Northborough Composting:

A Peri-Urban Land Conflict

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Submitted by:

Nicholas Bograd
Brett Carbonneau
Alexander Krasa
Benjamin Preston

Submitted to:

Professor Rosbach
Professor Dehner

Project Sponsor:
Office of Massachusetts State Senator Harriette Chandler

Abstract

Since the 2014 waste disposal ban, Northborough, Massachusetts has experienced an ongoing land-use conflict. Neighbors are concerned about an agricultural, large-scale composting operation at the Davidian Brothers Farm. In order to help resolve this conflict, we spoke with neighbors, farm owners, state agencies and legislators, and other experts to gain an understanding of the situation and knowledge of its causes and results. Our project culminated in providing the Office of State Senator Harriette Chandler with two videos and an informational matrix and website to educate food waste recycling operations on methods to mitigate concerns and create positive relations with their surrounding communities. We also detailed recommendations for the town and farm to aid in the resolution of their land-use conflict.

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Additionally, we would like to thank our sponsor, the Office of Massachusetts State Senator Harriette Chandler, specifically the senator and her Legislative Director and General Counsel, Mr. Bryan Barash. We thank them for their knowledge and willingness to assist our project in any way we asked for. Thanks to their foresight, contacts, and understanding of community projects, we were able to execute a strong project and create usable, effective deliverables.

Lastly, we would like to thank the large number of farms, organizations, state agencies, state and town officials, businesses, and communities who contributed to our project through interviews, survey responses, focus groups, and more. Without their assistance and willingness to aid in our research, we would not have been able to understand this type of issue and thus would have fallen short in our findings and recommendations made within this study.

Executive Summary

Introduction

In 2017, Northborough, Massachusetts is experiencing a land-use conflict in the form of a large-scale agricultural composting operation that is upsetting the nearby community. Since 2014, the Davidian Bros. Farm has been engaged in large-scale composting. This composting operation has partially resulted from a 2014 Massachusetts Department of Environmental Protection (MassDEP) regulation that promotes food waste recycling on large scales, the Commercial Food Waste Disposal Ban (Thompson, 2016). The farm uses large windrow compost heaps that some Northborough residents find visually imposing. The community members of Northborough have filed complaints with town officials, state legislators, and state agencies in regards to the composting operation. Additionally, some have complained of health problems they believe may be results of compost related pathogens or drinking water contamination. Due to this conflict, the Office of State Senator Harriette Chandler sponsored a study to better understand this situation and how stakeholders could work towards a resolution that could be beneficial for everyone involved.

Methodology

In order to positively influence this situation, we formulated two related goals to guide our work. First, we aimed to appease the community's concerns by presenting recommendations that all stakeholders could agree to. Second, we hoped to facilitate a lasting relationship between the Davidian Bros. Farm and its surrounding community in order to provide an example for other food waste recycling operations to follow.

We were able to make meaningful strides towards these aims by dividing our project into two phases.

<u>Phase 1: Develop a Northborough Case Study</u>

1. Investigate the primary concerns of the surrounding community and perspectives on those

concerns from experienced individuals outside of the situation.

2. Investigate the extent to which compost practices and outside forces, such as weather influence neighbors' complaints.
3. Explore possible composting legislation and its impact on local communities and farms.

Phase 2: Case Study Analysis and Solution Development

4. Identify cases with similar issues to the case study we have developed and comparatively analyze them against the Northborough case.
5. Develop and present a creative proposed solution tailored to the situation in Northborough.

We accomplished these objectives using a variety of methods to gather, analyze, and present data. Specifically, we distributed surveys, facilitated two focus groups, and conducted interviews with neighbors, town officials, state legislators, state agents of regulatory bodies, composters, and others who have investigated the issue. We chose to speak with these groups in order to gain the perspectives of different points of view involved in or investigating the situation. We also researched documentation such as news articles, reporting documents to state agencies, regulations, and other written information in order to expand our understanding of the situation and gather as much data as possible.

In order to investigate cases with similar aspects to that of Northborough, we surveyed over 20 Massachusetts farms and over 100 farms and organizations across the country. We communicated with three state agencies, as well as key stakeholders such as 31 farm owners in the other situations we studied. Using all of the data we amassed, we developed two videos and a vast matrix of information to educate future food waste recycling sites on best practices.

Findings

As a result of our research we found that there are a number of ways to deal with land-use conflicts ranging from implementation of technical systems to mitigate concerns to community outreach strategies to facilitate positive relationships between rural operations and their neighbors. Additionally, the keys to preventing such conflicts lay in inclusive planning, compromise, and communication. Food

waste recycling sites can be the source of many positive benefits for all stakeholders involved if they are operated with all parties in mind. This positive operation involves comprehensive oversight of variables within the composting process, as well as use of strategies to mitigate concerns that can arise. Additionally, all possible concerns and variables must be taken into account as individuals have different tolerances to different impacts of food waste recycling sites. Finally, although not a specific aim of our initial research, we also discovered that regulations governing these sites can vary widely and have a large effect on whether conflicts may or may not arise.

Recommendations

In an effort to resolve the current land-use conflict in Northborough, Massachusetts, we recommend that the Davidian Bros. Farm acquire several technical systems to mitigate the concerns of the surrounding neighbors including use of compost covers and bio-organic catalysts to reduce odors, health concerns, and wildlife attraction. We also recommend that both parties take steps to rebuild a positive relationship that can serve as an example for other communities. For instance, we recommend that concerned neighbors and the farm hold meetings on a monthly basis to revitalize communication between the stakeholders so that the situation may be resolved through compromise. Through these recommendations we hope to aid in the resolution of the Northborough land-use conflict.

Conclusion

As the need for sustainable practices and the sprawl of urban areas increase, the likelihood of this type of conflict arising increases as well. Thus, we hope that our educational videos and comprehensive matrix of strategies to mitigate concerns will help to resolve or prevent other land-use conflicts in the future. In terms of the situation in Northborough, we believe that our recommendations can play a significant role in the resolution of their conflict. We also note that should they resolve the tension in their situation they can serve as an example for other, similar cases in the future.

Table of Authorship

Section Title	Primary Author(s)	Primary Editor(s)
Abstract	Benjamin Preston	All
Acknowledgements	Benjamin Preston	All
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1. Introduction	Benjamin Preston	Brett Carbonneau Nicholas Bograd, Alexander Krasa
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2.4 Composting and Peri-Urban Agriculture (Introduction Paragraph)	All	Benjamin Preston
Importance of Composting	Benjamin Preston	All
Composting Methods and Regulations	Nicholas Bograd	Benjamin Preston, Nicholas Bograd, Alexander Krasa
Challenges and Resulting Solutions to Composting in a Peri-Urban Environment	Brett Carbonneau, Nicholas Bograd	Benjamin Preston, Nicholas Bograd
2.5 Davidian Bros. Farm in Northborough, MA	Benjamin Preston	Nicholas Bograd, Brett Carbonneau, Alexander Krasa
3. Methodology (Introduction Paragraph)	Brett Carbonneau	Benjamin Preston

3.1 Ethical Considerations and Institutional Review Board	Benjamin Preston	All
3.2 Phase 1	Brett Carbonneau	Benjamin Preston
Objective 1.)	Benjamin Preston, Brett Carbonneau	Brett Carbonneau, Benjamin Preston, Alexander Krasa
Objective 2.)	Benjamin Preston, Brett Carbonneau	Nicholas Bograd, Benjamin Preston, Alexander Krasa
Objective 3.)	Brett Carbonneau, Benjamin Preston	Nicholas Bograd, Alexander Krasa, Benjamin Preston
3.3 Phase 2	Brett Carbonneau	Benjamin Preston
Objective 4.)	Brett Carbonneau, Benjamin Preston	Nicholas Bograd, Alexander Krasa, Benjamin Preston
Objective 5.)	Benjamin Preston	Brett Carbonneau, Benjamin Preston
Findings Chapter (Introduction Paragraph)	Benjamin Preston	Alexander Krasa, Nicholas Bograd
4.1 Findings Group 1	Benjamin Preston Brett Carbonneau	Nicholas Bograd, Alexander Krasa
Finding 1.)	Benjamin Preston	Nicholas Bograd Brett Carbonneau, Benjamin Preston
Finding 2.)	Brett Carbonneau, Benjamin Preston	Alexander Krasa, Nicholas Bograd, Benjamin Preston
4.2 Findings Group 2	Benjamin Preston	Nicholas Bograd Brett Carbonneau, Alexander Krasa
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Finding 7.)	Benjamin Preston, Brett Carbonneau	Alexander Krasa, Nicholas Bograd
4.4 Findings Group 4	Benjamin Preston	Brett Carbonneau, Alexander Krasa
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6. Conclusion	Benjamin Preston	Brett Carbonneau
Appendix A	Nicholas Bograd	Nicholas Bograd, Alexander Krasa
Appendix B	All	All

Appendix C	Brett Carbonneau	All
Appendix D	All	All
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Appendix G	All	All
Appendix H	All	All
Appendix I	All	All
Appendix J	Brett Carbonneau	Benjamin Preston, Brett Carbonneau
Appendix K	Nicholas Bograd	Alexander Krasa, Nicholas Bograd
Appendix L	Brett Carbonneau	All
Appendix M	Brett Carbonneau	Benjamin Preston, Brett Carbonneau
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1. Introduction

Environmental education and consciousness, ecotourism, a strong sense of community pride, and local, fresh produce are just a few examples of potential benefits that can be seen by residential communities which border farms. Over the past 30 years, as more rural communities are becoming urbanized, an increasing number of small towns have reaped these benefits (Cohen & Reynolds, 2015).

One such area that has experienced difficulty attaining these benefits is the town of Northborough, Massachusetts. Northborough is a small town of about 19 square miles located in central MA, just northeast of Worcester (Town of Northborough, 2016). The town has a population of just over 14,000 people (Town of Northborough, 2016). There are three farms located in the town, including the subject of a peri-urban land conflict, the Davidian Brothers Farm.

Since 2014, the Davidian Bros. Farm has been composting on a large scale with a 12 acre operation. This composting has partially resulted from a 2014 Massachusetts Department of Environmental Protection (MassDEP) regulation that promotes food waste composting on large scales, the Commercial Food Waste Disposal Ban (Thompson, 2016). While there are many possible benefits to peri-urban agriculture and composting, the town of Northborough and the Davidian Bros. Farm have not been able to realize all of these. Instead, Northborough residents have been filing complaints with the town government, the Massachusetts Department of Agricultural Resources (MDAR), MassDEP, and the Office of Massachusetts State Senator Harriette Chandler about possible negative consequences of the farm's composting. These include concerns with strong odors, wildlife attraction, and possible health risks related to the composting.

These concerns are dividing the community from the farm and threatening the relationship between these two stakeholders. This lack of understanding between the two parties prevents either side from enjoying the benefits of peri-urban agriculture and composting. Thus, alleviating the concerns of the neighbors without alienating the Davidian Bros. Farm is vital to facilitating the creation of a lasting

understanding between the farm and its surrounding community. Once these concerns are mitigated, the town of Northborough will be able to enjoy more benefits from peri-urban agriculture.

We have worked with the Office of Massachusetts State Senator Harriette Chandler to ascertain the key concerns of the Northborough community and to address these issues, without negatively affecting the farm's business. In order to better understand the situation and our project, in Chapter 2 of this report, we explore relevant background to the issue and describe composting and its challenges in peri-urban environments. Following the background, we describe our methodology for working through the project, data and findings. Finally, in Chapter 4 we share our project findings and in Chapter 5 our recommendations for both the Davidian Brother's Farm and the town of Northborough.

2. Background

In order to better understand the tension surrounding the situation in Northborough, Massachusetts, we explored the importance of agriculture, the benefits and challenges of peri-urban agriculture and composting, and finally how these factors play into Northborough's land conflict.

2.1 Farming's Importance in the 21st Century

Population growth, the availability of farmable land, scarcity of usable water, and climate change greatly affect production of food in the modern agricultural environment and will for the years to come. These factors include population growth, the availability of farmable land, scarcity of usable water, and change in climate (Cohen & Reynolds, 2015). The population of the planet is increasing at an exponential rate. Experts predict that the planet's population will increase by roughly 3 billion people by the mid-21st century (Fedoroff et al., 2010). Farmers will need to produce a continuously increasing amount of food and resources in order to account for the rising population. To do so, these farmers will need to increase

access to available farmland and supplies. Due to deforestation and urban growth, much usable farmland has been developed into cities and urbanized areas (van Veenhuizen, 2005).

An urban ecological footprint, the sum of all the land and water required to meet the material consumption and waste processes of a specific population, can show how the surrounding rural and natural areas are affected by cities (Mougeot, 2000). An analysis of current US ecological footprints reveals an increasing demand for natural resources and thus competition for natural resources and raises the issues of both equity and the long-term sustainability of food production (van Veenhuizen, 2005). The affected competition for supplies illustrates the need for agriculture today and agricultural expansion for the future.

Urban agriculture will grow more important as urban sprawl, the continuous expansion of cities and suburbs, continues to impact open space and more land becomes urbanized. Expanding peri-urban agricultural practices is one way to ease the impacts of urbanization. As agricultural operations become more prevalent and farming easier in a more urban environment, the concerns around limited resources and space for farming will lessen while the importance of food production continues to rise (Mougeot, 2000).

2.2 Peri-Urban Agriculture

Peri-urban agriculture is an important part of the economy in the 21st century. As a result of increasing population and the sprawl of urbanized areas, agriculture and farms once located in rural areas are becoming surrounded by more and more people (Cohen & Reynolds, 2015). This rural-urban transition zone, where these respective land uses collide and can create controversy, is described as a peri-urban area. This situation puts both new residents and established farm owners in positions that they have not been in before. Issues may arise that previously had not existed due to farms' isolated locations. However, if agriculture and surrounding residents can be integrated in an effective way, both parties can

benefit. According to Mougeot (2000), the defining characteristic of peri-urban agriculture is the role it plays within the urban economic, social, and ecological systems. An example of a peri-urban area abutting farmland is shown in Figure 1.

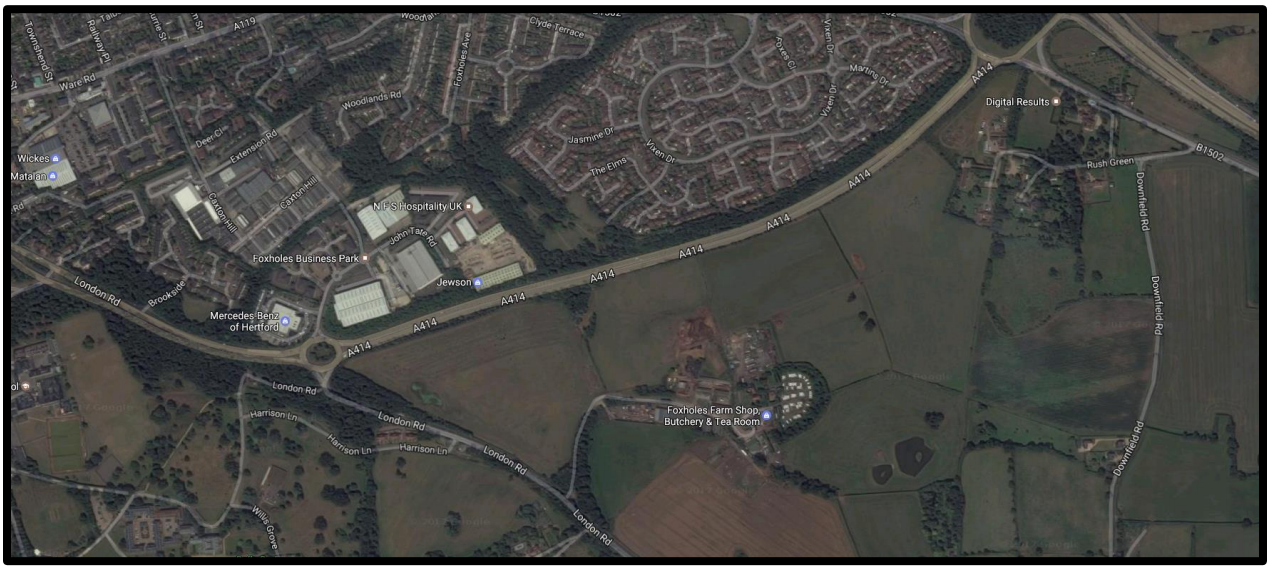


Figure 1: Peri-urban area abutting farmland example
(Google Maps imaging: Hertford SG13, UK, 2017)

Even though farms on the interface of urban and rural areas produce thirty-three percent of the value of agricultural output in the United States, these peri-urban farms only account for sixteen percent of the cropland (Heimlich & Anderson, 2001). These farms have access to many resources that allow them to thrive in their communities. Some of these resources include access to a larger labor supply, opportunities for farmers to be employed while still operating their farms, additional markets for selling crops, and increased income from community-based activities (Levi & Sperry, 2007). Economically, peri-urban agriculture has the ability to open up new micro-industries such as businesses in the community to supply farms with fodder, compost, worms, etc. (van Veenhuizen, 2005). Additionally, there is the possibility of using urban organic wastes and water for recycling practices. Agricultural practices such as composting, vermiculture, and wastewater recycling can also reduce the ecological footprint of the nearby community (van Veenhuizen, 2005), allowing for environmental benefits as well as a sense of pride for

the farm in the town or city. Nearby residents have easy access to local, fresh food, landscaping related businesses, and recreational opportunities. However, these benefits need to be viewed alongside possible disadvantages in order to understand the best type of peri-urban agriculture for a community so that the town or city can enjoy all that peri-urban agriculture can offer.

2.3 Challenges and Mitigations to Peri-Urban Agriculture Issues

Due to the effects of urban sprawl, farmers may have to adapt to rising land values and an increasing number of neighbors. Farmers can adapt by emphasizing higher value products, focusing on urban marketing, and using practices that better fit an urban setting (Heimlich & Anderson, 2001).

One significant challenge to peri-urban agriculture is possible health issues arising from agricultural practices. Human illnesses can result from peri-urban agriculture due to heavy metals from industries and traffic emissions near the farm which can contaminate soil and crops (van Veenhuizen, 2005). In addition, many diseases can be spread from agricultural practices such as the transmission of illnesses from livestock due to the farm's close proximity to its neighbors. For example, *Leptospirosis*, a bacterial disease which can lead to flu-like symptoms and kidney or liver failure, can spread from infected cows, pigs, sheep, or other livestock to community members (van Veenhuizen, 2005). Other diseases spread by livestock include *Brucellosis*, *Campylobacteriosis*, and *Influenza* (Ministerrådet, 2009).

In 2000, a Wall Street Journal article described an issue relating to urbanization and agriculture in Whidbey Island, Washington. Following a population increase of 20 percent between 1990 and 1999, recent studies found that a type of fecal bacteria that may have originated from the surrounding farms, was measured at unsafe concentrations in nearby wetlands (Jung, 2000). Under Washington State's Growth Management Act, farms are not required to protect wetlands (Jung, 2000). The Growth Management Act requires the state's fastest growing areas to simply develop plans for the protection of wetlands and accommodation of growth but does not establish a method to monitor these plans (Jung, 2000). Thus, the farms and town in Whidbey Island, must regulate themselves on such matters. However,

the main problem is the level of difficulty town officials had in identifying the exact sources of the fecal contamination and therefore they are unable to decide the specific regulations needed to appropriately resolve this contamination issue (Jung, 2000). Consequently, both the farmers and town are now working together to develop solutions that take into account both economic impacts and environmental concerns. This compromise and collaborative work is the goal for any land conflict situation. In this example both parties understand the benefits possible if they are able to alleviate concerns surrounding the farm's practices.

Another example of a peri-urban agricultural challenge is the conflict resulting from peri-urban land use and right-to-farm laws. The purpose of these laws is to protect existing investments of farms by enabling farmers to continue farming even if their operations created some sort of nuisance for nearby landowners. In the late 20th century, the loss of farmland and increase in nonagricultural uses of land in the countryside justified right-to-farm legislation (Centner, 2006). The existence of these laws and their use illustrate the conflict between agricultural farms and residential neighbors who have nuisance complaints with the farms.

