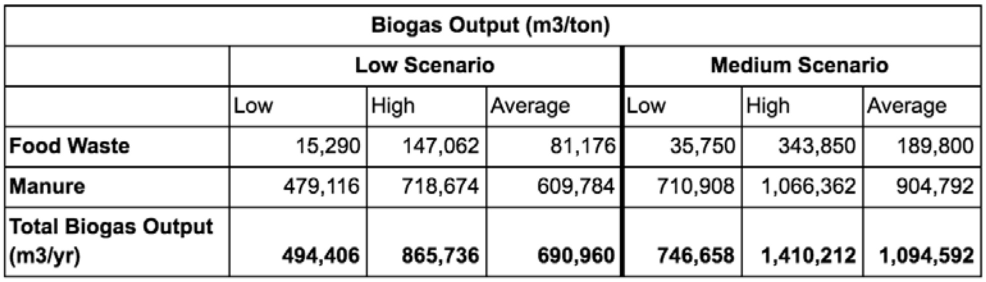
4.4 Analysis of the Economic Feasibility of Multiple Scenarios

In the following section, we analyzed multiple scenarios where we show how a change of one or more factors can influence the potential biogas output, the electric revenue, tipping fee revenue, capital and operational costs and our payback period. We also show our methods and processes used in obtaining our payback period.

4.4.1 Methods

Biogas output for food waste and manure were calculated using numbers obtained from NYSERDA (See Table 4). The numbers from NYSERDA gave us a low, high and midpoint range for biogas output and electricity output. To figure out the range of biogas output that would be produced, we multiplied each number in the low, high and midpoint section for biogas output for food waste by our low and medium scenario food waste numbers from table 6. This gave us three potential biogas output scenarios for food waste within our low scenario: a low, low scenario; a low, high scenario; and a low, average scenario; and three potential biogas output scenarios for food waste within our medium scenario: a medium, low scenario; a medium, high scenario; and a medium, average scenario. We followed the same process for manure waste by multiplying each number in the low, high and midpoint section for biogas output for manure waste by our low and medium scenario manure numbers from table 5. We ended up with the same three potential biogas output scenarios within our low scenario: a low, low scenario; a low, high scenario; and a low, average scenario and the same three potential biogas output scenarios within our medium scenario: a medium, low scenario; a medium, high scenario; and a medium, average scenario. We then added together our low, low scenario biogas output for food waste and manure waste to get a total low, low scenario biogas output of 494,406 m3/yr and added our medium, low scenario biogas output for food waste and manure to get a total medium, low scenario biogas output of 746,658 m3/yr (See Table 6). We added our low, high scenario biogas output for food and manure waste to get a total low, high scenario biogas output of 855,736 m3/yr and added our medium, high scenario biogas output for food waste and manure to get a total medium, high scenario biogas output of 1,410,212 m3/yr (See Table 6). We added our low, average scenario biogas output for food and manure waste to get a total low, average scenario biogas output of 690,960 m3/yr and added our medium, average biogas output for food and manure waste to get a total medium, average scenario biogas output of 1,094,592 m3/yr (See Table 6). In the following scenarios that we analyze, we will be using our average biogas output for both our low and medium scenarios (See Table 6).

Table 6: Total Biogas Output Scenarios



Biogas Output (m3/ton)						
	Low Scenario			**Medium Scenario**		
	Low	High	Average	Low	High	Average
Food Waste	15,290	147,062	81,176	35,750	343,850	189,800
Manure	479,116	718,674	609,784	710,908	1,066,362	904,792
Total Biogas Output (m3/yr)	**494,406**	**865,736**	**690,960**	**746,658**	**1,410,212**	**1,094,592**

4.4.2 Assumptions

Based on other feasibility studies, we are assuming out of the total biogas produced, 10% is retained to heat and operate the digester; therefore, only 90% of the total biogas produced is available to go into the combustion turbine to produce electricity and heat. Typical effective electrical efficiencies for combustion turbine-based CHP systems range from 51-69%

(CHPcitation). For the purpose of our project, we assumed our CHP will be 60% efficient, therefore, only 60% of the biogas will go on to create heat and power.