Right-to-farm laws have been put in place to protect agricultural operations, but place many burdens on neighboring residents. One problem for farmers of livestock involves increased resistance from neighbors concerning odors, health, and property values: "environmental laws, zoning ordinances, health regulations, and nuisance lawsuits are being used to confront objectionable agricultural activities" (Centner, 2006). Residents who neighbor farms are having difficulty finding ways to come to terms with the impacts of right-to-farm legislation. Another defense for farmers is the coming-to-a-nuisance doctrine. The doctrine states that people who move near agricultural areas, cannot use nuisance laws to end the farmer's activities and practices. The states of Minnesota, Mississippi, Pennsylvania, and Texas are also trying to limit nuisance actions by adopting statutes of limitation (Centner, 2006). For example, according to the statutes, neighbors who fail to file their nuisance claim after a certain time period cannot maintain their claim.

Some states have tried to encourage better agricultural management processes by requiring farms to qualify for nuisance protection. The right-to-farm laws in these states have provisions that restrict nuisance protection to operations with sound agricultural practices, generally accepted practices, and the best practices, depending on the state. These laws act as an incentive for agricultural operations to refrain from negative practices (Centner, 2006). Right-to-farm laws exemplify some difficulties and solutions to peri-urban land conflicts between farmers and neighbors with nuisance complaints. For instance, in Massachusetts, no nuisance claim may be maintained against an agricultural operation that has been present for over a year, unless negligent conduct or actions inconsistent with generally accepted agricultural practices exist. Additional state laws, including those in California, Pennsylvania, and Iowa, are described in the Right-to-Farm Statutes Chart in Appendix A.

2.4 Composting and Peri-Urban Agriculture

One practice of peri-urban agriculture that can be both a challenge and a benefit to peri-urban communities is composting. Composting is a natural biological process that biodegrades organic waste (i.e. food waste, manure, leaves, grass, wood, etc.) and transforms it into organic fertilizer (Composting, 2014). Composting is a great way to recycle many types of waste but there are a multitude of challenges to composting safely and successfully. Additionally, if the composting is maintained and carried out with the community in mind, it can be a great method for a community and farm to build a relationship and support each other.

Importance of Composting

Quality compost has many benefits but, is only generated within limited desired temperature, moisture, and ingredient ranges. Compost is used in gardens, greenhouses, and on farmland as a natural fertilizer and soil enhancer (Miller, 1997). Certain composting processes, such as maintaining relatively high temperatures while not high enough to harm beneficial microbes, have been proven to reduce

pathogens from biological waste (Kim, Shepherd, & Jiang, 2009). However, composting alone is not the solution to attaining healthy crops, but it is an integral part of the process and essential for organic farms (Miller, 1997). Many plants that are grown using organic methods show an increase in crop height, width, and yield (Norton & Johnson, 2008). A 2010 study performed by the University of Maine Cooperative Extension and Woods End Laboratories using sweet corn found that seeds planted with compost produced significantly longer ears of corn and taller plant stalks over multiple seasons (Jackson, Briton, Handley, Hutchinson, & Hutton, 2013). This increase in crop yield and quality from composting only adds to the existing benefits of peri-urban agriculture.

Composting also has numerous advantages that can improve the surrounding environment. Compost is a natural fertilizer, and can be used as a natural pesticide as well. This natural pesticide primarily targets weeds, fungi, and nematodes (Cayuela & Millner, 2008). The compost retains moisture, reducing the requirement for water during the product's growth. Additionally, compost is completely natural and thus is much better for the soil as its use does not degrade the soil over time as other fertilizers do because of their toxic ingredients. Compost is an effective strategy for waste disposal reduction as well. This decrease in the disposal of organic materials means that landfills do not have as much material, thus reducing the amount of carbon monoxide, methane, and nitrous oxide released into the atmosphere (Epstein, 1997). Nitrous oxide is a greenhouse gas 310 times more harmful than carbon dioxide, so its removal from the atmosphere is essential (Eureka Recycling, 2008).

The economic advantages of using compost over synthetic fertilizers and pesticides target costs. The cost of buying either fertilizers or pesticides is eliminated when compost can be created from leftover waste and used for those purposes. Additionally, compost reduces transportation costs as some of waste can go into compost piles instead of being transported to a landfill. Finally, there is the option to sell the compost to the community and surrounding businesses for an added profit (Eureka Recycling, 2008).

Composting can be a method for peri-urban farms and their communities to develop positive relationships and benefit farm-community interactions (Epstein, 1997). This beneficial relationship can

take many forms including the farm composting waste for the town and providing education opportunities for the community. Agricultural composting is an effective strategy for teaching visitors to a farm the importance of sustainability and the environmental benefits of composting (van Veenhuizen, 2005).

The multitude of positive impacts that agricultural composting can have is what signifies the practice as integral to modern recycling operations. Thus, while composting without an understanding of the negative externalities on neighboring persons can have detrimental effects on communities, it is possible to address neighbors' concerns in order to accentuate the benefits.

Composting Practices and Regulations

There are a multitude of ways to implement composting. These different approaches for setting up a compost system and maintaining different levels of aeration, moisture content, and temperature include windrow or heap/pile composting, bin or in-vessel composting, trench or pit composting, vermiculture, and more (Types of composting, 2016). These categories represent the most common types of composting.

Windrow composting is the most basic but also the most common for large-scale facilities, as it involves piling up material in elongated heaps called windrows (van Veenhuizen, 2005). These windrows can be over 8 feet high, over 11 feet wide, and over 100 feet long. *Bin composting* is similar to windrow composting except that the piles are contained by a structure on at least three sides to create a more efficient use of space (Domingo & Nadal, 2009). *Trench composting* has a lot of different variants including: long open-air trenches in the ground filled with organic material, covered trenches, and even completely buried trenches to support a planting bed on the covering soil (van Veenhuizen, 2005). *Vermiculture* is another viable option for smaller composting practices and, given a pre-existing source for the worms used to break down organic material, larger facilities as well (Types of composting, 2016). Thus, with all of these different types of composting and the differentiation in temperature, oxygen levels, and moisture changes, the real difficulty is deciding which type of composting will work best for a given

situation.

For each type of composting there are different advantages and drawbacks. Bin composting can require an external energy supply and is usually an intensive investment for large scale operations (Sherman, 2005). Additionally, once bin-composting systems are set up, they are more expensive to operate and maintain than other options. However, the advantage of using bin composting is that less space is required since the compost is contained. For trench composting, it is difficult to control leaching but the composting material can be buried in the trench and serve as a bed for planting (Miller, 1997). In the end, the most common type of composting used by developing countries and developing operations is windrow composting (van Veenhuizen, 2005). Each of these composting methods has various pros and cons but it comes down to the balance between the ease of operation and cost. Table 1 summarizes the benefits and drawbacks of these composting types.

Overview of Four Basic Composting Types			
Compost Type	**Characteristics**	**Benefits**	**Drawbacks**
Windrow Composting	➢ Large, elongated heaps of compost	➢ Suitable for large scale operations and extensive amounts of compost ➢ Simple upkeep methods	➢ Open to wind and weather ➢ More odor propagation ➢ Expensive machines for large scale heap-upkeep ➢ Space needed
Bin/in-vessel Composting	➢ Compost is contained by structure on at least 3 sides of pile	➢ Contained pile ➢ Simple compost style ➢ Little space required ➢ Less seasonal limitations	➢ Size limitations ➢ Can be difficult to access/turn with containment structure ➢ More expensive to maintain
Trench Composting	➢ Long, open air trenches ➢ Covered trenches ➢ Completely buried trenches	➢ Less susceptible to wind patterns ➢ Provides nutrient-rich base for soil put on top of trench	➢ Difficult to control leaching or runoff ➢ A lot of space necessary ➢ Initial setup costs and installation processes ➢ Difficult pile maintenance
Vermiculture	➢ Worms breaking down biodegradable material	➢ Ease of operation ➢ Low initial investment ➢ Can use in a bin or windrow style pile (simple) ➢ Little space needed	➢ Worms sensitive to changes in climate ➢ Pests attracted can consume worms ➢ Bin opened can produced smelly odor

Table 1: Overview of Four Basic Composting Types
This table shows the comparative benefits and disadvantages of each of the above basic types of composting.

According to Massachusetts state laws, there are various regulations that owners of compost operations must follow. Both MassDEP and MDAR are responsible for composting registration oversight (Agricultural Composting Program, 2014). For agricultural composting operations, MassDEP has granted conditional exemptions under the Solid Waste regulations (310 CMR 16.00) (Martinson, S., van de Kamp, M., & Tso, S, 2010). This exemption allows for composting operations on agricultural land specifically to fall under MDAR instead of MassDEP. Agricultural composting operations only have to register with MDAR if they are planning to compost waste materials on their property (Martinson, S., van

de Kamp, M., & Tso, S, 2010). Once a farm is registered with MDAR it attains the status of an agricultural operation conditionally exempted from site assignment as a solid waste facility. This status means that the agricultural composting operation is legitimized, has exemption from related permitting requirements and that MassDEP has minimal regulatory control over the farm (Martinson, van de Kamp, & Tso, 2010). Thus the farm has a wide range of control over its own composting operation as long as it follows base guidelines set by MDAR, which is important as the MassDEP has stricter regulations. For instance, MassDEP requires an odor control plan, toxic control plan, contingency plans, and more for composting operations, while MDAR simply states that the operation must attempt to limit odor. However, practices under MDAR regulations do not need to follow these MassDEP guidelines at all, as they are exempt.

Some states, including Oregon and Washington, are developing laws requiring businesses to compost all of their food and organic waste (Risse & Faucette, 2009). Other states already require counties to compost. Massachusetts however, does not require composting, but any site producing over a ton of organic waste per week needs to send it to a more sustainable type of site than a landfill. For instance, a compost site or anaerobic digester (Solid Waste Management, 2014). While these regulations are beneficial, the effects to the surrounding community present many challenges that need to be considered.

Composting Challenges and Methods to Mitigate them in a Peri-urban Environment

The main challenges of composting in a peri-urban area include: health hazards, odors, and wildlife attraction. While these effects are common, there are ways to minimize these negative effects in order to take advantage of positive ones brought by composting.

The health hazards associated with composting can affect workers of composting facilities, nearby residents, and the consumers of products treated with compost fertilizers (Pichtel, 2014). These health effects stem from many sources throughout the composting lifecycle. Shown in Figure 2 is a chart

illustrating these sources and how their detrimental effects can be spread.

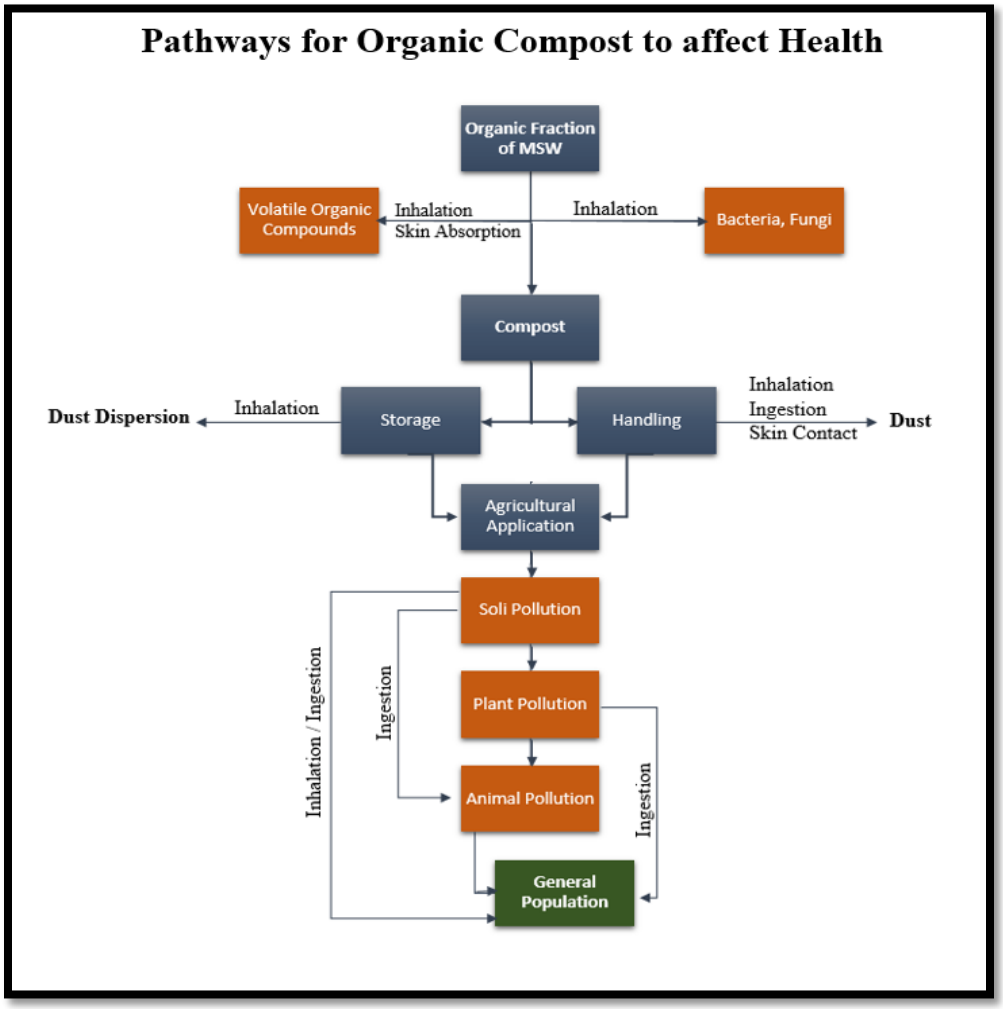


Figure 2: Pathways for Organic Compost to affect Health
(Domingo & Nadal, 2009)

To start, the organic fraction of municipal solid waste (MSW) can produce volatile organic compounds or bacteria/fungi that can be inhaled or absorbed by the skin. Following the chart downwards, emissions from the organic MSW in composting can also be inhaled, absorbed, or ingested by humans and animals throughout the different stages of composting.

The many adverse health effects that can result from compost include, but are not limited to, pulmonary inflammation, asthma, bronchitis, fevers, infections of eyes, ears, and skin, as well as other diseases (Domingo & Nadal, 2009).

Maintaining a moderate temperature and proper aeration of a compost pile can minimize or prevent these adverse health effects. There are two main types of composting aeration: passive aeration

systems, which require little attention, and active aeration systems, which are controlled through mechanical processes (Sherman, 2005). It is important to maintain the correct temperature in both of these composting methods because when there is an excessive amount of heat, the compost will dry out and kill the beneficial microbes in the pile (Miller, 1993). Horizontal-vertical aeration technology is one way of controlling the temperature passively. Inverted, T-shaped pipes are perforated and placed into the compost pile (Kutsanedzie, Rockson, & Achio 2012). This practice allows fresh air to enter the piles and waste gasses to exit. Another way of controlling air intake is through forced aeration technology. This idea uses an electric blower controlled by timers that blows air through perforated pipes (Kutsanedzie & Rockson, 2012). While these methods were found to improve the quality of the compost, they cannot prevent all of the negative health effects associated with composting.

Another main disadvantage of composting is the potential resultant odor. This is especially an issue when food waste is involved, as in the case of Davidian Bros. Farm in Northborough, Massachusetts. Similar to minimizing the health effects, odor can be minimized by ventilation. Increasing the pH level can also decrease odor as this promotes cooling and oxygen supply and is carried out by adding materials high in pH such as wood-ash (Ministerrådet, 2009). This practice will treat the odors before they are released into the surrounding environment. Adding water to the compost may be necessary since food waste is high in energy and matured compost has low energy levels (Ministerrådet, 2009). In terms of oxygen levels in the pile, the goal is to keep these levels above 10% to prevent the pile from becoming aerobic (Richard & Trautmann, 1996). Table 2 below, is a chart that summarizes the sources of various odors produced from composting.

Odors from Composting with Food Waste		
Source/Odor Category	**Associated Gasses**	**Possible Odors**
Sour milk, vinegar, yeast	➢ *Acetic Acid* ➢ *Butyric Acid* ➢ *Propionic Acid* ➢ *Heptanal*	➢ Pungent (*Acetic Acid*) ➢ Rancid, sour, sweaty (*Butryic Acid, Propoinic Acid, Heptanal*)
Rotten eggs, garlic	➢ *Merkaptans* ➢ *Sulphides* ➢ *Allyl Mercaptan*	➢ Putrid (*Merkaptans*) ➢ Rotten eggs (*Sulphides*) ➢ Garlic, skunk *(Allyl Mercaptan)*
Feces, manure	➢ *Indole* ➢ *Skatole*	➢ Fecal odor (*Indole, Skatole*)
Terpenes, pine citrus	➢ *Limonene* ➢ *Menthol* ➢ *a-pinene* ➢ *b-pinene*	➢ Orange, pine (*Limonene*) ➢ Minty (*Menthol*) ➢ Pine odor (*a-pinene, b-pinene*)
Grass, wood, smoke	➢ *Pyrans* ➢ *Furans* ➢ *Cis-hexen-1-ol* ➢ *b-cyclocitral*	➢ Burning wood, smoky (*Pyrans, Furans*) ➢ Tobacco, woody, grassy (*Cis-hexen-1-ol*) ➢ Hay, burnt (*b-cyclocitral*)
Sweet fruit, vegetables	➢ *Aceton* ➢ *Acetaldehyde* ➢ *1-dodecanol*	➢ Sweet (*Acetaldehyde*) ➢ Soapy, fruity (*1-dodecanol*)
Fish, ammonia	➢ *Ammonia* ➢ *Amines* ➢ *Dimethylamine* ➢ *Methylamine*	➢ Medicinal odor (*Ammonia*) ➢ Fishy (*Trimethylamine, Dimethylamine, Methylamine*)
Yard trimmings	➢ *Volatile Fatty Acids (VFAs)*	➢ Vinegar, body odor (*VFAs*)
Other gasses from composting	➢ *Isovaleric Acid* ➢ *Propionic Acid* ➢ *Benzaldehyde* ➢ *Decanal*	➢ Rancid, moldy cheese, fecal (*Isovaleric*) ➢ Sour, pungent, rancid (*Propoinic*) ➢ Bitter, possibly pleasant (*Benzaldehyde*) ➢ Citrus, soapy (*Decanol*)

Table 2: Odors Adapted from Composting with Food Waste
(Rosenfeld et al. 2007; Campbell & Gage; Goldstein, 2002; McGee, 2005)
A chart showing what types of odors common materials used in composting generate and their associated gasses.

Electronic noses, or odor sensors, represent one recent technological development that may help target the sources of odors so that they may be reduced. They have been used in the food industry, but also have the potential to identify specific odors that come from composting (Sironi, et al., 2007). Many companies rent, lease, sell, or perform testing using these electronic noses or similar air quality sensors. These odors can then be minimized after determining the location of the odor's origin material. Then the odors can be contained, treated or diluted, or even masked (Ministerrådet, 2009). For instance, knowing the material origin of an odor allows one to make sure that material no longer makes its way into the compost or to make sure that it is suitably pre-processed to neutralize its smell. Knowing the specific compound that the smell comes from enables one to deal with the specifics of chemically treating that compound to counteract its odor. Figure 3 is a summarized chart of what the ideal properties of composting piles should be in order to improve the overall quality and reduce odors.

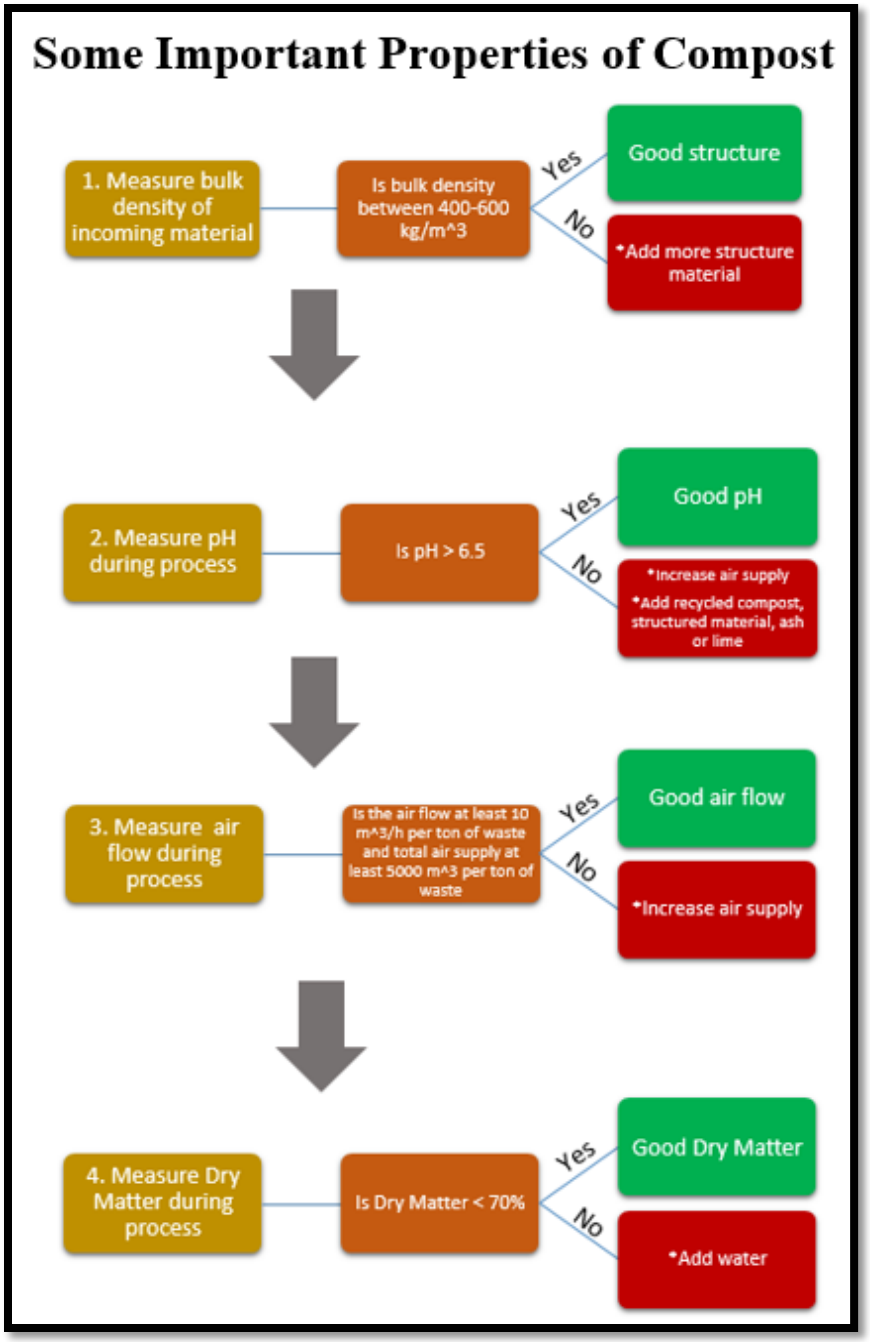


Figure 3: Some Important Properties of Compost
(Ministerrådet, 2009)
A chart detailing some optimal properties of composting with food waste.

An initial method used to prevent odor problems is to start by determining a suitable site location to begin composting, which minimizes the potential for odor issues in the future. Some factors for determining site location include distance to needed suppliers, a buffer zone between the compost and residents, soil topography and characteristics, as well as the amount of land needed for the operation (Pichtel, 2014). These factors can be very important to avoid safety and nuisance concerns. One way to limit concerns is by having an extensive natural buffer zone in the form of trees and shrubs around the compost. Specific buffer zones sizes are determined by state and local regulations (Pichtel, 2014). A firm base for soil is also preferred so that any runoff is controlled and groundwater contamination prevented. Sufficient land is necessary for the pre-processing, processing, and post-processing stages of composting (Epstein, 1997). Other factors to consider are existing infrastructure, zoning issues, and nearby residents (Pichtel, 2014). These safe management practices are necessary to the success of any composting operation.

A further drawback is the activation of pathogens as a result of certain composting methods and practices. Pathogens are harmful microbes that reside in the compost and can cause illness in humans. The most common pathogens seen in composting are harmful fungi, bacteria; though, there are also volatile organic compounds (VOCs) that can be harmful to humans when ingested (Vaddella et al., 2016). Many of these are ingested or inhaled with organic dust and can cause a multitude of illnesses ranging from gastrointestinal disturbances, fevers, and infections and irritations of eyes, ear and skin (van Tongeren et al., 1997). Some fungi, such as *Aspergillus fumigatus,* can travel on the organic dust from unmonitored compost piles more than 800 ft. downwind and affect those who inhale it (Pandey et al., 2016). Thus, in a peri-urban area where residences are located close to the farm, it is imperative to take measures to neutralize these pathogens.

Some steps to minimize dust production include keeping compost piles moist, having proper ventilation, and providing gas masks for those working with the compost (Pichtel, 2014). Moisture

content needs to be monitored though, as an over moisturized compost pile can promote pathogen activation rates to raise exponentially. However, a very dry compost pile can kill microbes that decompose organic matter and lead to compost fires (Pandey, 2016). The optimal range when composting yard waste is between a 40% and 60% moisture content (Cochran, 1996). While this factor is important in minimizing pathogen activation, the aspect with the largest impact is that of temperature. Temperature range can be the determining factor between successful compost and a pathogen-infested compost. A 2016 study (Pandey et al.) showed that the optimum temperature for composting with a specific in-vessel system was 60ºC. This temperature, in an aerobic compost pile, was extremely effective in pathogen inactivation. E. coli populations were undetectable after 16-25 hours and Salmonella counts reached the same in only 80 minutes (Pandey et al., 2016). Thus, while many pathogens can come from composting, there are effective ways to make composting safe so its benefits may be enjoyed.

A final, more modern method for mitigating many of the negative side effects associated with compost is anaerobic digestion (AD). AD is the process through which biodegradable material is broken down in the absence of oxygen (Harvest Power, 2017). While this process is similar to composting and does occur in nature, it can be performed on a large scale through controlled, man-made processes. These occur within anaerobic digesters, or large, enclosed structures where temperature and other variables can be controlled and monitored (Fitzgerald, 2015). An example of an anaerobic digester from the Jordan Dairy Farm in Rutland, Massachusetts can be seen in Figure 4 below.

Figure 4: Photo Image of Jordan Dairy Farm's Anaerobic Digester
This figure shows an example of an anaerobic digester situated on a dairy farm.

Much of AD in the United States is performed in water treatment plants to separate and degrade the wastes within the water those operations receive. However, the process is also a viable option for waste management similar to composting, as it is widely used in Europe (Fitzgerald, 2015). For instance, it can even be compounded with traditional composting in order to achieve the same results while limiting compost-related issues. This setup can be seen in Figure 5 below.

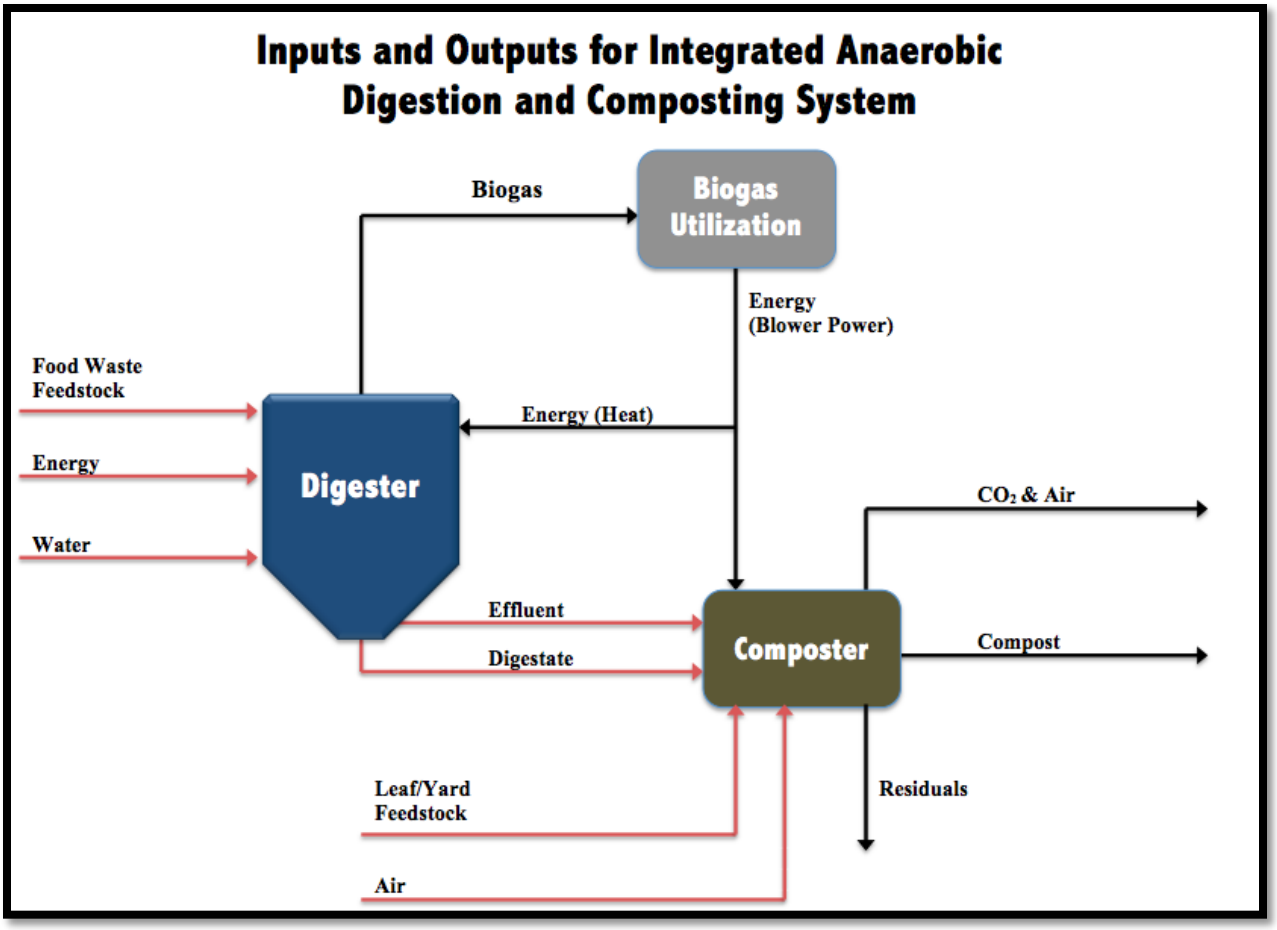


Figure 5: Inputs and Outputs for Integrated Anaerobic Digestion and Composting System (Kraemer & Gamble, 2014)

This figure shows an example setup for an anaerobic digestion system integrated with a compost system. It illustrates both the inputs and outputs of each part of the system and how the two practices are integrated into a single process.

In a composting role, AD is used to break down wastes including food waste, yard trimmings, and other biodegradable materials into biogas. This resultant gas is primarily made up of methane and carbon dioxide, generally making up at least 90% of the mixture (Kraemer & Gamble, 2014). As a natural gas this byproduct can then be used to power the anaerobic digester which requires less power than natural gas is produced; meaning that the operator of the anaerobic digester usually has excess power that can either be diverted to other operations on-site or given back to the grid for a monetary gain (Kraemer & Gamble, 2014).

Along with this biogas, AD produces resultants in the form of solid and liquid digestates. This result is the material that cannot be digested by the microbes in the AD process. The solid portion is mainly comprised of lignin and cellulose, stable and organic material that can be used as a compost-like fertilizer (Mutnuri & Bhavnagar, 2014). The liquid portion of the digestate, also referred to as effluent, is rich in nutrients and can be used as a fertilizer as well (Akhiar, Battimelli, Torrijos & Carrere, 2017). However, depending on the materials being digested, the effluent may have some level of potentially toxic compounds. Thus, it may need to be preprocessed or processed further following digestion to remove these toxins (Xu, Wang, Lin, & Li, 2016).

AD is a viable option for many composting operations and due to the confinement and controllability of anaerobic digesters, many composting related issues such as odor and health risks can be minimized or eliminated.

Below, in Table 3, the major challenges associated with composting can be viewed with their composting causes, resultant issues, as well as different methods that can be used to mitigate those issues.

Overview of Challenges of Food Waste Composting on a Large Scale in Peri-urban Areas				
Challenge	**Cause**	**Associated Issue**	**Possible Methods to address**	**Drawbacks of Methods to Address**
Odor	➢ Contents of the compost ➢ Inadequate aeration; moisture level ➢ Other properties of compost	➢ Illnesses ➢ Limited use of outside yards ➢ Wildlife attraction ➢ Stress ➢ Decrease in property value	➢ Anaerobic digester ➢ Breathable, tarp-like covers designed for compost ➢ Legislation regulating odor/gas concentration levels	➢ Anaerobic digester may still cause odors if performed incorrectly ➢ Composting covers may only reduce odor levels ➢ Legislation may negatively impact the composting farm ➢ Costs to farm, neighbors and/or government
Noise/Road Use	➢ Commercial Trucking	➢ Semi-trailer trucks using narrow residential roads to deliver food waste for composting ➢ Contents leaking from trucks ➢ Loud disrupting noises ➢ Stress ➢ Decrease in property value	➢ Moving composting location ➢ Legislation limiting road use for large trucks ➢ Limiting the hours of operation	➢ Moving the compost location may be difficult for the farm ➢ Legislation may negatively impact the composting farm ➢ Costs to farm, neighbors and/or government
Wildlife Attraction	➢ Contents of the compost (food waste) ➢ Location of the composting operation	➢ Flies/crows/mice/rodents/larger wildlife affecting neighboring properties ➢ Increase in the amount of wildlife in the area ➢ Stress ➢ Decrease in property value	➢ Anaerobic digester ➢ Breathable, tarp-like covers designed for compost	➢ Composting covers may only reduce the amount of wildlife ➢ Costs to farm, neighbors and/or government
Health Effects	➢ Contents of the compost ➢ Wind ➢ Emissions from the compost	➢ Children/neighbors being affected by the health hazards such as head migraines, vomiting; asthma, etc. ➢ Well contamination ➢ Water body contamination Stress ➢ Decrease in property value	➢ Anaerobic digester ➢ Breathable, tarp-like covers designed for compost ➢ Moving composting location	➢ Anaerobic digester may still cause health effects/contamination from the effluents and digestate ➢ The compost covers and moving the location may not resolve all the health effects Costs to farm, neighbors and/or government

Table 3: Overview of Challenges of Food Waste Composting on a Large Scale in Peri-urban Areas
The far left hand column lists various challenges associated with food waste composting in a peri-urban area. The rows detail common causes, issues, methods to address the issues, and drawbacks of those methods for each challenge.

2.5 Davidian Bros. Farm in Northborough, MA

The town of Northborough, Massachusetts is one example of a peri-urban area that is currently experiencing conflict resulting from a composting operation. Northborough can be seen as a textbook example of a peri-urban town. With a population of just over 14,000, and a limited area of about 19 square miles the town boasts a population density of 756 persons per square mile (Town of Northborough, 2017). This is well below a large city's population density such as Boston's 13,800

persons per square mile, but still much higher than a more rural town's density similar to Goshen, MA's 53 persons per square mile (Census Viewer, 2010). These factors give the town its mixed rural and urban feel.

Northborough has had farms within its borders since its founding in 1775 (Town of Northborough, 2017). Currently, the town boasts three large agricultural farms, one of which is engaging in large-scale, windrow composting. The Davidian Brother's Farm has been composting on this scale since August 2014 (Thompson, 2016). Large-scale composting refers to an operation that is bringing in metric tons of outside food waste each week for composting. With at least one semi-trailer truckload of compostable material being delivered to the farm each day, it is clear that this operation is extensive (Harriette Chandler, personal communication, February 23, 2017). The Davidian Bros. Farm has been composting on a large scale as a result of new waste management laws, which govern the disposal of solid wastes. The farm uses large windrows to compost their incoming materials which is shown in Figure 6.

Figure 6: Satellite Image of the Davidian Bros. Farm's Compost.

(Google Maps imaging, Green Street, Northborough, MA, 2017)

Due to increased traffic, odors, and wildlife attracted by the food waste, community members of Northborough are upset. Additionally, some farm neighbors have complained about health problems that may be a result of compost related pathogens or drinking water contamination (Julianne Hirsh, personal communication, March 22, 2017). Individuals have filed complaints to the town, the farm, and the state. Owners of the Davidian Bros. Farm disagree with the complaints and feel they are not responsible, stating that they have addressed the concerns: stating within an MDAR certification form that complaints were unsubstantiated. This back-and-forth has created a tense situation in the area.

The tense atmosphere permeating through the town has prevented the situation from being resolved since it appeared in 2014 and continues to hamper efforts to do so. This disagreement and distrust prevents the farm and community from enjoying the benefits of their geographically close relationship and represents a perfect example of a peri-urban land conflict. Due to this conflict, the Office of Massachusetts State Senator Harriette Chandler reached out to the Worcester Polytechnic Institute Worcester Community Project Center in hopes that together we could work collaboratively with the town residents and farm to come up with a mutually acceptable solution to not only this specific issue but also provide potential solutions to other areas with similar situations. In our next chapter, we discuss our methodological approach to the project.

3. Methodology

In order to positively influence the situation in Northborough we formulated two related goals to guide our work. First, we aimed to appease the community's concerns by presenting recommendations that all stakeholders could agree to. Second, we hoped to facilitate a lasting relationship between the Davidian Bros. Farm and its surrounding community in order to provide an example for other agricultural operations to follow.

We were able to make meaningful strides towards these aims by dividing our project into two phases.

Phase 1: Develop a Northborough Case Study

1. Investigate the primary concerns of the surrounding community and perspectives on those concerns from experienced individuals outside of the situation.
2. Investigate the extent to which compost practices and outside forces, such as weather, influence neighbors' complaints.
3. Explore possible composting legislation and its impact on local communities and farms.

Phase 2: Case Study Analysis and Solution Development

4. Identify cases with similar issues to the case study we have developed and comparatively analyze them against the Northborough case.
5. Develop and present a creative proposed solution tailored to the situation in Northborough.

These objectives allowed us to compile data and observations from a variety of sources in order to develop a solution that is appealing to both the farm and the surrounding community. We worked collaboratively with both the farmers and their surrounding community so that we were able to carry out a project that can have a lasting and positive effect on the community. Throughout this chapter we discuss each objective in detail.

3.1 Ethical Considerations and Institutional Review Board

This project, prior to any interviews, focus groups, or site visits, went through WPI's Institutional Review Board (IRB) approval process. As part of this approval, all participants were informed of potential risks that could possibly occur with participating in the study and then asked to give their consent to participate.

3.2 Phase 1: Develop a Northborough Case Study

A case study is defined as an "empirical inquiry that investigates contemporary phenomenon within its real life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 1994). Essentially, case studies allow for a deep understanding of an incident or happening by gathering as much information as possible, describing its factors and results, placing the incident in an understandable context. Phase one of our project includes the first three objectives, through which we created a case study of Northborough in order to organize all of the information we gathered. This strategy of looking at a situation allowed us to place the issue and its stakeholders within its key causes and products. The chart below in Figure 7 outlines how we went about accomplishing Phase 1 of this project (rising up the pyramid).

Figure 7: Phases and Objectives of Methodology (1)

Objective 1: Investigate the primary concerns of the surrounding community and perspectives on those concerns from experienced individuals outside of the situation.

We investigated these concerns by interviewing or surveying groups of abutting neighbors, other residents, town officials, and similar individuals from other situations. Examples of these people include John Coderre, Northborough Town Administrator, and Julianne Hirsh, a member of the community living near the farm. The best strategy for validating this data was to triangulate the information between the sources we found. Triangulation aims to reveal complementarity, convergence, and dissonance among findings in order to filter out extraneous data and highlight the most relevant information (Erzerberger & Prein, 1997). Data can vary based on when it was collected, the specific people involved, and the setting where the data was collected (Hussein, 2009). Triangulation was helpful in the corroboration of the data we gathered. Additionally, we used other sources to triangulate the interview data, such as documentation

and news reports.

We began by performing focus groups with several gatherings of neighbors, ranging from two to five participants. To maximize the efficiency of those interactions, we considered pre-interview questions among ourselves in order to shape the interactions. Those questions included: is there already data on this subject we can look into first, what data we need to create, and how much work will it be to collect the data, etc. (Stoeker, 2013). Having asked ourselves those questions prior to interviewing individuals, we conducted the interviews to a high standard with no superfluous information sought out.

Next, to add to our understanding of the concerns of neighbors regarding the farm we conducted semi-structured interviews. Semi-structured interviews allow some flexibility when asking questions but maintain enough structure to stay on topic (Bailey, 2007). Please see Appendix B for the neighbor interview questions.

Additionally, we gave out a survey to community members living within a few miles of the farm. Here, we acquired a geographically diverse set of individuals spread out from the composting site in all directions in order to gain the perspective and concerns from different stakeholders. The neighbors surveyed lived anywhere from a few feet from the compost site to a few miles away. The goal of this survey was to quantify the smell and concerns from the point of view of the neighbors three times a day over the course of a week. We received 13 responses for the survey. This survey can be found in Appendix C.