In order to incentivize the separation of wastes and collection and delivery by local waste haulers, it is necessary for the anaerobic digester to have a lower tipping fee than the local landfill. According to the Jennifer Merriman, Data Collector at the Saratoga Springs Department of Public Works, the town currently pays a tipping fee of $50/ton; therefore, to incentivize the separation of wastes and the collection and delivery by local waste haulers, we selected a tipping fee of $40/ton to be used in our analysis. Based on the feasibility study conducted by Kristi Moriarty, “Feasibility Study of Anaerobic Digestion of Food Waste in St. Bernard, Louisiana”, this $10 cheaper tipping fee would incentivize the separation of food wastes and the delivery of the wastes to the digester facility (Moriarty, 2013).

4.4.3 Costs/Revenues Stream

The projected revenues from this project are from the electricity being sold back to the grid, which we label as “electric revenue” and tipping fee revenues. The projected costs in this project are from the upfront capital costs of the digester and the annual operation and maintenance costs, both which vary depending on the amount of feedstock that will be put into the digester. The following scenarios analyze different payback period outcomes with different variations in our revenue and cost streams.

4.4.4 “Worst Case” Scenario (A)

Our baseline worst case scenario contains our low scenario food waste of 278 tons/yr and our low scenario manure waste of 21,778 tons/yr. This will produce our lowest amount of biogas, which in turn will produce our lowest amount of energy, giving us our lowest electric revenue, it will also give us our lowest tipping fee revenue. However, it will cost us the least in capital and operation and maintenance costs.

4.4.4.1 Methods

Taking the average biogas output for food and manure waste from Table 6, we multiplied the average biogas output for food by our low scenario food waste number of 278 ton/yr and got a biogas output of 81,176 m3/yr. We then multiplied the average biogas output for manure by our low scenario manure waste number of 21,778 tons/yr and got a biogas output of 609,784 m3/yr. We added together our food waste and manure waste biogas outputs to get a total biogas output of 690,960 m3/yr. Due to the fact that 10% of the biogas goes back to heat and operate the digester, we will only have 621,864 m3/yr of biogas available. To convert this biogas into BTUs, we first need to convert biogas in m3/yr to ft3/yr using the conversion of 1m3 = 35.31 ft3. The next step in the conversion process is to convert ft3 to BTUs using the conversion of 1ft3 = 600 BTUs (Air Emissions Factors and Quantifications). This gives us our total heat and power output; however, since our CHP is only 60% efficient, our total available heat and power output is 7,905,930,840 BTUs/yr. We converted BTUs to kWh using the equation 1 BTU = 0.000293071 kWh.

4.4.4.2 Costs/Revenues

In this scenario, we are assuming that we will sell 50% of electricity to the grid, and we calculated our electric revenue using $0.06 per kWh, giving us an electric revenue of $69,510/yr (Saratoga Springs Electricity Rates). The majority of our revenue will come from our tipping fee of $40/ton, giving us a total tipping fee revenue of $882,240/yr. Our largest cost is the upfront capital cost of the digester and then we also need to take into account our annual operation and maintenance fee, both costs are directly correlated with the amount of feedstock that will be put in. Therefore, for our worst case scenario, we have a total payback period of 10.4 years (See Table 8).

4.4.5 "Increased Electric Revenue" Scenario (B)

In our next scenario, we are assuming our food waste collection rate increases to our medium scenario food waste of 650 tons/yr, but our manure waste stays the same at its low scenario of 21,778 tons/yr, giving us a total waste collection of 22,428 tons/yr (See Table 8).

4.4.5.1 Methods

Using the same methodology as in the previous scenario, we take the average biogas output for food and manure waste from Table 5, and multiply the average biogas output for food by our medium scenario food waste number of 650 tons/yr and got a biogas output of 189,800 m3/yr. We then multiplied the average biogas output for manure by our low scenario manure waste, as we did in the previous scenario, to get a biogas output of 609,784m3/yr. We added together our food waste and manure waste biogas outputs to get a total biogas output of 799,584 m3/yr. Due to the fact that 10% of the biogas goes back to heat and operate the digester, we will only have 719,626 m3/yr of biogas available. Again, we need to go through the conversion process of getting the biogas in m3/yr into BTUs/yr. Using the same process as in the previous scenario and also accounting for the 60% efficiency of the CHP system, we get a total BTU output of 9,148,806,720 BTUs/yr.

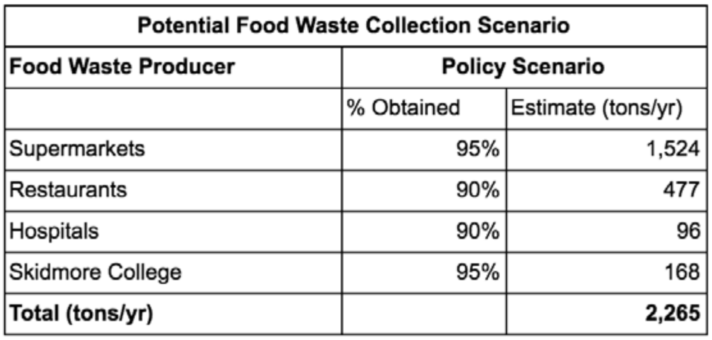
4.4.5.2 Costs/Revenues

In this scenario, we are increasing the amount of electricity we would sell back to the grid to 70%, as opposed to the 50% in the previous scenario. Using the same conversion of BTUs to kWh as in the previous scenario, we calculated our electric revenue using $0.06 per kWh, giving us an electric revenue of $112,612/yr. Again, the majority of our revenue will come from our tipping fee of $40/ton, in this scenario with our increased amount of waste, we will have a total tipping fee revenue of $897,210/yr. Our capital costs and operation and maintenance costs slightly increase due to the increased amount of waste, and our payback period drops to about 9.9 years (See Table 8).

4.4.6 "Favorable Policy" Scenario (C)

In our next scenario, we are assuming favorable policy has been put in place that mandates the separation of organic wastes and collection and delivery of the organic waste to a facility such as our anaerobic digester. We are assuming our food rate collection rate increases to 90-95%, which would give us 2,265 tons/yr of food waste (See Table 7). We are also assuming our manure collection rate will increase to our medium collection scenario of 32,314 tons/yr, giving us a total collection rate of 34,579 tons/yr.

Table 7: Favorable Policy Food Waste Collection Scenario



Potential Food Waste Collection Scenario		
Food Waste Producer	**Policy Scenario**	
	% Obtained	Estimate (tons/yr)
Supermarkets	95%	1,524
Restaurants	90%	477
Hospitals	90%	96
Skidmore College	95%	168
Total (tons/yr)		**2,265**

4.4.6.1 Methods

Using the same methodology as in the previous scenarios, we take the average biogas output for food and manure waste from Table 6, and multiply the average biogas output for food by our policy scenario food waste number of 2,265 tons/yr and got a biogas output of 661,380 m3/yr. We then multiplied the average biogas output for manure by our medium scenario manure waste number of 32, 314 to get a biogas output of 904,792 m3/yr. We added together our food waste and manure waste biogas outputs to get a total biogas output of 1,566,172 m3/yr. Due to the fact that 10% of the biogas goes back to heat and operate the digester, we will only have 1,409,555 m3/yr of biogas available. Again, we go through the conversion process of getting the biogas in m3/yr into BTUs/yr. Using the same process as in the previous scenario and also accounting for the 60% efficiency of the CHP system, we get a total BTU output of 17,920,067,400 BTUs/yr.

4.4.6.2 Costs/Revenues

We are keeping the amount of electricity being sold back to the grid at 70%, so using the same conversation as in the previous scenarios we converted BTUs to kWh, and calculated our electric revenue using $0.06 per kWh. This gave us an electric revenue of $220,577/yr. Like in the previous scenarios, the majority of our revenue is coming from the tipping fee of $40/ton, which increased greatly with the increase in our total waste. Our capital costs and operation and maintenance costs increase due to the increased amount of waste, and our payback period drops slightly to 9.7 years (See Table 8).