To gain the town government's perspective, we interviewed Northborough town officials, including John Coderre, Town Administrator, Stephanie Bacon, Board of Health Agent, and Kathy Joubert, Town Planner. This work helped us to better understand their concerns with the legislative side of the issue and the feasibility of possible solutions in the town. These more structured interviews allowed us to acquire specific information and set the interview pace (Bailey, 2007). Questions asked are listed in Appendix D.

We also interviewed owners of other farms composting on a similar level to the Davidian Bros. Farm. These farms were identified by finding other community conflicts where an agricultural composting operation was involved. We gathered this information from news articles and discussion with Senator Harriette Chandler, John Robertson of the Massachusetts Municipal Organization (MMA), the Northborough Town Officials, and Suzanne Condon, the former Associate Commissioner of the Massachusetts State Department of Public Health. For instance, we were put in contact with the Jordan Dairy Farm, which uses an anaerobic digestion process to compost that has not created any conflict among its neighboring community to date. We did these interviews to better understand their successes and how these could solve similar issues in the Northborough Community. These questions are listed in Appendix E.

We also chose to send the farm owners a survey in regards to their composting practices and any complaints they may have received. The survey was sent to over 80 individual farms across the US as well as over 20 further agricultural and composting organizations that are made up of composting farms. The 80 individual farms included about 25 from Massachusetts. This information was gathered using databases from agencies such as the U.S. Environmental Protection Agency and state-level environmental and agricultural agencies, as well as compost searches online. We chose to survey because it was the most effective method for gathering information from a large number of farms all using a similar process in composting. Additionally, visiting every farm would not have been the most effective use of our time. The survey allowed us to receive information from a wide array of sources that we may not have otherwise been able to reach. This survey can be found in Appendix F.

To supplement this survey data, we also analyzed past documentation related to this situation. For instance, we gathered records of filed complaints, local and regional news stories, past interviews, town meeting histories, letters to state agencies such as MDAR, as well as reporting documentation from the state level officials and departments. According to Stoeker, when analyzing this type of data, it is best to incorporate some community members as they will have a better sense of what data points are of the most

importance (2013). For example, we referred back to certain officials and town members to better analyze our data. Furthermore, we coded this data. We grouped our results into broad categories, such as odors observed, rather than noted how many specific responses we had such as an observation of a rich tobacco smell. This allowed us to gain a sense of how different parts of our data compared to each other (Schreier, 2014).

Once we completed our interviews and surveys, we used the answers, along with the supplementary information received from our other sources, to understand the main flashpoints of the relationship between the stakeholders in the situation. We performed this analysis by comparing the data received between neighbors to quantify which concerns had the greatest impact and the greatest number of stakeholders. Through identifying each of the main goals or issues from the eyes of the stakeholders, we better understood each party and their perspective. This information helped us to target our research efforts more effectively.

Objective 2: Investigate the extent to which composting practices and outside forces, such as weather, influence neighbors' complaints.

In order to explore the composting practices at the Davidian Bros. Farm we obtained permission from neighbors to carry out observations from the sites and neighboring the compost operation. This allowed us to see the operation first hand and identify any opportunities to decrease issues causing neighbor concerns, while maintaining the farms' composting operation.

After obtaining permission to carry out research on locations neighboring the farm - we were unable to obtain permission to get onto the farm itself - we made observations of the composting practices in order to identify the specific causes of the odor, wild animal attraction, health problems, and other complaints. For instance, we viewed practices from different neighbors' lands to quantify their concerns as well as note smells and trucks seen from their land as well. We also took into account weather and wind patterns, compost ingredients used, scale of the composting, as well as pile-turning, moisturizing, and aeration habits in order to build up information on the farm's composting.

One important obstacle we had in completing this objective was our inability to gain access to the Davidian Bros. Farm. We attempted to get in contact using emails, phone calls, third parties, and postal mail but were unable to establish a dialogue with the owners of the Davidian Brothers Farm. We anticipate that this may be partially due to the spring timing of our project as it coincides with spring planting on the farm and thus a busy schedule for a farm owner.

Additionally, we were able to gather two months of trucking data from a neighbor to the farm who had a motion sensor camera facing the road. This camera was able to take a picture every time a truck passed an intersection a few hundred feet from the composting site. The neighbor then went through the pictures organizing the data including date, time of truck entrance to the site, time of exit, frame number of picture, type of truck and company. The neighbor's organization of the data in this way allowed us to effectively check his numbers and work. Thus, for the months of October and November 2016, we were able to obtain and verify records of deliveries made to the composting site. This data quantifies the neighbors' reports about truck traffic and noise.

Following this activity, we investigated the reporting documents the farm uses to inform government organizations of their practices. For instance, the composting operation's government oversight is through the Massachusetts Department of Agricultural Resources. As this is a state organization, the farm must report on certain practices and outcomes, so we obtained the certificates of registration for the Davidian Bros. Farm's agricultural composting practice. Adding this information to the data gained from our observations and interviews improved our understanding of the situation and how to reduce impacts on nearby residents.

These observations helped us to complete our case study for phase 1 of our project, and later to find similar case studies. While creating a case study for use in finding a solution was the main goal here, identifying improvable facets of the issue so early in our project, was invaluable. For example, through the communication with MDAR representatives, we were able to learn simply ways to test well water for contaminants.

Objective 3: Explore possible composting legislation and its impact on local communities and farms.

We used interviews and online research in order to finalize our case study. These interviews and correspondences included state legislators such as Senator Chandler and her legislative advisor Bryan Barash, as well as state regulatory officials such as Greg Cooper of MassDEP, Gerry Palano of MDAR, and industry experts such as Bill Jorgenson, the Managing Director of Vanguard Renewables an environmental sustainable technological company. These sources aided us in gathering the information that we needed to know to complete our case study, which was the regulations that could affect the composting situation and whether those could have a positive or negative influence on the situation in Northborough. Currently, the Massachusetts State Senate and House of Representatives is proposing legislation that would directly affect how composting practices are regulated within the state of Massachusetts. In order to better understand this legislation and its effects, we spoke with the legislative advisor for Senator Chandler, Bryan Barash.

We also used information regarding regulations and legislation mentioned during interviews with farm owners and community members to further our research in this area. Additionally, we contacted Massachusetts Department of Environmental Protection (MassDEP) and Massachusetts Department of Agricultural Resources (MDAR) employees for further information on their specific regulations. Questions for these interviews are listed in Appendix G. We employed snowball sampling, beginning these conversations with contacts in MDAR that were given to us via the Office of Senator Chandler and then branching out to other departments based off the information we gathered from the first contacts we met with (Schreier, 2014).

Furthermore, we reviewed agricultural and composting legislation in other states to see if any had more comprehensive composting legislation. We also used the MDAR website and public documents in addition to other Massachusetts state government websites and offices in order to expand on the knowledge we received from our interviews and other research. These resources helped us to better understand the full extent of agricultural legislation and its impact on communities.

3.3 Phase 2: Case Study Analysis and Presentation of Solution Tailored to the Northborough Case

Through the completion of the tasks in Phase 1, we developed a case study of Davidian Bros Farm's composting practices and their impact on Northborough residents living in close proximity to the farm. Then we moved on to Phase 2 of this project. In Phase 2, we identified cases with similar land use issues that have been resolved. Next we comparatively analyzed the case study created in Phase 1 against those cases we found to be similar. We conducted this analysis to uncover potential solutions to the Northborough case. We then presented these potential solutions to the stakeholders to get their feedback. Phase 2 of our project can be seen in the chart below in Figure 8.

Figure 8: Phases and Objectives of Methodology (2)

Objective 4: Identify cases with similar issues to the case study we have developed and comparatively analyze them against the Northborough case.

By finding similar case studies created by other researchers and building some of our own, we were able to gain a better understanding of conditions at other sites that related to the situation we were studying. In our case study research, data collection and data analysis proceeded simultaneously because analysis is giving meaning to first impressions as well as giving meaning to the results (Stake, 1995).

After developing our case study for the subject farm, we had a better sense of what related case studies to analyze. For instance, we focused more on composting cases involving asthma concerns, anaerobic digesters and other factors that the Northborough case exhibited. Searching for cases with data points similar to Northborough meant taking into account a number of different sources. These sources included news articles, technical papers, land conflict histories, interviews with similar and local farms, and interviews with town and state officials. In order to find these sources we employed search methods and language geared towards finding similarities to our case. Additionally, we asked our previous interviewees and contacts for any further sources they knew of. These data points included the following:

- Location/climate
- Farm details (i.e. type, size, and age of farm)
- Type of composting
- Neighboring community (i.e. size, demographics, area, etc.)
- Stakeholders
- Regulations and legislation involved

For instance, we spoke with individuals involved with the cases we found such as Adam Martin of the Martin's Farm in Greenfield, Massachusetts, Bill Jorgenson of Vanguard Renewables, and Tom Gilbert of Black Dirt Farm in Greensboro Bend, Vermont. Vanguard Renewables is a firm that works with composting and dairy farms to install Anaerobic Digesters. We spoke with their lobbyists and technicians in order to gain a better understanding of how their digesters work and the benefits that farms can expect from them. Please see Appendix H for our Vanguard interview questions.

Objective 5: Develop and present a creative proposed solution tailored to the situation in Northborough.

For this objective, we used the information from our case study analysis and a matrix we created of different options, which can be found in Appendix P, in order to compare methods used in other cases to mitigate concerns (Stake, 2013). We used these cases, research information, and matrix to develop a set of recommendations to aid in the resolution of the issue at the subject farm. This practice involved examining the solutions used in those other cases to determine if they would be appropriate for our case and then tailoring these solutions together to fit Northborough. We tailored our recommendations by using the matrix we created, which puts possible solutions side by side and for comparison across criteria selected during our project. Additionally, as this resource would prove helpful to future operations and current operations with concerns, we also created a webpage displaying the information within the matrix so that it is easy accessible to those sites and their operators as a resource. Snapshots of the matrix and website we created can be found in Appendix I.

Additionally, after formulating our pilot solution, taking into account the farms' and community's wants, we presented our idea to the necessary stakeholders. For instance, we conversed with the neighbors and different farm owners in order to gauge their acceptance of the proposed idea and to gain their feedback.

Finally, this proposal is made up of our recommendations for the Davidian Bros. Farm and the community of Northborough, Massachusetts. Issues of this type however will grow in prevalence, as urbanization increases and more food waste recycling operations are located in residential communities. Thus, we have also compiled our research into a vast matrix and website that detail various aspects of concern mitigation for food waste recycling sites. We also plan to approach MassDEP and MDAR to see if they would like specific access to either source for prospective site operators who need to plan for the prevention of concerns.

Specifically, in order to create the matrix, we chose to use Google Sheets as it is a free and easy to use and update medium for displaying our information. The matrix consists of a home page with all of

the concern mitigation strategies listed, while successive sheets go into detail on either a single method or comparing multiple methods. Each single method sheet contains detailed descriptions, costs, benefits, drawbacks, time of implementation, and other important aspects of each strategy. However, after creating this source of information, we wanted to make it more accessible and easy to use than a Google Sheet. We decided that a Google Site was the best method for doing so as the site would update automatically from the sheet and it was free and easy to maintain. Additionally, the two videos we created contain much of the same information. The first of which is a short video to add a visual element to the information and a succinct format, as the video is about 6 minutes long. The second video is about 30 minutes long and takes the viewer on a tour of an exemplary compost operation to better understand the benefits and operation of a successful compost site.

In using the above data gathering, organizing, and analyzing strategies and finding the sources we did, we were able to derive a number of important conclusions. These conclusions can serve to aid not only the town of Northborough and its land-use conflict, but other current and potential conflicts involving food waste recycling as well.

4. Findings Chapter

Over the course of our project we were able to gather a large amount of data in the form of personal opinions, numbers, and facts. Through analyzing this data we developed the following findings. We grouped our findings by the aspects of agricultural composting that they represent. In this section, we discuss our findings and the support for those assertions in the hopes that they can help to resolve current, and prevent future, land-use conflicts resulting from residential food waste recycling operations.

We would also like to preface our findings and recommendations by noting that while we attempted to do so using emails, phone calls, third parties, etc., we were unable to connect with the owners of the Davidian Brothers Farm. We anticipate that this may be due to the spring timing of our

project as it coincides with spring planting on the farm and thus a busy schedule for a farm owner.

Additionally, any reference to a company or organization within this chapter does not serve as a recommendation or endorsement of that company, but simply as a reference for information.

4.1 Peri-Urban Food Waste Recycling Operations and Their Potential to Create Land-Use Conflicts.

The following findings fall under the specific theme of land-use conflicts. They encompass what we have come to understand about these conflicts and their resolutions with regards to agricultural composting.

Finding 1: Avoiding land-use conflicts benefits all stakeholders but requires communication, compromise, planning, and an understanding of opposing views.

Our interviews with state agencies, town officials and residents, farmers, and food waste recycling experts, as well as Northborough resident and farm owner surveys, reveal a clear correlation between communication and the level of success of a composting operation. The Davidian Brothers Farm neighbors wanted to be consulted or made aware of the farm's new composting situation as they live in the immediate area. 100% of the 14 neighbors we interviewed stated that if the farm staff had attempted to communicate with them prior to beginning the composting operation at the Davidian Bros. Farm the issues would have been less severe. Not least among these issues was the surprise that these neighbors felt at finding a large-scale composting operation next to them without prior warning or inclusion in the decision-making process (Northborough residents, personal communications, March 22, 2017 - May 1, 2017).

Every neighbor that we spoke to stated that one of the largest issues inherent in this situation was the lack of voice they felt. One neighbor whose home is located less than a mile from the compost site stated that, besides the odor, they did not know of the operation during the first year of activity because there was no prior communication with the community. This same fact was stated by the Northborough Town Administrator John Coderre (John Coderre, personal communication, April 4, 2017), Northborough

Town Planner Kathy Joubert (Kathy Joubert, personal communication, April 4, 2017), and Northborough Board of Health Agent Stephanie Bacon (Stephanie Bacon, personal communication, April 4, 2017) as they were unaware of the operation prior to complaints being filed with their office. Furthermore, lines of communication are not required for composting farms in Massachusetts, nor does any part of the Massachusetts Department of Agricultural Resources (MDAR) registration process require a dialogue between operations and their communities (Agricultural Composting Program, 2014).

While issues can arise regardless of communication between stakeholders in land-use concerns, some issues can be prevented if parties engage in open communication. For instance, the Martin's Farm in Greenfield, Massachusetts began composting in 1987 and has since kept an ongoing dialogue with the nearly 300 neighbors presently residing close to the farm's operation (Adam Martin, personal communication, April 11, 2017). As a result of this communication, concerns have been heard and addressed and neighbors have been educated and engaged, resulting in a positive relationship between the stakeholders in this situation and the longevity of this operation (Adam Martin, personal communication, April 11, 2017). The many neighboring houses are shown in Figure 9. Adam Martin is the owner of the Martin's Farm, which has been composting for over 30 years. He has solely owned the farm since 2014, operating its successful compost site as well.

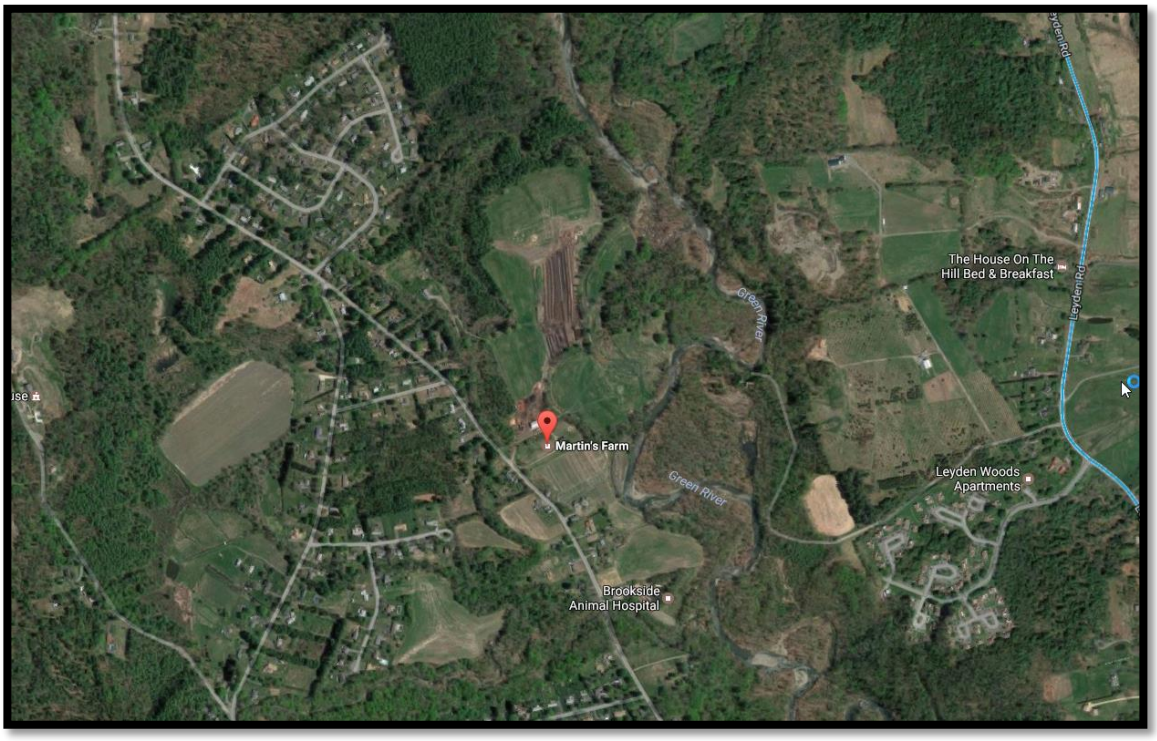


Figure 9: Satellite image of the Martin's Farm and its surrounding neighbors (Google Maps imaging, Plain Road, Greenfield, MA, 2017)

In addition to communication, planning and inclusion of stakeholders is vital to avoiding land-use conflicts. In viewing land-use conflicts across the state, we found that a majority of conflict sites were not required to include their communities in the planning and early development of their operations. This evidence points to the fact that inclusion of potentially impacted parties near a site should be included in its planning to reduce the likelihood of conflict in the future. For instance, of the 29 individual farm responses to our survey, none that included stakeholders in the planning and operation of their sites reported long standing issues with neighbors.

Tom Gilbert, the owner of composting farm, Black Dirt Farm, in Greensboro Bend, Vermont summed up the keys to peri-urban composting:

> Community composting systems are dynamic and they are different than traditional recycling systems . . . . Altogether these are harder programs to pull off well. What that means is that we need to relate to them differently and recognize that they are unique. And it's their uniqueness that is exciting. People must buy into the systems level thinking, the values, and the details of these programs at all levels. If they don't it doesn't work . . . . Community food scrap recycling is powerful social change work - it becomes a stepping off point for people to become more literate about local economies, ecological parameters and so on, and therefore getting it right and authentically educating/partnering with them can become a lever for preparing them to become more engaged community members, resource stewards, etc. If you just focus on the mechanics you will miss the most important issue - paradigm shift. The composters themselves need to be hungry for quality, just like the produce workers in the grocery. They will only operate effective facilities if they genuinely desire to get it right and make excellent product, and in turn contribute to excellent communities! (2017 April 5, Personal Communication).

His assessment illustrates the level of benefit that peri-urban composting can have on the environment and community around it, but that it also has the very real potential to cause harm if attention is not given to the fine details of an operation and its community's concerns.

The Barnside Farm Compost Facility LLC in Schwenksville, Pennsylvania also stated in our farm survey that when neighbors complained of composting smells, they changed their ingredients and altered their process. Following these changes, they have not received any complaints about their composting operation. From our farm survey we also found that the Brick Farm Inc. in Augusta, Georgia has taken measures to communicate with their neighbors. After receiving complaints about odors and health effects from their compost, they improved their process by ensuring proper ratios of brown waste to green waste and by turning the windrows more often. A third farm that revised their process to compromise with their neighbors is The Fairfax Companies, LLC. They reduced windrow heights, added bulking materials, and changed some of their input materials. Thus, while communication is important in planning a food waste disposal site, it is also invaluable during its operation. In sending a survey to over 100 composting farms and organizations across the country, we saw that no site which engaged in some form of community

outreach or dialogue had significant complaints from its surrounding neighbors or dealt with the concerns and complaints stopped.