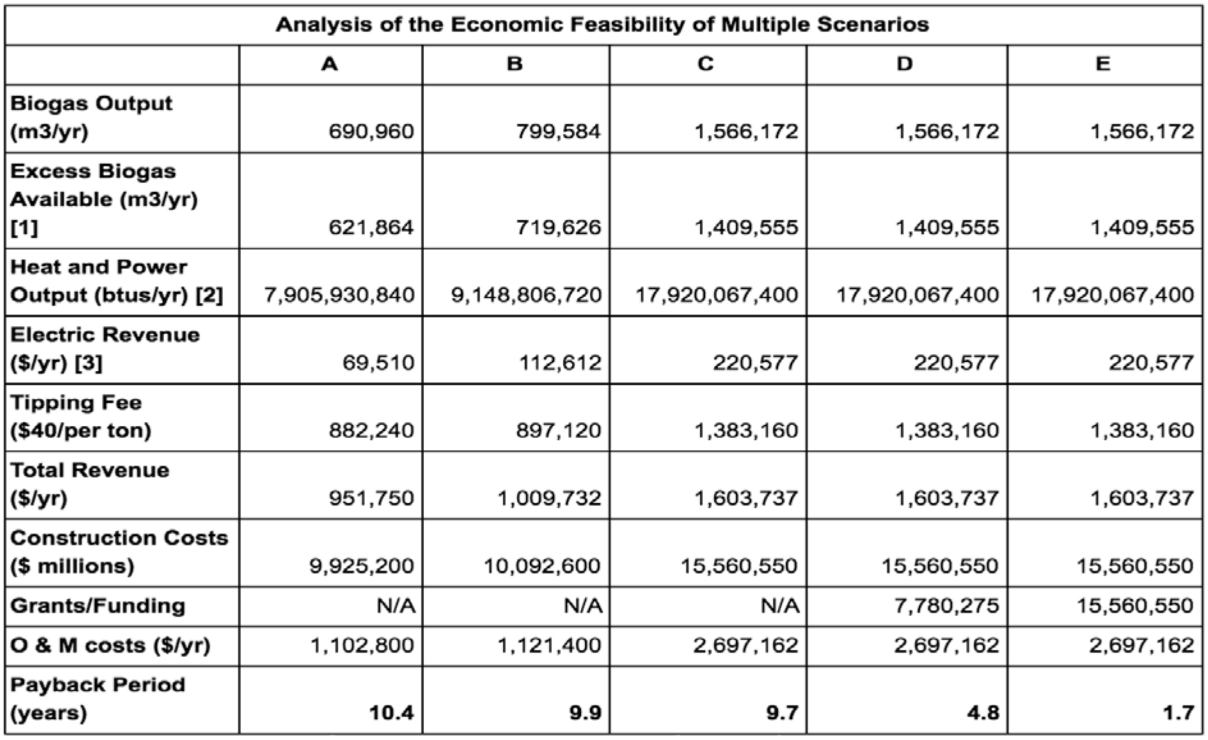
4.4.7 "Partial Funding" Scenario (D)

In our next scenario, we are keeping everything the same as in the "Favorable Policy" scenario, but we are assuming we will get 50% funding for the project. This decreases our upfront capital costs to $7,780,275, reducing our payback period to 4.8 years (See Table 8).

4.4.8 "Best Case" Scenario (E)

Obtaining full funding for the capital cost of the digester will greatly increase the economic feasibility of the project. In this scenario we are assuming we will get 100% funding for the digester, meaning no upfront costs. We predicted in this scenario that we will not get funding to cover operation and maintenance costs, therefore, the payback period is 1.7 years (See Table 8). However, if we do obtain funding to cover operation and maintenance costs, the project will start making a profit immediately.

Table 8: Analysis of Economic Feasibility of Multiple Scenarios



Analysis of the Economic Feasibility of Multiple Scenarios

	A	**B**	**C**	**D**	**E**
Biogas Output (m3/yr)	690,960	799,584	1,566,172	1,566,172	1,566,172
Excess Biogas Available (m3/yr) [1]	621,864	719,626	1,409,555	1,409,555	1,409,555
Heat and Power Output (btus/yr) [2]	7,905,930,840	9,148,806,720	17,920,067,400	17,920,067,400	17,920,067,400
Electric Revenue ($/yr) [3]	69,510	112,612	220,577	220,577	220,577
Tipping Fee ($40/per ton)	882,240	897,120	1,383,160	1,383,160	1,383,160
Total Revenue ($/yr)	951,750	1,009,732	1,603,737	1,603,737	1,603,737
Construction Costs ($ millions)	9,925,200	10,092,600	15,560,550	15,560,550	15,560,550
Grants/Funding	N/A	N/A	N/A	7,780,275	15,560,550
O & M costs ($/yr)	1,102,800	1,121,400	2,697,162	2,697,162	2,697,162
Payback Period (years)	**10.4**	**9.9**	**9.7**	**4.8**	**1.7**

[1] 10% of biogas is retained to heat and operate the digester

[2] CHP has an efficient of 60%

[3] Assuming we sell 50-70% of our CHP output as electricity depending on the scenario; electric revenue is calculated using $0.06 kWh

4.5 Moving Forward

4.5.1 Policy Changes

Regulatory changes that mandate or incentivize diversion of organic waste from landfills and/or incentivize construction of waste-to-energy facilities will increase the feasibility of an anaerobic digester. Regulatory change would help create a market for food waste disposal and could enhance the economic viability of food waste collection and implementation of anaerobic digesters (VERMONT). Many states, including California, Vermont and New York City, have implemented laws and regulations that ban organic waste from landfills. While upstate New York has not yet implemented such a law, it is promising that it will happen because Governor Cuomo has set an aggressive goal of becoming 50% renewable by 2030. In 2016 Cuomo announced $150 million dollars were going to be allotted for renewable energy projects where the funding will build and expand large solar, wind, hydro and other renewable energy projects to meet the state goal (NYSERDA).

4.5.1.1 California

California implemented their Mandatory Commercial Recycling Law in May 2012. The Mandatory Commercial Recycling Law was one of measures adopted in the Assembly Bill 32 Scoping Plan by the Air Resources Board (ARB) pursuant to the California Global Warming Solutions Act (Mandatory Commercial Recycling, 2017). This law focuses on increased commercial waste diversion as a method to reduce GHG emissions. The law mandates that businesses that generate 4 cubic yards or more of commercial solid waste per week or multifamily residential dwellings of five units or more must source separate their recyclable materials and arrange for recycling services (Mandatory Commercial Recycling, 2017). There are multiple benefits associated with the Mandatory Commercial Recycling Law such as opportunities for businesses or multifamily complexes to save money, creating jobs by providing materials for recycling, reducing GHG emissions, keeping valuable materials out of landfills, and creating a healthy environment for the community (Mandatory Commercial Recycling, 2017).

4.5.1.2 Vermont

In 2012 Vermont passed Act 148: Universal Recycling and Composting Law. The law is designed to encourage the development of infrastructure and systems that will keep reusable resources out of the landfill and make progress in energy and resource conservation (Universal Recycling & Composting Law). The law includes bans on the disposal of certain materials and institute landfill bans which will be phased in through the year 2020. By 2020, food scraps from all business and residents will be banned from the landfill. This is designed to create demand for food scrap collection and support investments in new food scrap collection infrastructure. The law requires that haulers who offer services for collecting trash must also offer services for collecting mandatory recycles by 2015, and food scraps by 2017 (Universal Recycling & Composting Law). A proven incentive for residential customers to reduce the amount of recyclables that end up in the trash can is a program call "Pay-As-You-Throw (PAYT). PAYT is a variable rate pricing based on volume or weight of trash collected from a household (Universal Recycling & Composting Law). Therefore, those who engage in recycling or separating their food waste will pay proportionately less than those who do not.

4.5.1.3 New York City

In December of 2013, New York City passed Local Law 146: Commercial Organic Waste Law. The law took effect in July 2015 and mandated specific large-scale generators to arrange for the recycling of their organic materials or employ department-approved methods to process the materials themselves. Each waste generator is required to either ensure collection by a private carter, transport their own organic waste to a facility or provide organics processing on-site (ILSR). Under this law, establishments that produce food waste are also required to provide separate bins for the disposal of organic waste and post instructions on the proper separation of organic waste (Platt, 2016). Private waste haulers are required to deliver collected organic waste materials to a transfer station or directly to a facility for anaerobic digestion. Transfer stations that accept source-separated organic materials are also required to arrange for delivery of these materials to an anaerobic digestion facility (Platt, 2016). Any establishment, transfer station, or private carter that violates the Commercial Organics Law will be liable for a civil penalty of $250-1,000 per violation. The city is hoping to have an impact that reaches beyond NYC and sets an example on a national stage.