Additionally, if a farm or other composting site is able to include its surrounding community through forms of outreach programs, the community with not only feel a greater sense of involvement and stake in the process, but will also gain a better understanding of how and why the process is run the way it is.

In surveying farms and other operations across the country we found that about 44% of farms used some form of community outreach in their regular operation. This inclusion can take the form of regular tours of the facility, forums with the town to present data on the operation, education events to inform the community of processes and the science of compost, and site events such as a compost day or gathering on the farm. Additionally, of the operations that stated they use these types of practices, none had community complaints or any complaints that did exist were addressed and fixed.

We were able to see the results of these strategies first hand at the successful food waste recycling operations we visited. For instance, while visiting an anaerobic digester in Deerfield, Massachusetts managed and owned by Vanguard Renewables, we were able to take a tour of the facility with an individual from the Connecticut Department of Environmental Protection as well as another group aiming to learn more about digesters. The enthusiasm of the farmer infected the tour group; the group stated they were vastly more intrigued and knowledgeable about digesters and food waste recycling following the tour. The same type of increased positive relationship was seen at another composting farm we visited. This operation used tours, compost education days, specific days for children to come learn, and other types of educational events such as these to not only expose individuals to the operation but also help them understand why it runs the way it does. We were able to see the result of these practices when different neighbors and farmers came to purchase finished compost product. Every individual who came while we were at the farm was happy to be involved with the farm and its owners as well as expressing satisfaction about the site and its practices.

Community inclusion efforts such as those described above play a vital role in helping the community to understand how and why the operation uses the procedure it does and to feel a sense of pride and association to the site. This positive sentiment can prevent conflicts or concerns before they arise as well as allow for communication and understanding to aid in the mitigation of concerns that do come about.

Finding 2: Residential composting operations can function effectively and without significant complaint, however this requires large expenditures and/or comprehensive oversight.

Through investigating over 30 composting farms and businesses, we saw that no composting operation was run exactly the same. There are many popular input materials used in composting such as wood chips/sawdust, food waste, yard waste, and manure. However, there are also many input materials that depend on the geographical location of the site. For example, from our survey we found that Kupa's farm in Hawaii uses crushed basalt rock powder, Benson Farm LLC in Maine uses seafood waste, and TAM Organics in Vermont uses short cotton fiber. Their survey answers illustrated that all of these composting farms and businesses get their input materials from private residences, other farms, restaurants, etc.

The variety of input materials and methods of composting create numerous factors that successful composting farms must take into consideration in order to minimize concerns. One factor that we found to be important is the carbon to nitrogen ratio of the compost and maintaining it at around 30:1 as suggested by MassDEP. The 'brown' inputs such as yard trimmings, leaves, clean wood, etc. being high in carbon while the 'green' inputs such as food waste and manures are high in nitrogen. If the nitrogen content is too low the compost piles will not attain a high enough temperature, which will not kill the pathogens and result in a lower quality compost. If the nitrogen content is too high then the compost piles will become too hot, rising well over the desired temperature of 133 degrees Fahrenheit. This rise in temperature will kill the beneficial microorganisms in the compost thus degrading the operation and leading to more odors

etc. (Richard, 1996). For this reason, the successful composting farms we surveyed and interviewed went to great lengths to get this ratio correct. One such farm spent 8-9 hours sorting through the feedstock they received each week in order to pick out contaminants and measure the right amount of each material into their compost piles (Adam Martin, personal communication, April 11, 2017).

Alternatively, non-extensive oversight can lead to negative effects on a site and its neighbors. For instance, we found a farm in Tewksbury, Massachusetts that did not have this high level of detail or oversight in their operations. Without that oversight and regulation, complaints towards this farm reached a peak in the form of a civil lawsuit against the farm (Miller, 2013).

The Martin's Farm in Greenfield, Massachusetts however, represents a farm taking their relationship with their over 300 neighbors and surrounding community very seriously, regardless of the cost or extra work necessary. This farm has taken out hundreds of thousands of dollars in loans for their composting business to fund everything from odor control, to windrow turners, to high end screeners that ensure a quality final product.

To begin, the trucks entering Martin's farm drop off organic waste to weigh in at their weigh station, as shown in Figure 10(a), so that the farm knows how much feedstock they are taking in per day and to be able to charge accordingly. Once the feedstock is dropped off they spend 8-9 man-hours sorting through the waste by hand to remove any contamination such as plastics, glass, and metals. They then put the feedstocks into a grinder that they call "the beast," which is shown in Figure 10(b) and from there they put the feedstock into the windrows.

Figure 10: Martin's Farm Strategies

a.) Truck Weigh Station

b.) Feedstock Grinder

Their odor control efforts, which cost around $40,000 to $50,000 a year to maintain, consist of a perimeter vapor system from Global Odor Technologies, a topical bio organic catalyst spray, and a bio-filter consisting of finished compost that was not filtered during the screening process and wood chips. The perimeter vapor system, which is shown in Figure 11(a), is 1,300 linear feet and uses a large air pump that mixes an odor solution, shown in Figure 11(b), and forces the mixture through a raised, perforated pipe. This mixture is not a chemical but is an odorless, organic vapor that attaches to odor molecules so that it can either: cause the molecules to become denser than air and fall to the ground, change the compounds of the odor molecule to eliminate the odor, and/or completely destroy the odor molecules. This type of odor control system is one of the first in the country and is proving to be very effective at not only minimizing odor and insects but also at maintaining a positive relationship with their surrounding community (Adam Martin, personal communication, April 11, 2017). The perimeter vapor system can be applied to not only composting locations but also to wastewater treatment plants, anaerobic digesters, and

other similar businesses. Mr. Martin, the farm's owner, stated that while these endeavors are costly and are not all required under the regulations that govern his operation, he feels pride in constantly improving his operation for the sake of those around him. Martin's Farm also has other specialized equipment to help them maintain their composting operation. Their windrow turner is basically a large covered auger that goes down over the windrows and mixes everything in the row along with adding oxygen. A picture of it is shown in Figure 12(a). They then screen their compost to 5/16 minus with their screener to minimize any contaminants, wood chips, and rocks. The unscreened compost is dumped onto the screener. Then the compost goes through a rotating drum with the screens which removes the contaminants and then out through the conveyor to a pile. This process removes about 95% of any of the plastics/contaminants and the plastics that fall through the vacuum out. This screener is shown in Figure 12(b). Many of these composting processes work as mitigation for composting concerns which can be seen in more detail in the matrix we created in Appendix P.

Figure 11: Martin's Farm Perimeter Vapor System from Global Odor Technologies

a.) Perimeter Vapor System Shed and Fence

b.) Odor Control Solution

Figure 12: Martin's Farm Windrow Turner and Compost Screener

a.) Windrow Turner

b.) Compost Screener

4.2 Concerns Resulting from Agricultural Food Waste Recycling

The following findings discuss the different concerns of the parties involved in land-use conflicts that pertain to composting operations. Both farmers and community members have concerns that need to be addressed in order to facilitate a positive relationship within these situations.

<u>Finding 3: Owners of food waste recycling sites are concerned that land-use conflicts can result in a loss of income from the termination of their operation.</u>

Through interviewing and surveying over 30 farms and businesses, as well as state-wide organization officials including Massachusetts Municipal Association (MMA) Legislative Director John Robertson, we found that composting is a reliable and substantial source of income for those in operation of large-scale sites. Should these sites be shut down or affected by complaints, this income can be lost or lessened. Additionally, operators may be less inclined to alter their practices if this income is affected, especially due to the scale of monetary gain possible. For instance, Benson Farm LLC. on Gorham, Maine has received some complaints with regards to its compost and knows of many different concern

mitigation techniques such as anaerobic digesters, compost covers, and biofilters. However, the farm does not currently use any of these practices, which all require extra funds. The farm does however use more inexpensive compost quality testing.

The composters first get paid tipping fees, or a charge for a given amount of waste received, for allowing people and businesses to dump their food and yard waste on their property. This fee can range between $500 and $1,000 per truck load for food waste in Massachusetts, but also depends on the contracts that the composting business has and their geographic location (Harriette Chandler, personal communication, February 23, 2017). Adding to the availability of composting input materials, as a result of the 2014 Commercial Food Waste Disposal Ban in Massachusetts, businesses and institutions that generate over a ton of food waste per week must divert their organic wastes to composting, conversion, recycling, or reuse (Solid Waste Management, 2014). Not only can composters charge for the incoming materials, but they can also sell their finished compost product. Various types of finished compost, along with other mixtures the one farm sells can be seen in Appendix J.

Additionally, if a farm uses an anaerobic digester they have the potential for even greater profit. First, large anaerobic digesters require an immense amount of organic material to operate, on the scale of up to 20 tons a day of material. Each of the three digesters we were able to visit in Massachusetts, located at Bar-Way Inc. Farm, Barstow's Longview Farm, and the Jordan Dairy Farm, used over 15 tons of material a day to sustain the operation. Thus, the number of trucks transporting material to those sites is higher than a normal composting operation, leading to increased profit. For instance, while a compost operation such as the Davidian Bros. Farm may receive 10 to 20 truckloads a week, an anaerobic digester on the scale of Bar-Way Inc. Farm's can receive between 20 and 35 truckloads a week. Aside from tipping fees, anaerobic digester operations also receive an economic gain from the outputs of the digester. Producing one MWh allows the site to power the digester and the rest of the farm. There is also generally more than enough power to then sell the excess at market value as an energy surplus to other consumers buying from the same utility provider. The other outputs of the digester, solid and liquid digestate, can be

used as fertilizer on the farm with excess being sold to other farms and gardeners. Especially in wet digesters, the amount of liquid digestate, effluent, is so large that there is enough excess to pay for transportation costs and still have a large profit.

For instance, the anaerobic digester in Deerfield, Massachusetts produces over eight million gallons of effluent a day. This can fertilize anywhere from 500 to 1000 acres of farmland continually. Most larger farms in Massachusetts are between 100 and 250 acres so there is a large area available for profit from sale of the effluent to other farms.

Thus, with all of these different ways that composting and food waste recycling operations can take in large amounts of income, operators are naturally concerned about the possibility of losing that income should their site be shut down or forced to change its process. This could cause tension between a site operator and his community if there are complaints for the operation to change.

Finding 4: Individuals have different tolerances and physical reactions to compost operations.

One important fact to note with land-use conflicts and other issues that involve sensory concerns such as odor and noise, is that individuals have vastly different reactions to the sources of those concerns. These differences of reaction or opinion result from different experiences, exposures to that source, and personal history of the individual.

One manifestation of this fact is how different stakeholders can react to smells in very different ways. For instance, when asked about an odor surrounding the Davidian Brothers Farm's compost operation in Northborough, farmers and MDAR representatives stated that it resembled a 'rich tobacco smell' while some neighbors felt that it smelled more like 'garbage' or a 'waste dump.' These differences of opinion were formed by the different experiences of those individuals. In one case, an MDAR representative that has worked around compost or with compost for a number of years could be desensitized to an odor while a community member may have never smelled compost before in their life. Additionally, individual olfactory sensitivity can play a role in these different tolerances as well. Some

groups of people and individuals simply have better senses of smell than others (Goldstein, 2002). One illustration of this is that, as a whole, women are more sensitive to and observant of odors than men are (Ministerrådet, 2009). Within the neighbors that we surveyed alone, vastly differing opinions were noted for different smells. While only about 8% of the 13 neighbors found a citrus odor to be unpleasant, and about 16% found garlic to be unpleasant, 100% found the smell of compost to be unpleasant, but this was also to different degrees. For instance, only about 47% said that the smell caused headaches compared to 100% labeling it as unpleasant.

Aside from odor, difference in tolerances can also be found in noise reactions. Similar to the differences in experience and personal history to smell, noise affects everyone in different ways. Some neighbors noted the operation of the compost site as noisy while others solely said that the truck traffic was a source of unwanted noise. Furthermore, some had no issue with the level of noise from any compost-related source.

Even when taking into account many of the negative effects of composting described in Northborough, there are different answers for which effects are the most impactful. While every neighbor ranked odor and health risks as the most impactful, the other four options, increased wildlife activity, truck noise and traffic, increased insects, and possible water contamination, were ranked more varied. For instance, the increase in insect activity was listed between the second most and least impactful effect of the operation. This fact holds true for all of the other options as well with the exception of truck noise and traffic being listed between the third most and least impactful effect. Thus, while some externalities do not affect certain people as negatively as other individuals, all concerns must be taken seriously and addressed.

Finding 5: Truck traffic on small roads in residential areas puts an additional burden on neighbors.

One critical, negative externality of food waste recycling that has not received the extensive research of others is food waste trucking for compost operations. While there are a multitude of possible

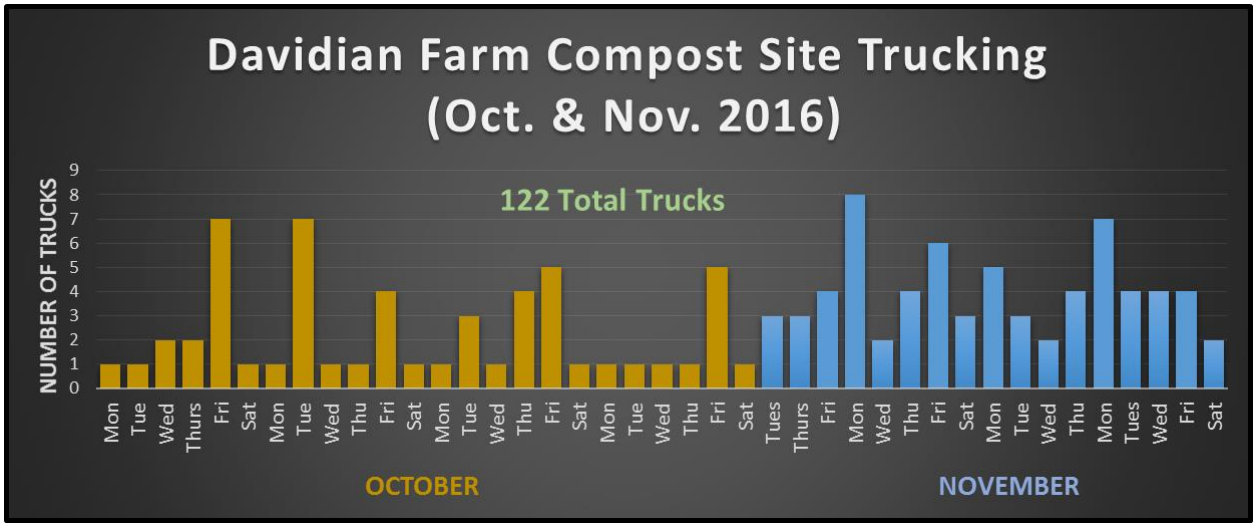
issues that can be associated with composting and other food waste recycling operations such as strong odors and health risks, none have been addressed to a lesser extent than the food waste's transportation. This is to say extensive studies have been performed on mitigating odor or health risks from a site, but trucking is often overlooked.

It is clear from the Northborough site that significant truck traffic and noise can be one of the most impactful externalities of a food waste recycling operation. For instance, about a fourth of those surveyed neighboring the compost site stated that truck traffic and noise was the third most impactful effect of the site. Additionally, when a focus group of five neighbors was asked if all other concerns were mitigated and only the current level of trucking remained, would there still exist complaints, and the answer from every member was yes. We were told this concern would remain for a number of reasons. For example, the roads surrounding the compost operation are narrow almost single lane roads, as with many peri-urban communities, and thus cars are forced to pull off the road when a truck needs to use the road. The irregular timing of material drop-offs also causes issue as trucks can hold up traffic during times when residents are leaving work, picking up kids from school, etc. The noise of the trucks must also be noted, as significant noise during early morning or late night hours can wake up neighbors.

We were able to gather trucking data from a confidential source that recorded the large trucks on the roads by the composting area. From the source we estimated that there were approximately 54 trucks in October (2016) and 68 trucks in November (2016) coming and going from the composting location. We also were able to back up some of the claims from the neighbors that there was a larger amount of trucks coming and going from the composting site on Mondays and Fridays. Figure 13 shows some of the trucks recorded and shows how the size and number of the trucks is a problem on residential roads.

Figure 13: Large Food Waste Trucks on Narrow Town Roads

a.) Photos of trucks carrying organic waste to the Davidian Bros. Farm's composting site



b.) Chart of observed trucking deliveries based on anonymous neighbor's records

Aside from noise and traffic, debris falling off of trucks can propagate odors and health risks outside of the site and the operator's control. For instance, one neighbor described liquid that had spilled off a food waste transportation truck. The neighbor described the smell as worse than the compost odor on an average day. Thus, monitoring trucks and their possible spillages can be vital to preventing complaints and concerns from arising. More detail on trucking mitigation strategies can be seen in our matrix in Appendix P.

4.3 Technical Approaches to Create Compromise and Mitigate Impacts

This section of our findings encapsulates the effective methods we found for creating positive relationships between composting operations and their nearby communities. These include techniques to mitigate neighbors' concerns, increase the operation's effectiveness and monetary gain, as well as the factors that need to be taken into account in order to do so.

Finding 6: There are many variables in the composting process that must be controlled in order to prevent concerns arising when operating with food waste.

While composting operations can lead to a host of concerns if not run effectively, the most important concerns are the variables that affect compost sites. These variables, when not taken into account and monitored, can lead to negative impacts. For example, of neighbors we surveyed in Northborough, nearly 40% listed odors as their primary concern. Multiple neighbors even stated that the site smelled more like 'a garbage dump' than a farm. There are multiple methods for mitigating odors but more importantly, a multitude of possible sources for the odor. One possibility is that compost odors can arise from low levels of oxygen in piles, causing them to become anaerobic and thus odorous (Adam Martin, personal communication, April 11, 2017). Additionally, an inadequate carbon to nitrogen ratio, one that strays to far from the 30:1 goal, can cause odors to arise as temperature is not maintained. For

instance, as pile temperature decreases, pathogens and other odorous compounds are able to survive and flourish, introducing strong odors (Goldstein, 2002).

In addition to odor, the feedstock of a compost pile is pivotal to the success or failure of the operation. Different ingredients require different kinds and lengths of time for preparation prior to being introduced to a compost pile. For instance, animal products such as dairy, manure, and meats contain high levels of nitrogen and thus their amounts within a compost pile need to be strictly monitored as do all food waste inputs. Other inputs such as newspaper and cardboard should be shredded in order to aid in the process. We were able to determine that these types of practices and attention to detail were shown by farms that boasted successful composting operations and positive relations with their communities. One such farm, in Missouri uses differing amounts of food waste based on the time of the year and thus needs to carefully control the amount of carbonous material they add to achieve the correct ratio. According to Suzanne Condon, former Associate Commissioner of the Massachusetts State Department of Public Health, odor and the underlying compounds are not addressed, it can become the least intrusive resultant as health risks from contamination of feedstock possible (Suzanne Condon, personal communication, April 3, 2017).

The length of time material is composted and processed also represents a key factor in the creation of composting issues. While an average compost pile based on our survey and research needs 10-13 weeks to complete its digestion of the materials, this time can vary widely depending on the inputs, type of composting, and additional methods used to enhance the compost (Risse & Faucette, 2009). For instance, using specially made compost covers can shorten the time necessary to achieve the desired product while using more leaves or yard trimmings can lengthen the necessary time. Weather inconsistencies can cause wide variation in these times as well. When piles are not specifically monitored and these time schedules are not followed, the final product can be unfinished containing pathogens or other contaminants. This fact can also be seen prior to the end of the piles' lifespans. As compost piles need to be turned in order to stay aerobic and keep oxygen and temperature levels at desired values,

following time schedules is a vital part of composting. For example, one farm we surveyed kept specific times and data on each pile they had over their average 13 week lifespans to ensure that schedules and product qualities were met.

Keeping these variables in mind is vital to a compost operation's management as they are the basis of whether a site runs smoothly or causes concerns in its neighbors. Thus, control of them can not only improve final compost products and the operation itself, but also avoid complaints from arising by preventing issues before they have manifested.

Finding 7: Use of anaerobic digesters, compost covers, bio-organic catalysts, and/or other technical systems can effectively reduce odor, health effects, and wildlife attraction from composting operations while maintaining existing benefits or creating new ones.

While monitoring variables like temperature and input materials in the process of composting can prevent many unintended consequences, there are methods to mitigate issues that arise despite these precautions. For instance, while controlling temperature, oxygen, and moisture levels are effective strategies for minimizing odor, there will always be some level of odor from compost piles due to the nature of their process (Adam Martin, personal communication, April 11, 2017). Thus, other methods can, and should, be employed to mitigate any remaining odor or issues.

One such method involves implementing an anaerobic digester or different process of food waste recycling. Bill Jorgenson, the Managing Director of Vanguard Renewables, told and showed us that anaerobic digesters are large-scale, expensive biogas producers that use food waste and other composting inputs as a feedstock. The investment for a large-scale digester can range from about $1 million to upwards of $6-$8 million depending on size and location. These digesters work by enclosing the feedstock and allowing the microbes to process the material anaerobically, or without oxygen. This process creates a significant amount of biogas in the form of methane among other gases, which is used as a natural gas power source. However, there are a multitude of different types of anaerobic digesters that make sense for different sized operations in different locations with different feedstock. A chart detailing

various types of anaerobic digesters is shown in Appendix K. We were able to view three different sized wet, complete mix digesters that Vanguard Renewables operates, as well as the farms they are located on in Western Massachusetts.

For example, in Deerfield, Massachusetts, the Bar-Way Inc. Farm uses a wet, complete-mix anaerobic digester. This set-up works for the dairy farm's immense amount of manure that is used as feedstock for the digester. Using about 20 tons of manure and food waste per week, this type of digester works well for the large amount of liquid that the inputs contain. According to the owner of the farm, Peter Melnick, this digester, like others that are run effectively, is quiet and due to its contained process has little to no odor and virtually no chance of pathogen production in the final products (Peter Melnick, personal communication, April 7, 2017). In addition to biogas, this specific digester also produced solid digestate that the farm could use for fertilizer or bedding for its cattle, as well as about 8 million gallons of liquid digestate that is used as fertilizer. This operation produced 1 MW of power each hour and uses that to power the farm and the digester before selling any excess for a profit. Other similar digester sites produce energy on a comparable scale. Figure 14 shows this specific digester. Additionally, Appendix L shows the various parts of this anaerobic digester.

Figure 14: Drone Image of Anaerobic Digester at the Bar-Way Farm Inc. in Deerfield, MA
This figure shows an example of an anaerobic digester situated on a dairy farm.

We were also able to view the Barstow's Longview Farm in Hadley, Massachusetts. Michael Bland, a Vanguard Renewables Technician, gave us a tour of the digester, also uses a wet, complete mix design that will be producing nearly 800 kW each hour in the coming months. Thus, not only does a digester system mitigate concerns of waste recycling such as odor and health risks, but it can also provide significant benefits to an operation in the form of fertilizer, heat, and power production as well as monetary gain from selling excess power and fertilizer (Michael Bland, personal communication, April 7, 2017).

If the upfront cost of a digester is outside the range of possibilities for an organic waste recycling operation, there are other less costly options to improve composting sites. For instance, specially manufactured compost covers represent a less expensive mitigation technique as they generally cost between $2 to $50 per square yard. These covers are made of special non-woven fabric or geotextile membrane that sheds rainfall, benefits the compost piles, reduces contaminated leachate, and last for 4 to 10+ years. This material can be breathable to maintain oxygen, temperature, and moisture levels thus reducing odor significantly while also speeding up the compost process. In surveying composting operations across the US, we found that a third used compost covers for their operations while a further 61% had either heard of or researched the covers. There are a variety of types of compost covers ranging from lower cost options to weather adapted covers to combinations with mechanical aeration systems. For instance, Kupa's farm in Hawaii tried using breathable compost covers but since they dried out too fast in their climate, they now use non-breathable covers. Other covers are designed to withstand sub-freezing temperatures as well. This technique exemplifies a well-used and proven method for mitigating negative impacts of composting operations. Appendix M details some of these compost cover options.

A further strategy for mitigating negative effects is the use of bio organic catalysts. These compounds are sprayed on or mixed into compost piles during aeration or turning of the compost. They act similarly to a steroid for the microbes allowing them to more efficiently use oxygen in the piles and

raise temperature levels, thus reducing pathogen generation and odor production. Martin's Farm uses this strategy in addition to another form of bio organic catalyst. The farm also employs a perimeter vapor system that sprays an odor-neutralizing compound into the air around the compound. This compound is odorless and safe to breathe but when it comes in contact with an odor particle, depending on the particle, it will bond with the compound and either destroy it, nullify the smell by altering the compound, or simply make it denser than the surrounding air so it falls to the ground. Since implementing the system this year, the farm has not received a single odor complaint from its 300 neighbors (Adam Martin, personal communication, April 11, 2017).

Through interviews with neighbors of Davidian Brothers Farm we found that runoff/leachate contamination from the compost was a large concern. When it rains compost windrows that are not covered have the possibility of adding contaminants to the rainfall that can then flow to nearby water bodies, seep into the ground, or spread to other properties. However, there are a range of products to help minimize this contamination. Filter tubes are mesh tubes that you fill with compost, woodchips, and other additives in order to reduce pollutants like heavy metals, petroleum products and others, minimize erosion, slow the velocity of the water, and manage storm water. Other types of leachate control include manmade leachate management ponds, bioswales, and berms, which are located in Appendix N.

A number of operations across the nation also employ other methods such as weather monitoring, compost turners or specific machinery to operate the site more effectively and efficiently, and quality testing throughout their process. For instance, over 80% of operations we surveyed use quality testing either at the final compost product stage or throughout the entire process. This strategy allows sites to understand if and how their product or process is falling short and how it can be improved. A map and chart detailing methods that various composting operations use across the country is shown in Appendix O. While many different concerns can arise from composting and food waste recycling operations, there are a wide variety of methods to mitigate some or all of these as they arise.

4.4 Legislative Findings

The final findings of our project fall under the theme of legislation and regulations. These findings explore what we have learned through our research and interviews regarding the oversight of agricultural and other compost sites. The main focus of our work was understanding the difference between MassDEP and MDAR regulatory authority.

Findings 8: Massachusetts Department of Environmental Protection's oversight of food waste recycling operations generally leads to improved relations between operations and their surrounding communities.

Legislation regarding composting differs between the two different agencies in Massachusetts that oversee such operations, MDAR and MassDEP. MassDEP has stricter regulations regarding compost sites and their implementation, which are laid out over 40 pages of in depth legislation (Site Assignment Regulations for Solid Waste Facilities, 2012). These regulations govern the setup of a site by putting forth a number of necessary plans and requirements that must be met, as well as including the town or nearby community in the planning process. For instance, while requiring an odor management plan, toxic management plan, and contingency plans among others, the regulations also include a requirement for a town meeting where the plan will be presented and discussed. They also contain strict operational standards and reporting criteria. In terms of MDAR, the department has regulations that are considered more lenient, which allow farmers an easier and quicker setup process for their possible compost operation (Agricultural Composting Program, 2014). While this can be beneficial to a farm owner in that they are allowed more freedom and ease in operation, when compared to MassDEP operations there can be a larger number of complaints as there are less regulations to hold the operation to a higher standard. However, this is not say that all MassDEP governed operations are free of complaints or concerns, simply that we have seen more tension between operations under the less extensive regulations.

During a meeting with the town officials of Northborough, they described to us their thoughts that the best way to solve this and future food waste recycling problems was to set up a proper procedure and

use local bodies, such as a zoning department, to determine optimal locations for a site. The officials would use this as the basis of a process that would give the neighbors, town, and farmers the opportunity to discuss if composting in a certain location with a certain plan is the best choice for the community. Such a description is very similar to the actual MassDEP regulations regarding composting operations.

One farm that voluntarily decided to register under MassDEP instead of MDAR is Martin's Farm in Greenfield, Massachusetts. This farm represents a prime example of a farm exceeding MassDEP's regulations and succeeding in terms of community relationship and financial income from the operation. While this route requires higher setup, permitting, and initial costs, only two percent of the farm's neighbors had complained in 2016 and thus far in 2017, late April, there have been no complaints filed regarding the compost operation. It must also be noted that the farm is taking extra precautions not specifically required by either department to prevent concerns from arising in the community.

Proposed legislation is also being worked through the Massachusetts State Government that would transfer all composting operations under the oversight of MassDEP regulations. In the end, while the stricter guidelines would initially make some farms' operations more difficult to maintain from the increased regulations, permitting fees, and local input, the overall relationship with the communities of new operations would improve, as communication with both town officials and the neighbors would increase. The farms would also gain a greater backing from the community, as all stakeholders are able to express their concerns and ideas on the new development, before things deteriorate the relations of the neighbors and farm.

Finding 9: From a regulatory standpoint, agricultural composting operations are generally easier to establish and maintain than municipal and commercial operations.

As stated in the previous finding, Finding 9, the different regulatory bodies that oversee composting and other food waste recycling operations in Massachusetts allow for very different experiences when beginning or maintaining such a site. For instance, it is much simpler and quicker to

establish a composting operation under MDAR regulations when compared to MassDEP regulations. While MDAR does have a certification process and standards for operating compost processes, its current 3 pages of regulations, 330 CMR 25.00, and proposed 7 page update simply are not as extensive as MassDEP's 40 pages, 310 CMR 16.00, on the subject.

For example, in starting a compost operation under MDAR regulations, a prospective operator needs to submit a certification application including a description of methods for their operation, types of feedstock they will be using, the source of the materials, site information, and the proposed site's compliance with at least one of three criteria regarding where materials come from or are used. While including very significant pieces of information and necessities for setting up such an operation, MassDEP regulations include all of the above with exception of the compliance to the specific criteria for where portions of the material originate and are used. However, they also require, detailed odor, toxin, and vector, or mosquito and fly, mitigation plans, contingency plans, descriptions of how product will be used and at what specific amounts, maintenance plans, equipment lists and replacement plans, a design plan, site maps, characteristics, and plans, permitting through local offices, inclusion of a town or local meeting where all of the above plans are presented and discussed, as well as much more. This is not to say that MDAR regulations are poor in design, but simply that MassDEP regulations are more detailed and comprehensive. There is much more planning and consideration to all aspects of the process required.

This same fact carries over into the operation and continued oversight of the process with more sections requiring reporting, site visits, and inspections in MassDEP regulations. Thus, it is much more difficult to obtain a certification and maintain a composting site under MassDEP regulations. For instance, in interviewing the owner of the Martin's Farm in Greenfield, Massachusetts, we were able to discuss this exact fact. In choosing to register under MassDEP, the farm chose to take on these extra regulations. While requiring extra work, documentation, and planning, the farm sees this as beneficial as the extra oversight necessary to abide by MassDEP require an operator to maintain a high standard of operation.

Thus, due to the more in depth nature of MassDEP regulations, if a site is abiding by the standards they set forth, it is most likely also an exceptional operation. This is not to say that all sites under MassDEP certification are exemplary however, or that all sites under MDAR are of poor quality, but merely that the first's regulations, if followed, provide a better environment for successful composting without complaints.

5. Northborough Specific Recommendations

From our above findings, we have developed five recommendations that, if implemented by the Davidian Bros. Farm and the town of Northborough, may ease the existing tension within the community. Based on our research we believe that these recommendations will aid their situation by reducing the concerns of the neighbors while lessening the tension between stakeholders in the case. In addition, we believe these recommendations will be useful for other farms that wish to develop large scale composting operations and as guidelines for any future compost related policies. We have reached these recommendations after considering costs, the farm's size, the neighboring community, and the size of the composting operation.

5.1 Recommendation 1: We recommend meeting(s) between the community and farm to discuss and consider further compromise to mitigate concerns and continue composting operations.

Though we understand the tense nature of the situation due to its longevity, in all of our research we have noted that similar situations in which communication is maintained, more compromises and favorable outcomes can be seen for all stakeholders. Thus, we suggest the farm initiate more open communication with the neighbors, a possible meeting or time-based update such as a monthly discussion in which concerns and responses can be discussed. This communication, while difficult to begin, should help to ease concerns in the long run when coupled with the other recommendations.

5.2 Recommendation 2: We recommend that the Davidian Bros. Farm use of a type of compost cover.

Compost covers represent an effective method for mitigating odor, airborne health risks, and both wildlife and insect attraction. They also help to control the temperature, oxygen, and moisture levels of the compost piles while also shortening the cycle of a compost pile, thus increasing the quality of the final compost. At a cost of between $2 and $50 per square yard and with a lifespan of at least four years, these covers pay themselves off over time as using a cover can increase the price of their final compost being sold in a shorter amount of time while also minimizing the sources of complaints.

Taking this step, in addition to those that follow, will result in a streamlined composting process that produces a higher quality final product that can be sold for a higher price. Use of compost covers will also reduce expenditures on resources that would be used for maintaining the temperature and moisture levels of the piles if the covers were not used. Finally, use of this recommendation, along with those following, will be seen as a show of goodwill from the point of view of the surrounding community. This type of action can aid in rebuilding communication lines and allowing for discussion that could help to resolve the tension in the situation for the benefit of all parties.

5.3 Recommendation 3: We recommend that the Davidian Bros. Farm use of a type of bio-organic catalyst on piles.

Similar to compost covers, bio-organic catalysts serve as a proven method for mitigating sources of complaints from those neighboring a composting operation. Also akin to compost covers, bio-organic catalysts aid in the composting process and in raising the final quality of compost produced. As stated above, these compounds act similar to a steroid for the microbes in the pile, allowing them to more efficient use oxygen and speed up the composting process.

This type of catalyst can be mixed into the water that is used to control the moisture level of the pile. For instance, one company that the farm may look into for further information, Bio-Organic Catalysts Inc. (BOC Inc.), sells their product for $35 per gallon with the compound being mixed 1 part

per 100 parts water. Again, we do not necessarily recommend this company, but suggest the farm can contact them for further information should they want more.

5.4 Recommendation 4: We recommend that the Davidian Bros. Farm consider a limitation of material deliveries during busy traffic hours such as before 10am.

We additionally recommend that the farm consider slight alterations to the times that materials are delivered to the sight. While truck traffic and noise remain an important concern of the neighboring community, this concern could be minimized if fewer residents are on the roads at the same times as the trucks. For instance, during high traffic hours, such as when individuals are leaving for work prior to 10am, limiting truck traffic could significantly lower complaints.

5.5 Recommendation 5: We recommend that the Davidian Bros. Farm consider use of a Windrow Turner.

Windrow turners, similar to other machinery specific for composting operations, help to improve the compost operation and the time it takes to operate the site. These turns not only significantly decrease the time needed to turn these windrows, but also improve aeration during the turning process. For instance, the Martin's Farm uses a windrow turner that we observed turn about 30 feet of the pile in about a minute. Some turners that act as an attachment to a tractor can cost anywhere between $16,000 and $80,000, though this price can change depending upon the type and size of the turner.

6. Conclusion

The need for more sustainable practices is increasing across industries as environmental consciousness becomes regular practice. For this reason, the prevalence of composting and food waste recycling operations will grow. This growth, coupled with the urbanization of many areas surrounding agricultural operations, indicates that large-scale composting operations near these communities will

increase in number. Thus, the issues that the community of Northborough and the Davidian Bros. Farm currently face are not isolated ones, but concerns that will continue to arise at a greater frequency.

While we have created a matrix detailing different methods for mitigating and preventing concerns from arising, it is important moving forward that this type of issue be addressed before it arises. Whether that take the form of more extensive regulation and community inclusion in planning or simply altering these sustainable practices, more research and action on this subject is required. We recommend that further studies look into small scale and affordable advanced technologies such as pocket anaerobic digesters, developing community involvement techniques, and food waste disposal regulations.

In terms of the Davidian Bros. Farm and the town of Northborough, we hope that our recommendations and research can aid in the resolution of their situation and the softening of tension between the stakeholders while helping to improve the farm's current operation and profitability. This community has the potential to become an example of how these land-use conflicts can be resolved for the benefit of all involved.

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Appendices

Appendix A: Right-to-Farm Statutes Chart

Right-to-Farm Statutes Chart	
State	**Right-to-Farm Statutes**
Massachusetts	· Mass. Gen. Laws ch. 243, § 6. No action in nuisance may be maintained against any person or entity resulting from any ordinary aspect of a farm operation or related activities. Said farm shall have been in operation for more than one year. This section shall not apply if the nuisance is determined to exist as the result of negligent conduct or actions inconsistent with generally accepted agricultural practices. · Mass. Gen. Laws ch. 128, § 1A. Farming, agriculture, farmer; definitions: See Statute.
Pennsylvania	· § 951. The policy of the Commonwealth is to conserve, protect, encourage the development and improvement of its agricultural land for the production of food, agricultural products and reduce the loss of its agricultural resources by limiting the conditions under which agricultural operations may be the subject matter of nuisance suits and ordinances. · § 952. Agricultural Definitions. See Statute. · § 953. (a) Every municipality shall encourage the continuity, development and viability of agricultural operations within its jurisdiction. Every municipality that defines or prohibits a public nuisance shall exclude any agricultural operation conducted within agricultural norms and that does not have a direct adverse effect on the public health and safety. · § 954. (a) No nuisance action shall be brought against an agricultural operation that complies with normal agricultural operations or if the operation is expanded has either: (1) been operating for one year or more prior to the date of bringing such action, or (2) has an approved plan prior to the Nutrient Management Act, provided, that nothing restrict or impede the protection of public health, safety and welfare or the authority to enforce State law. (b) The provisions of this section shall not affect or defeat the right to recover damages for any injuries or damages sustained from any agricultural operation.

California	· Cal. Civ. Code § 3482.5: (a)(1) No agricultural activity or operation conducted in a proper manner shall be or become a nuisance due to any changed condition after it has been in operation for more than three years if it was not a nuisance at the time it began. (2) Also applying to any activity of a district agricultural association that is operated in compliance with Division 3 of the Food and Agricultural Code. (b) Paragraph (1) of subdivision (a) shall not apply if the agricultural activity or operation obstructs the use of any navigable body of water, or any public park, square, street, or highway. (c) Paragraph (1) of subdivision (a) shall not invalidate any provision in the Health and Safety Code, Fish and Game Code, Food and Agricultural Code, or Division 7 of the Water Code., if the agricultural activity constitutes a nuisance. (d) This section shall prevail over any contrary provision of any ordinance or regulation of any city, county, city and county, or other political subdivision of the state. (e) For purposes of this section, the term "agricultural activity, operation, or facility, or appurtenances thereof": Definition, See Statute.

Appendix B: Questions for Focus Group with Neighbors of Davidian Farm and Preamble

Preamble:
Note: Specific wording will change between data gathering methods.

We are a group of students from Worcester Polytechnic Institute (WPI). We are conducting interviews of Northborough residence, farmers, and representatives to learn more about composting and its effects on neighboring communities. We strongly believe this kind of research will ultimately benefit communities and farms coexisting and the long-term success and sustainability of composting in Massachusetts. Your participation in an interview is completely voluntary and you may withdraw at any time. Please remember that your answers will remain anonymous. Unless you give us your express consent, no names will appear on any of the project reports or publications. This is a collaborative project between the Office of Senator Harriette Chandler and WPI, and your participation is greatly appreciated. If interested, a copy of our results can be provided at the conclusion of the study.

QUESTIONS TO BE ANSWERED BY RAISING HANDS (if over 6 people present)

- How long have you lived here in this community?
    - Under 2 years
    - Between 2 and 4 years
    - Between 4 and 10 years
    - Between 10 and 20 years
    - Over 20 years
- What would you say is your favorite aspect of living here?
    - Location?
    - Community?
    - Schools?
    - Rural feel?
    - Town attractions?
    - Weather?
    - Other?
- Which of these, if any, have affected your everyday life?
    - Traffic from vehicles transporting compost?
    - Noise from vehicles transporting compost?
    - Noise from composting practices?
    - Odor from composting practices?
    - Headaches due to odor?
    - Possible compost related asthma?
    - Other possible compost related health issues?
    - An increase in wildlife activity in the area, such as coyotes and crows?
    - An increase in pests in the area, such as flies?
- Have you publically tried to have your voice heard on this issue?
    - Town Meetings?
    - Legislative/Regulatory Meetings?

    - Letters/Emails to State Officials?
    - Public Complaint Filed?
    - Spoken to the Farm?
    - Other?
- Would you be comfortable with us coming back to perform odor testing from your property? (This will be done with odor sensors that detect compounds in the air)
    - Yes?
    - No?
- Would any of you be interested in participating in a qualitative odor study over the next few weeks? (it would take only a minute a few times a day)
    - Yes?
    - No?