4.5.2 Funding Opportunities

Research was conducted on the various types of funding that would potentially be available for this type of project. Government incentives, which could include tax credits, grants, and low interest loans are a key determining factor in the economic feasibility of many anaerobic digester facility operations. For the funding of the Vermont Tech Community Anaerobic Digester, project feasibility and capital funding comes from grants from the U.S. Department of Energy, obtained with the help of U.S. Senator Patrick Leahy, and bond funding from the Vermont State Colleges (Vermont Tech Community Anaerobic Digester).

Past funding for similar projects revealed that there are a range of funding opportunities for renewable energy projects in New York state. Funding from NYSERDA can be considered for the first stages of construction for the anaerobic digester facility as the production grant awards new renewable energy projects based on their electrical capacity.

Funding was also available through a USDA program called, Rural Energy for America Program or REAP. The REAP program offers various loans for competition throughout the year as well as, up to $500,000 for green energy projects like anaerobic digestion. They have loan guarantees on loans up to 75% of total eligible projects costs; grants for up to 25% of total eligible project costs; combined grant and loan guarantee funding up to 75% of total eligible project costs. Where $5,000 is the minimum loan amount and 25 million is the maximum loan amount (Rural Energy for America Program Renewable Energy Systems).

4.6 Barriers to Implementation

During each stage during the process of anaerobic digestion there are barriers to implementation. However, they do not necessarily prevent an anaerobic digestion project from being successfully completed and utilized. Many barriers can be easily fixed or made up for, but some - like capital costs - are not an easy fix. There are high initial capital and operating costs depending on how much funding is received for the type and size of digester being built. Without finding a source for partial if not, all funding there would be no project.

The project would involve obtaining wastes from multiple sources as well as, contain some post-consumed food which increases the risk of contamination. Food waste from some manufacturers are generated in packaged containers, and removing packaging can be a serious obstacle (MA Department of Environmental Protection). In regards to the output, the biogas may need to be treated before it is used to generate heat and electricity. The most significant contaminant in biogas is hydrogen sulfide, which will corrode equipment if it is not treated; it could cost 25,000 dollars for hydrogen sulfide treatment equipment (Moriarty, 2013).

Keeping up with maintenance can be tedious, but is crucial. Whoever will be running the digester will have to be dedicated to the management of the digestion system and carefully pay attention to equipment maintenance and safety issues.

Some barriers for restaurants include space. Space is always a challenge for restaurants, many do not have space in their kitchen to have an extra bin to collect food waste. There is also an unaesthetic and gross appeal to food waste collection bins because they tend to smell and attract flies and rodents. Also, many restaurants might not be willing to pay any service fee for a collection program if they aren’t getting anything in return - what is their incentive? Then there is the component of teaching all employees to get into the habit of scraping only food waste into these bins.

5. Conclusion

Based on the conceptual analysis, the installation of an anaerobic digester at the Transfer Station on Weibel Avenue in Saratoga Springs represents long term economic, environmental and social benefits. In theory, anaerobic digestion is a step closer to achieving the triple bottom line by being an environmentally friendly means of waste reduction, by closing the waste loop cycle by turning a waste product into an economic asset and by providing a local source of renewable energy. As you can tell from our different scenarios, there is a great deal of uncertainty at every step of the process, and one changing factor can greatly help or hurt our bottom line. Through our analysis of the feasibility of this project, we realized the major hurdle to implementation would be the risk associated with the project. The risk lies in willingness of the community to participate and in the financial risk of a long payback period. The first risk, willingness to participate, can be overcome with the implementation of an organics law that would mandate the separation, collection and delivery of local organic wastes to the digester facility. This will create a steady and reliable waste stream, which is essential for the operation of the digester. While our study does not suggest that any of our potential feedstock suppliers will divert their waste to this digester, participating in this project can lead to positive publicity for any stakeholders involved. The second risk is the financial risk of a long payback period. Our conservative payback period time frame, which can be as high as 10.4 years, isn't very attractive to investors; but this risk can be combated with funding to cover the major capital cost of the digester. This can greatly reduce our payback period and make the project more economically attractive. Although this project essentially hinges on the economic feasibility, it is important to remember that this technology has many environmental benefits associated with it. Anaerobic digestion diverts food waste from landfills, which reduces the amount of methane that is emitted into our atmosphere. If the town can take into consideration the positive environmental and social aspects of the project, they can be one of the first towns to make this great leap toward sustainability and achieving the triple bottom line through anaerobic digestion and me a leader in the renewable energy movement.

7. References

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