<u>QUESTIONS TO BE ASKED IN SMALLER GROUPS (6 maximum)</u>

- How did you feel living next to the farm BEFORE it began composting?
- How have aspects of your lifestyle been affected by the composting operation over the past few years?
    - Social Lives?
    - Outdoor living?
        - Less time spent outdoors?
    - Traffic?
    - Noise Creation?
        - Times of day most noisy?
    - Health?
        - Possible related illnesses?
        - Can you explain these?
    - Concerns for Children?
    - Wildlife attraction near your home?
    - Domestic pet ownership?
    - Property value problems?
- We have read through all of the complaints filed through the town, but are there any others that anyone has not publically filed?
    - What do you think should be done about these?
- If the odors, health effects, and wildlife attraction were minimized, would the trucking be something that would be acceptable?
    - If not, would it be acceptable if we proposed legislation giving specific drop-off times?
- What do you know about Anaerobic Digestion?
    - *we explain*
    - Do you think this would be something that would be agreeable if the smell was controllable? (still truck-created noise and traffic)
- Do you know anything about composting covers?
    - *we explain*

    - Do you think this would be a workable solution if it mitigated wildlife attraction, odor, and health concerns? (still truck-created noise and traffic)
- Do you have any final thoughts or opinions on the composting program?
- Is there anyone else you feel we should be talking to?
- Any preferable ways for us to contact you if we would like to talk more?
    - Also you can always reach us at our email: chandleriqp@wpi.edu

Appendix C: Survey Handout for Neighbors near Davidian Farm

Preamble:

We are a group of students from Worcester Polytechnic Institute (WPI). We are conducting research involving Massachusetts residence, farmers, and state legislators to learn more about composting and its effects on neighboring communities. We strongly believe this kind of research will ultimately benefit communities and farms coexisting and the long-term success and sustainability of composting in Massachusetts. Your participation in this survey is completely voluntary and you may withdraw at any time. Please remember that your answers will remain confidential, unless you give us your express consent to share your name. No names will appear on any of the project reports or publications. This is an independent research project brought to us by the Office of Senator Harriette Chandler and WPI; your participation is greatly appreciated. If interested, a copy of our research/results can be provided at the conclusion of the study.

If you would like additional information, please feel free to contact us at chanderiqp@wpi.edu. You can also reach out to our faculty advisors, Corey Dehner (cdehner@wpi.edu) and Derren Rosbach (drosbach@wpi.edu).

Questions:

General Information:

Address (To be kept confidential): _____

Gender: _____

Estimated distance from composting site: _____

Questions 1-5 are designed to help us assess variable sensitivity to smells of survey respondents and to help us assess information about the current composting issue. Your responses to the remaining questions will help us identify appropriate placement of electronic noses (sensors used to determine odor concentration). By determining the concentration of specific odors, these electronic noses will help us to determine the cause of the odors and to put data next to the variability of odors in your area. This in turn will help us to examine the current regulations and determine the best way to find a targeted solution for the composting issue.

1. Check all that apply for each category/odor on the left-hand column. You may also write in your own category at the bottom of this table.

	Unpleasant odor	*Causes headaches for you*	*Causes allergies/colds for you*	*Write other health effects caused by the category*
Skunk				
Perfume				
Rotten eggs				
Fire/Smoke				
Fish				
Wood				
Citrus Fruit				
Alcohol				
Vinegar				
Sewage				
Cigarette Smoke				
Garlic				
Gasoline				
Expired Meat				
Manure				
Compost				

2. Check one box for each question below.

	Yes	*Sometimes*	*No*	*I don't know*
When someone is cooking in the kitchen, can you tell what they are cooking from the smell?				
When you visit someone else's house, do you notice how it smells?				
Do you notice the smell of people's breath or sweat?				
Do smells and odors influence your mood?				
Do odors (both pleasant and unpleasant) affect you in your everyday life?				

3. We understand that you may have concerns about issues regarding composting in Northborough. Please rank the impact (1 having the most impact and 6 having the most impact) of the following issues on your home life and fill out the rest of the table:

	Rank *(1-6)*	Does this issue exists for you? *(Yes or No)*	When these issues exist *(time or part of year)*	Other comments
Increase in wildlife				
Truck noise				
Compost operation noise				
Insects				
Health effects				
Odors				

4. Is there a time of day/week that odors/health effects from the compost are the most noticeable? If so, when and what kind of odors (describe)?

_____

_____

_____

5. Is there a time of year that odors/health effects from the compost are the most noticeable? If so, when?

_____

_____

_____

Appendix D: Questions and Table of Potential Solution Ideas for Town Officials

Information

- Solutions we are looking into/researching
    - Anaerobic digester (for reducing odor, wildlife, and health hazards)
    - Breathable, tarp-like covers designed for compost (for reducing odor, wildlife, and health hazards)
    - legislation/regulations (for reducing odor, limiting trucking times)
    - Moving the composting location (for reducing effects on neighbors)
    - Possibly widening the roads or certain junctions

- Variables we are considering
    - Effects to neighbors
    - Effects to farms
    - Costs to all parties involved
    - Reducing odors, wildlife, health hazards, truck/noise complaints

Questions

- What type of equipment/machinery does the Davidian farm use/own for their composting procedures?
- Have they tried covering the compost with various materials such as woodchips or fabric covers designed for compost?
- Do you know if Davidian's have control over deliveries of food waste?
- What challenges would come with a gravel or hard-pack road being placed on the Davidian farm to lessen traffic on the town roads?
- How difficult would it be to widen Ball St. and Green St. in some areas?
    - For instance, are there any town road laws that may affect that?
    - How much would it cost//how long would it take?
- Has the town looked into moving the composting to a different location off the farm such as a municipal lot while still allowing monetary benefits for the farm (farm rental of the land)?
- Does the Davidian Farm own land other than the main body of farmland?
- What changes do you think both the neighbors and the farm can live with?
    - For instance, all other concerns mitigated, would truck traffic still be an issue?
- What does the town currently do with its waste?
    - Food Waste?
- What does the town know of Anaerobic Digestion?
- Is there any current action being taken by the town with regards to the situation?
- How long have you held office for this community?
- What are your favorite aspects of the community?
- Have these been affected by the composting operation over the past few years?
    - If so, what have you done or thought about proposing to resolve this issue?
- What are some complaints that you have heard brought forth?

- What do you think should be done about these?
- What are your personal thoughts about the composting program?

Option	**Description**	**Costs**	**Monetary Gain**	**Concerns Addressed**	**Notes**
Anaerobic Digestion (AD)	~AD site on Davidian Farm	~$2-$6 M. Upfront (over 1.5-2 years) ~Upkeep depends ~Investors can help ~State can give grants	~Power farm ~Excess power back into Grid ~Fertilizer sale ~(For Farm)	~Health Risks ~Odors ~Wildlife Attraction	~Could result in more trucking ~18-24 months for full installation ~Wet, complete-mix digester
Compost Covers	~Breathable covers designed for compost that can also reduce odor and add benefits to composting operation	~$3/sq yrd. to $50/sq yrd.	~May allow for reduced composting times ~May result in better quality compost ~(For Farm)	~Odors ~Wildlife Attraction ~Some Health Risks	~Lifespan 6-10 plus years for some ~Short term installation
Widen Roads	~Possibility of widening roads in narrow areas to allow for ease of truck access	~Unknown ~TBD	N/A	~Truck size relative to road ~Easier road access for residents	~Town responsibility ~Possibly take away land from homeowners (& homeowners may not WANT wider roads)
Well/Water Testing	~Testing of nearby wells and bodies of water for contaminants	~Depends on self test vs Lab testing	N/A	~Compost Runoff ~Health risks from water contamination	~Lab tests are the only ones that would be verified

Odor Testing	~Use of odor detectors/ companies to determine odor causes and levels	~Depends on self test vs Lab testing	N/A	~Odor ~Health risks from VOCs and other airborne compounds	~Need a licenced operator to use the device/ perform “scan”
Road on Farm	~Private road on farm to cut down on road traffic	~Unknown	N/A	~Trucking ~Traffic	~Trucks on traveling safely on gravel?
Informing Farm of Worst Hours for Trucking	~Asking the farm to not receive trucks during x-y hours due to high traffic or other reasons	N/A	N/A	~Trucking ~Traffic	~Farm may not be in control of when trucks come
Moving Composting Site Off-Farm	~Moving the composting t an area where it won’t affect neighbors (i.e. municipal lots; other property of farm owners)	~Planning where to move it ~Moving it ~Unknown (large)			~Might not be considered an ‘agricultural compost site’ (commercial)

Appendix E: Questions for Farm Owners

- How long have you been farming in the community? (Or been working on this farm?)
- Were you part of the decision to start composting here?
    - How was that decision made?
- Can you walk us through how you go about composting?
    - Tonnage of compost per day? Per week?
    - Who transports the compost?
    - How do you hydrate and aerate the compost?
    - What are your general ingredients?
    - Regulations you have to work with?
- Where does the food waste for your composting originate?
- What do you know of Anaerobic Digesters?
    - Explain
- Have you ever heard of Odor Stop or CompostTex compost covers?
    - Explain
- What do you think about the concerns of the community? (For instance . . .)
- What do you think could be done to alleviate these concerns or are they false accusations?

Appendix F: Survey for Other Farm Owners

Preamble:

We are a group of students from Worcester Polytechnic Institute (WPI) conducting research involving Massachusetts residence, farmers, and state legislators to learn more about composting and its effects on neighboring communities. We strongly believe this kind of research will ultimately reduce community and farm conflicts and contribute to the long-term success and sustainability of composting in Massachusetts. Your participation in this survey is completely voluntary and you may withdraw at any time. Please remember that your answers will remain confidential, unless you give us your express consent to share your name. No names will appear on any of the project reports or publications. This is an independent research project brought to us by the Office of Senator Harriette Chandler and WPI; your participation is greatly appreciated. If interested, a copy of our research/results can be provided at the conclusion of the study.

If you would like additional information, please feel free to contact us at chanderiqp@wpi.edu. You can also reach out to our faculty advisors, Corey Dehner (cdehner@wpi.edu) and Derren Rosbach (drosbach@wpi.edu).

Questions:

1. What is the name of your farm/business?

   _____

   _____

2. Where is the composting site located?

   □❑□Massachusetts □❑□Other State: _____

   Town: _____

3. How long have you been composting for?

	Please Check one
0-2 Years	
2-5 Years	
5-10 Years	
10+ Years	

4. Where do you receive your raw composting ingredients from (i.e. your farm, other businesses in the area, community)?

   _____
   _____

5. What materials do you put into your compost? Please fill out the chart below:

	YES	***NO***	***Sometimes***	***Current Quantity (i.e. 1 ton of food waste per week)***	***Other Comments***
Food Waste					
Yard Waste (i.e. leaves, grass)					
Manure					
Cardboard/paper					
Woodchips or sawdust					
Other *(If yes Please list)*					

6. How would you describe your reactions with your surrounding community/neighbors? Please fill out the table below.

	YES	***NO***	***Sometimes***	
Are your finished compost customers satisfied with the product?				
Have you ever received complaints about your compost products?				
Have you ever received complaints about odor/health effects from your composting?				
Have you ever received complaints about trucking to and/or from your composting operation?				

7. If you have received complaints about odor, health effects, and trucking from your composting business, what actions (if any) have you taken to resolve the issues? Please describe.

_____
_____
_____
_____
_____
_____
_____

8. Are you aware of , have you researched, or have you used any of the following to improve your compost/compost operations:

	Not Aware of	***Aware of***	***Researched***	***Used***	***Other Comments***
Breathable, tarp like covers designed for large compost windrows					
Anaerobic Digesters					
Other types of bio filters					
Testing compost quality					
Other (Please specify)					

Appendix G: Questions for State Senate, Massachusetts Department of Environmental Protection, and Massachusetts Department of Agricultural Resources

- How long have you been a Senator (or employee of DAR, etc.)?
- How extensively have you worked with composting regulations?
- Have you sponsored (or worked with/enforced) any composting legislation?
- Which regulations may be relevant to the land use conflict in Northborough?
    - Accompanied by explanation of situation if not familiar with it?
- How would you describe the impact those regulations are having on the situation?
- Do you know of any similar cases to the one in Northborough?
    - How would you say they are similar?
- What do you know of Anaerobic Digesters and other methods for mitigating composting concerns on farms?

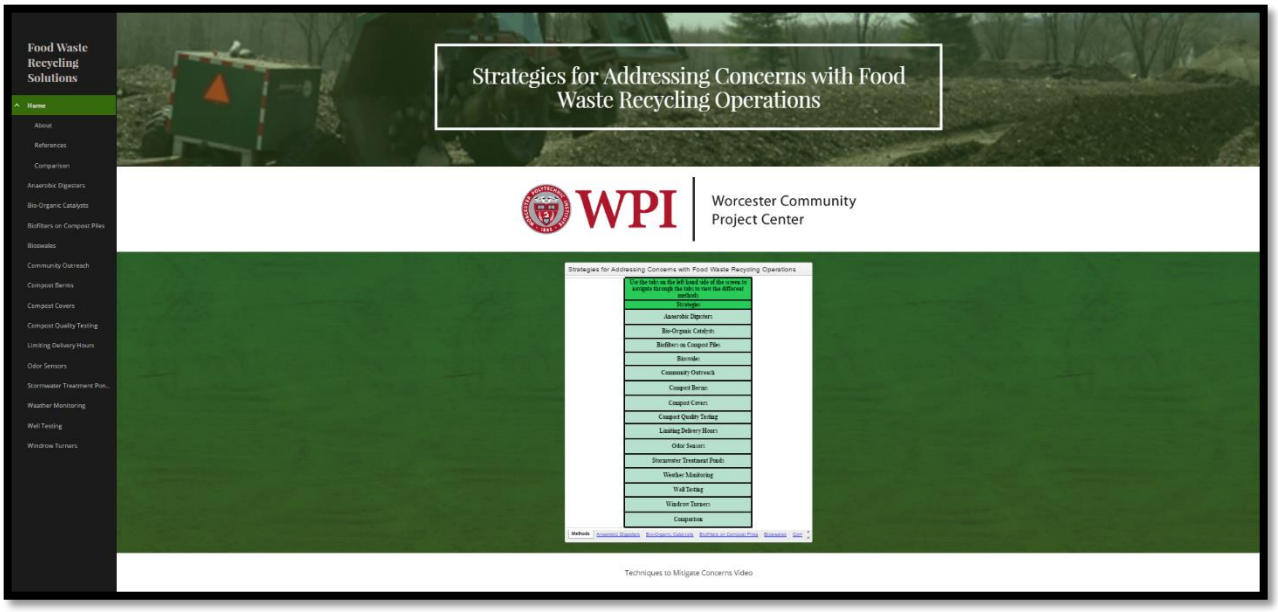
Appendix H: Questions for Vanguard Renewables

- What types of Anaerobic Digestion has Vanguard installed? (Wet digesters? Dry digesters?)
    - Where?
    - What is Jordan Dairy Farm's Digester?
    - Any digesters paired with typical composting?
- Would the digestate still be good for composting?
- How much space does an Anaerobic Digester and additional machinery take up?
    - We understand the Jordan Dairy Farm has a 500,000 gallon tank
- Do the raw materials have to be pretreated/separated or processed before entering the digester?
- How long does it take for this Anaerobic Digester to transform the waste into compost; and does this take the biogas it produces into account as well?
- How applicable would Anaerobic Digestion be to a composting operation primarily working with food waste, leaves, and grasses?
    - How would you describe the anaerobic digestion this operation would use?
        - How it would run?
        - What it would look like?
        - Space needed?
- How can the effluent, the liquid result from the anaerobic digester, be used?
    - Can it go straight into a compost pile as moisture content?
    - Or does it need to be 'cleaned' first?
- How much material is needed to make an Anaerobic Digester economically operable
    - This only using food waste?
- What odor levels result from the Anaerobic Digestion processes?
- What types of costs would an operation looking to implement such an operation need to account for and how long would it take to construct this operation?
    - For instance how much does the Anaerobic Digestion cost to setup, then maintenance costs?
    - What does the gain look like in terms of energy going back into the grid and monetary gain from that
- What noise is created by the Anaerobic Digesters that could bother neighbors?
- What would be your main selling points to a new customer?
- Who from your company could help us gain an even better technical understanding of the process?
- Can you help us to get in contact with the other farms you have worked with for a site visit?
- Are there any other people in your company or the industry that would be helpful for us to speak to?

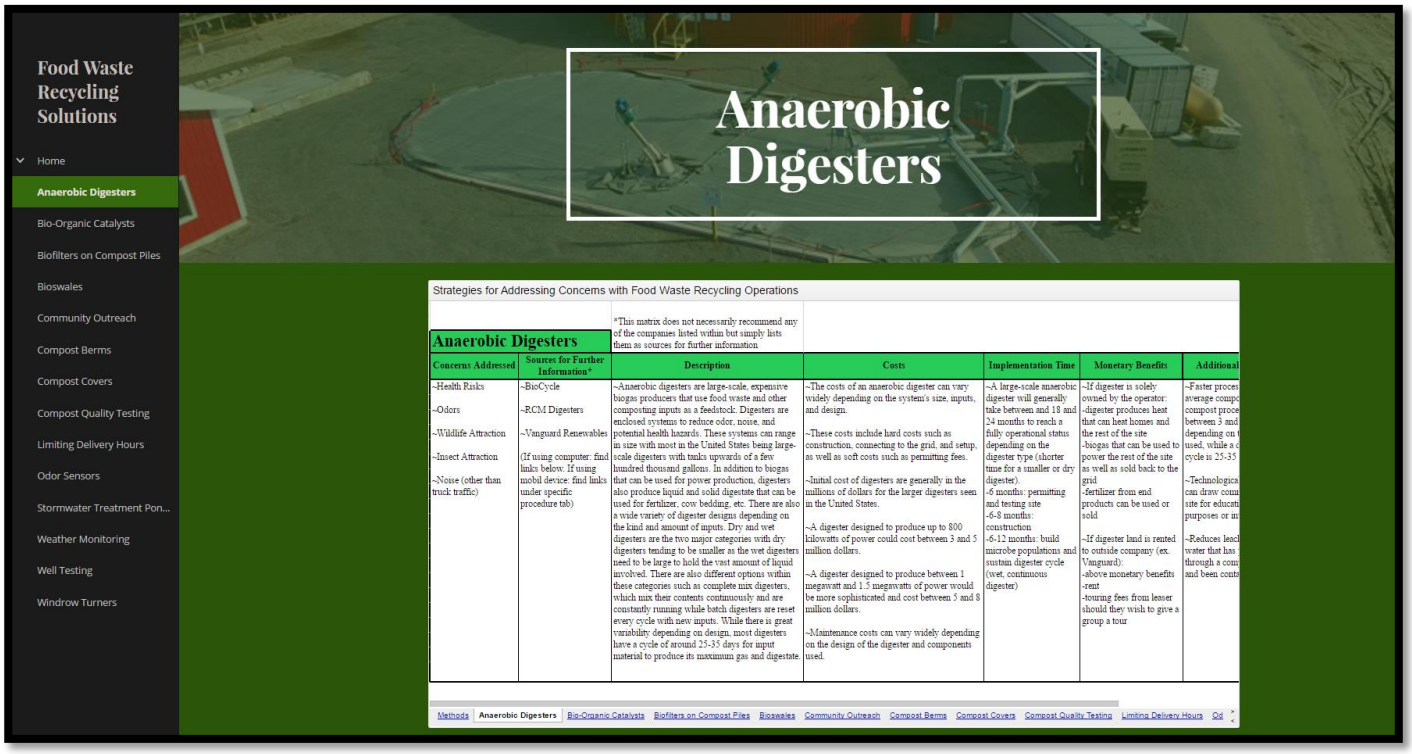
Appendix I: Matrix and Website Deliverables used to Formulate Recommendations and Aid Future Operations

Website Link: https://sites.google.com/view/food-waste-recycling-practices/home/comparison

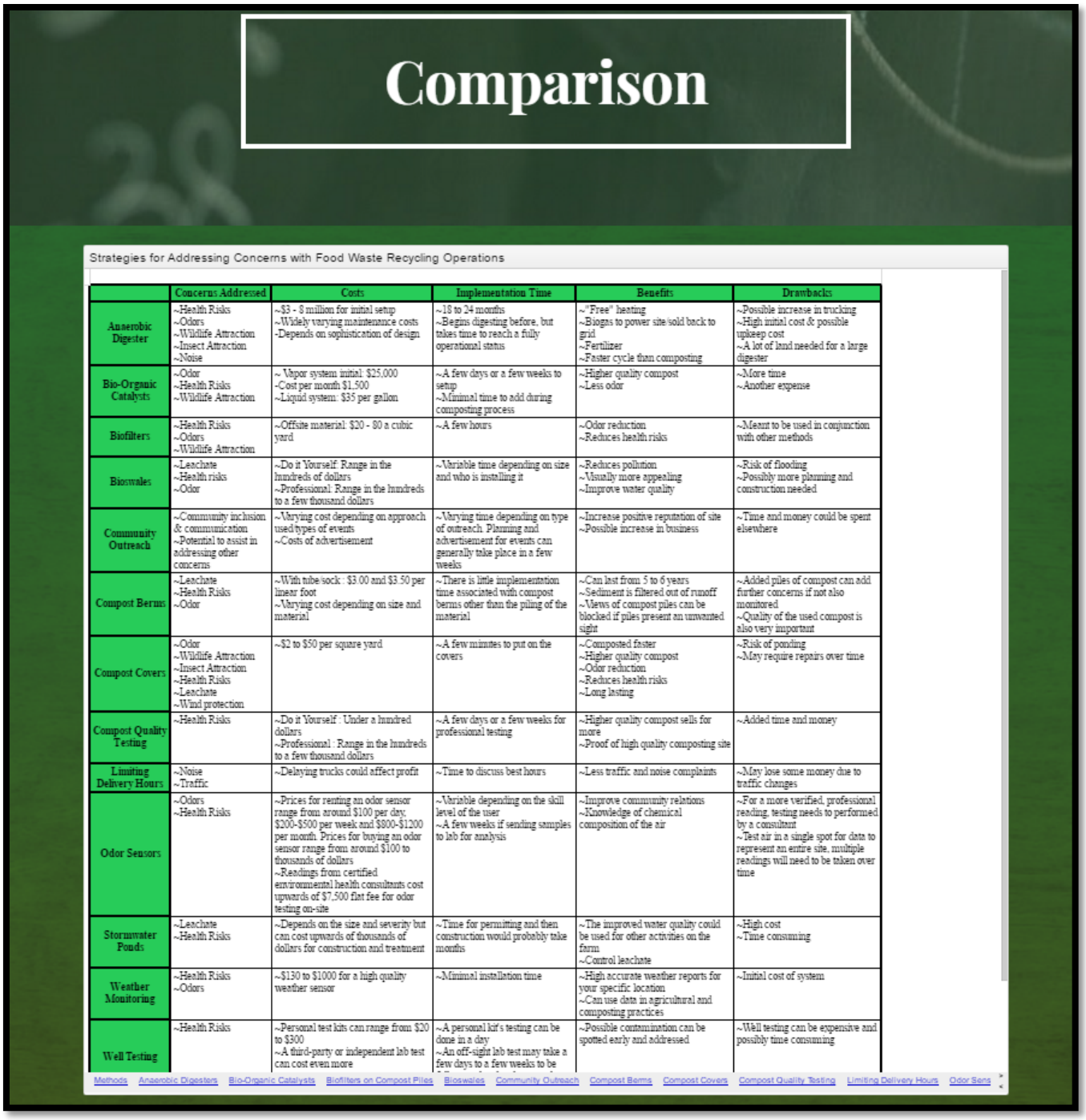
A.) Title Page with a Clickable List of Different Methods for Mitigating Concerns of Food Waste Recycling Sites



B.) Example Page of Website/Matrix Including Further Details for Each Method



C.) Example Page of Website/Matrix for Comparing Methods



	Concerns Addressed	Costs	Implementation Time	Benefits	Drawbacks
Anaerobic Digester	~Health Risks ~Odors ~Wildlife Attraction ~Insect Attraction ~Noise	~$3 - 8 million for initial setup ~Widely varying maintenance costs -Depends on sophistication of design	~18 to 24 months ~Begins digesting before, but takes time to reach a fully operational status	~"Free" heating ~Biogas to power site/sold back to grid ~Fertilizer ~Faster cycle than composting	~Possible increase in trucking ~High initial cost & possible upkeep cost ~A lot of land needed for a large digester
Bio-Organic Catalysts	~Odor ~Health Risks ~Wildlife Attraction	~ Vapor system initial: $25,000 -Cost per month $1,500 ~Liquid system: $35 per gallon	~A few days or a few weeks to setup ~Minimal time to add during composting process	~Higher quality compost ~Less odor	~More time ~Another expense
Biofilters	~Health Risks ~Odors ~Wildlife Attraction	~Offsite material: $20 - 80 a cubic yard	~A few hours	~Odor reduction ~Reduces health risks	~Meant to be used in conjunction with other methods
Bioswales	~Leachate ~Health risks ~Odor	~Do it Yourself: Range in the hundreds of dollars ~Professional: Range in the hundreds to a few thousand dollars	~Variable time depending on size and who is installing it	~Reduces pollution ~Visually more appealing ~Improve water quality	~Risk of flooding ~Possibly more planning and construction needed
Community Outreach	~Community inclusion & communication ~Potential to assist in addressing other concerns	~Varying cost depending on approach used/types of events ~Costs of advertisement	~Varying time depending on type of outreach. Planning and advertisement for events can generally take place in a few weeks	~Increase positive reputation of site ~Possible increase in business	~Time and money could be spent elsewhere
Compost Berms	~Leachate ~Health Risks ~Odor	~With tube/sock : $3.00 and $3.50 per linear foot ~Varying cost depending on size and material	~There is little implementation time associated with compost berms other than the piling of the material	~Can last from 5 to 6 years ~Sediment is filtered out of runoff ~Views of compost piles can be blocked if piles present an unwanted sight	~Added piles of compost can add further concerns if not also monitored ~Quality of the used compost is also very important
Compost Covers	~Odor ~Wildlife Attraction ~Insect Attraction ~Health Risks ~Leachate ~Wind protection	~$2 to $50 per square yard	~A few minutes to put on the covers	~Composted faster ~Higher quality compost ~Odor reduction ~Reduces health risks ~Long lasting	~Risk of ponding ~May require repairs over time
Compost Quality Testing	~Health Risks	~Do it Yourself : Under a hundred dollars ~Professional : Range in the hundreds to a few thousand dollars	~A few days or a few weeks for professional testing	~Higher quality compost sells for more ~Proof of high quality composting site	~Added time and money
Limiting Delivery Hours	~Noise ~Traffic	~Delaying trucks could affect profit	~Time to discuss best hours	~Less traffic and noise complaints	~May lose some money due to traffic changes
Odor Sensors	~Odors ~Health Risks	~Prices for renting an odor sensor range from around $100 per day, $200-$500 per week and $800-$1200 per month. Prices for buying an odor sensor range from around $100 to thousands of dollars ~Readings from certified environmental health consultants cost upwards of $7,500 flat fee for odor testing on-site	~Variable depending on the skill level of the user ~A few weeks if sending samples to lab for analysis	~Improve community relations ~Knowledge of chemical composition of the air	~For a more verified, professional reading, testing needs to performed by a consultant ~Test air in a single spot for data to represent an entire site, multiple readings will need to be taken over time
Stormwater Ponds	~Leachate ~Health Risks	~Depends on the size and severity but can cost upwards of thousands of dollars for construction and treatment	~Time for permitting and then construction would probably take months	~The improved water quality could be used for other activities on the farm ~Control leachate	~High cost ~Time consuming
Weather Monitoring	~Health Risks ~Odors	~$130 to $1000 for a high quality weather sensor	~Minimal installation time	~High accurate weather reports for your specific location ~Can use data in agricultural and composting practices	~Initial cost of system
Well Testing	~Health Risks	~Personal test kits can range from $20 to $300 ~A third-party or independent lab test can cost even more	~A personal kit's testing can be done in a day ~An off-sight lab test may take a few days to a few weeks to be	~Possible contamination can be spotted early and addressed	~Well testing can be expensive and possibly time consuming

Methods Anaerobic Digesters Bio-Organic Catalysts Biofilters on Compost Piles Bioswales Community Outreach Compost Berms Compost Covers Compost Quality Testing Limiting Delivery Hours Odor Sens

Appendix J: Martin's Farm Finished Compost

Martin's Farm in Greenfield, MA sells their premium compost for $46 dollars per cubic yard to homeowners, organic farmers, landscapers, etc. and it is commonly used to amend, or enhance as in make new, gardens every two to three years. They sell their loam and compost mix for $40 per cubic yard to people that do not have fertile soil yet because you need the loam to form a permanent base and the compost as a fertilizer. They sell their mulch compost mix for $43 per cubic yard. The farm also sells their top shelf 80% compost to 20% biochar blend for $70 per cubic yard for the more serious gardeners and organic farmers that know about biochar. Bio-char is a byproduct from a wood processing/biomass generator. Just like the compost, the bio char can hold five times its weight in water. The bio-char also adds a permanent carbon source and allows the microbes to thrive. They also sell straight bio-char for $100 a yard for anyone who wants to experiment with it.

a) Compost

b) 50% compost, 50% Loam

c.) 50% Compost, 50% Mulch

d) 80% Compost, 20% Bio-Char

e.) 100% Bio-Char

Appendix K: Anaerobic Digester Comparison Chart

Company-Anaerobic Digester-Type	Feedstock Input Quantity/Type	Output: Biogas, Digestate or Effluent Quantity/Type	Costs	Return Rate or Monetary Gain	Power Output	Concerns Addressed, Benefits, Additional Information	Source
Revolution Energy Solutions - Oak Leaf Dairy - Aumsville, Oregon, Wet Digester	Cow Manure plus some Off-Farm Feedstock, 30,000 gallons/day Total Digester Capacity: 820,000 gallons	Heat Source for Bioreactors: CHP (waste heat) from engine, Biogas Composition: 65-70% methane, Biogas Storage Capacity: 28,000 ft3	~	~	1,304,474 kWh/year, or the electricity to meet the annual needs of 94 homes	Reduction of 2,364 metric tons (CO2)/year, or the GHG emissions of 439 car	http://revolutionenergysolutions.com/digestate-enhances-pastures-at-forest-glen-jerseys/
Nestlé (AD) plant at its confectionery factory at Fawdon, Newcastle, Mix	200,000 liters of wash-waters per day and 1,200 tons of residual products per year, Over 250,000 liters of feedstock per day	Biogas	~	Annual energy savings of £300,000, £200,000 savings on disposal and discharge costs	up to 200kW	8% of power requirement supplied from biogas, 10% reduction in site's overall carbon footprint	http://clearfleau.com/portfolio/nestle-fawdon-factory-ad-plant/
Beijing Fangshan District Doudian Village Central Biogas Supply System	44 tons of cow dung/day (~1000 cows) Tank Volume: 1100m^3	Daily production of methane: 2000m^3 ; providing cooking as for 1900 households, Effluent: sold as organic fertilizer to local farm	Initial Investment :$1 million	~	~	User pay by IC card at the price equivalent to 30 US cents per m3, 20% cheaper than market natural gas price. In 2011.	https://colab.mit.edu/sites/default/files/D_Lab_Waste_Biodigester_Case_Studies_Report.pdf

Vanguard Renewables – Barstow's Farm Hadley, MA	20,000 tons of food waste annually, 9125 tons of manure a year, 600,000 gallon AD tank	30,000 tons/10 million gallons of odor-free, organic, liquid fertilizer annually	Ballpark - $5 to $8 million, includes extra automation /technical upgrades compared to other Vanguard sites	~	Produces more than 7,000 MWh of renewable energy/year ; equivalent to the needs of 1,600 homes	Offsets nearly 20,000 tons of CO2 emissions annually; the equivalent of the CO2 emissions from driving 3,790 cars for one year	http://vanguardrenewables.com/barstows-longview-farm/
Vanguard Renewables – Bar-Way Farm Deerfield, MA	660,000-gallon capacity Annual Digester Input: 9,125 tons of manure 36,500 tons of food waste	Liquid, organic fertilizer to increase crop yields	Ballpark - $ 3 to $5 million	~	Produces 7,700 MWh of renewable energy/year	Reduced energy cost, Odor reduction, Reduction in chemical fertilizer use, Heat reuse, Offsets 5,500 lbs. of CO2 emissions daily	http://vanguardrenewables.com/bar-way-farm-inc/
Vanguard Renewables – Jordan Dairy Farm Rutland, MA	500,000 gallon capacity Annual Digester Input: 9,125 tons of manure 20,000 tons of food waste	6-10 million gallons liquid organic fertilize	Ballpark - $ 3 to $5 million	~	Currently powers a 800kW engine, Produces 7,000 MWh of renewable energy/year	Offsets 19,779 lbs of CO2 emissions daily	http://vanguardrenewables.com/jordan-dairy-farm/

VTCAD (Vermont Tech Community Anaerobic Digester)	Total: 14,021 gallons /day, 52 tons/day	Average 1426.2 m^3 per day of biogas	Cost for permitting, construction and start up around $4.5 million	~	8000-9000 kWe	~	https://www.vtc.edu/sites/default/files/wysiwyg/PDFs/Digester%20Report/VT%20Tech_Digester%20Report_FINAL_All%20(1).pdf
Hunniford Energy Armagh, Northern Ireland – Wet Digester	35000 tons a year of slurry, silage commercial and industrial waste, including poultry processing waste and cow slurry	Biogas	~	~	500 kWe	~	http://www.biogas.org.uk/plants/hunniford-energy
Agriselect from agriKomp	3,200 cattle slurry 290 solid cattle manure 150 leftover food 780 silage tons/year	Biogas	~	~	625,150 kWh	Heat per year: 817,512 kWh	http://www.agrikomp.com/images/en-UK/pdf/agriSelect-Brochure.pdf
McDonnell Farms Biogas Limited, Shanagolden, Co. Limerick	10,760 tons/year – cattle slurry, food waste, poultry litter, dairy sludge, glycerin	950,000 m^3/year of biogas	Total capital cost: ~ €1.5m	Payback time: approx. 10 years	Electricity production: ~2,000,000 kWh/year	Primary energy savings: ~1,200 MWh/a CO2 savings: ~1,500 t CO2 /a	http://www.seai.ie/Publications/Renewables_Publications_/Bioenergy/Anaerobic_Digestion-Shanagolden_Case_Study_2010.pdf
GWE Biogas,	50,000 tons of	Biogas	Total	Payback	2 MWh per	Over ten years, it	http://www.co

Yorkshire, UK	food waste per year		project cost: £10m	time: aprox. 3 years, ~17.8 % return rate	year	will save around 260,000 tons of CO2	2sense.co.uk/files/3014/0551/1363/GWE_Case_study.pdf
RICARDO – AEA, Adnams Anaerobic Digestion Facility	~12,500 tons of food waste and brewery waste each year	600,000 m^3 of biogas supplied to the national gas grid each year	Total Project Cost: £2,968,493	~20% return rate	9.6 giga watt-hours per year	Reduce carbon footprint by up to 50% over five years	http://www.zerowaste.sa.gov.au/upload/resource-centre/publications/waste-to-energy/Case%20Study%204%20Adnams%20AD%20FINAL.pdf
Synergy Biogas, LLC – Synergy Dairy - Wyoming County, New York	Manure from ~2000 cows, 120,000-gallon digester,	16,000 yd^3 of bedding	Total unknown; $1,750,000 in grants	~	1.4 MWh per year, produces 10,000 megawatt-hours of renewable electricity annually	Reduce manure odors, reduce emissions equivalent to 10,000 tons of CO_2	http://ch4biogas.com/projects/synergy-biogas/
Quasar Energy Group – OSU AD – Wooster, Ohio	20,000 wet tons annual pump-able and high solids organic biomass, Tank Capacity of 550,000 gallons	Renewable Fuel Generation: 1,650 gge per day	~	~	5,256 MWh annually	Normal Digestion Time: 28 days	http://quasareg.com/New/wp-content/uploads/2016/10/Wooster-BBG-2016.pdf

Quasar Energy Group – Haviland AD System – Haviland, Ohio	42,600 wet tons annual bio-solids or 116 wet tons a day, FOG(Fats, oils and greases) and food waste, Tank Capacity of 980,000 gallons	CNG Fuel: (potential) 1,800 gge per day	~	~	1 MW per hour	Normal Digestion Time: 28 days	http://quasareg.com/New/wp-content/uploads/2016/10/Haviland-2016.pdf
Alliant Energy - Gordondale Farms – Nelsonville, Wisconsin – modified plug-flow anaerobic digester with vertical gas mixing.	22.2±1.0 gal per cow-day of influent, influent includes manure and milking center wastewater	55 tons of separated solids each week, excess of 22 tons per week, Total	$550,000	$0.015 per kWh	Predicted electricity generation potential of 2,775 kWh per day.	Reduction of 2,610 tons per year of methane	http://www.dvoinc.com/documents/gordondale_report_final.pdf

Appendix L: Bar-Way Farm Inc. Farm's Anaerobic Digester in Deerfield, MA

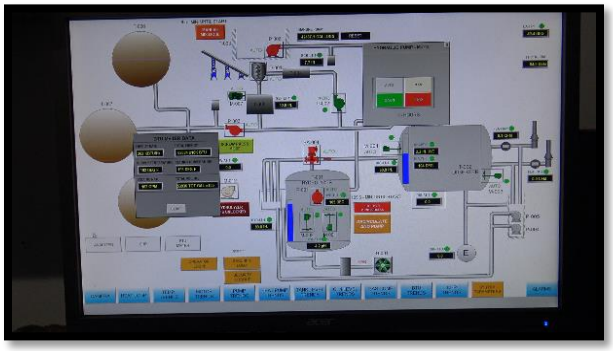
a.) closed food waste inlet

b.) Open food waste inlet

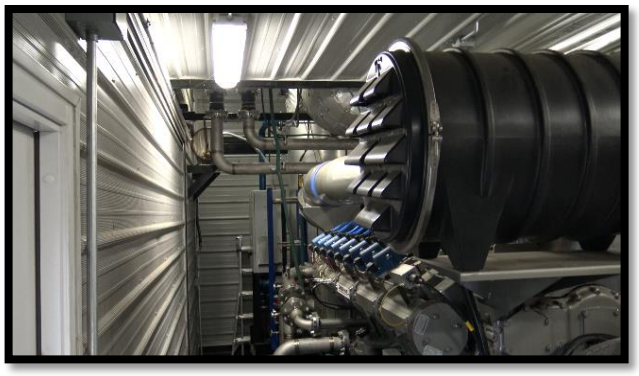
d.) Manure holding tank

c.) Anaerobic digester with hydrolyzer tank and mixers in foreground

f.) Odor Control Station



e.) Control screen that shows the entire anaerobic digestion process



j.) 16 cylinder biogas engine

i.) Effluent holding tank with hydrolyzer and mixers in foreground

h.) Separator – separates dry digestate and wet effluent

g.) Dry digestate coming out of the separator

Appendix M: Compost Covers Comparative Chart

Cover Type	CompostTex	Odour Stop™	Gore®Cover System
Description	➢ Breathable, geotextile membrane made of 100% UV-resistant polypropylene ➢ Sheds rainfall from covered windrows ➢ In business since 1994 and used on over 500 compost facilities around the world ➢ Weight: .37 lb/sq yrd ➢ Thickness: 1/16 inch Can use weights, tires, etc. to secure cover to ground	➢ Waterproof/breathable fabric ➢ Provides control of odor and VOCs ➢ Made in USA ➢ Training available ➢ Aeration system available ➢ Cover winder system available ➢ Software available	➢ Made with the same Gore-Tex material that is used for apparel ➢ Approved and proven in more than 200 locations in Europe and more than 25 locations in the U.S. ➢ For input volumes from 2,000-200,000 tons per year Equipped with an oxygen controlled, positively aerated system and oxygen/temperature sensors
Cost and Lifespan	➢ $2.36-$3.36 sq yrd ➢ Remains useful for 4-10 pus years	➢ $50 sq yrd Guarantee of 5 years	➢ Depends on the size of the facility but could be upwards of $500,000 for the entire system for larger facilities ➢ Lifespan is around 7 years
Benefits	➢ Ensures optimum aerobic compost conditions while preventing the anaerobic conditions that produce unpleasant odors and nutrient-laden leachate ➢ Keeps heat in in wet weather and moisture in in dry weather Wind protection	➢ Add-ons available such as an aeration/blower system, temperature/oxygen sensor probes, winder system, computer operating software	➢ Provides training ➢ Requires only 6 to 8 weeks from start of composting to the finished compost ➢ After preliminary mixing it requires no turning for the first four weeks and only one turn for the remaining two to four weeks ➢ Greatly reduced VOCs, ammonia, dust, and other emissions ➢ Up to 95% odor reduction ➢ Protection from ground water contamination so there is not a need for a large retention pond ➢ Effective in all climates, even subfreezing ➢ Scalable depending on the

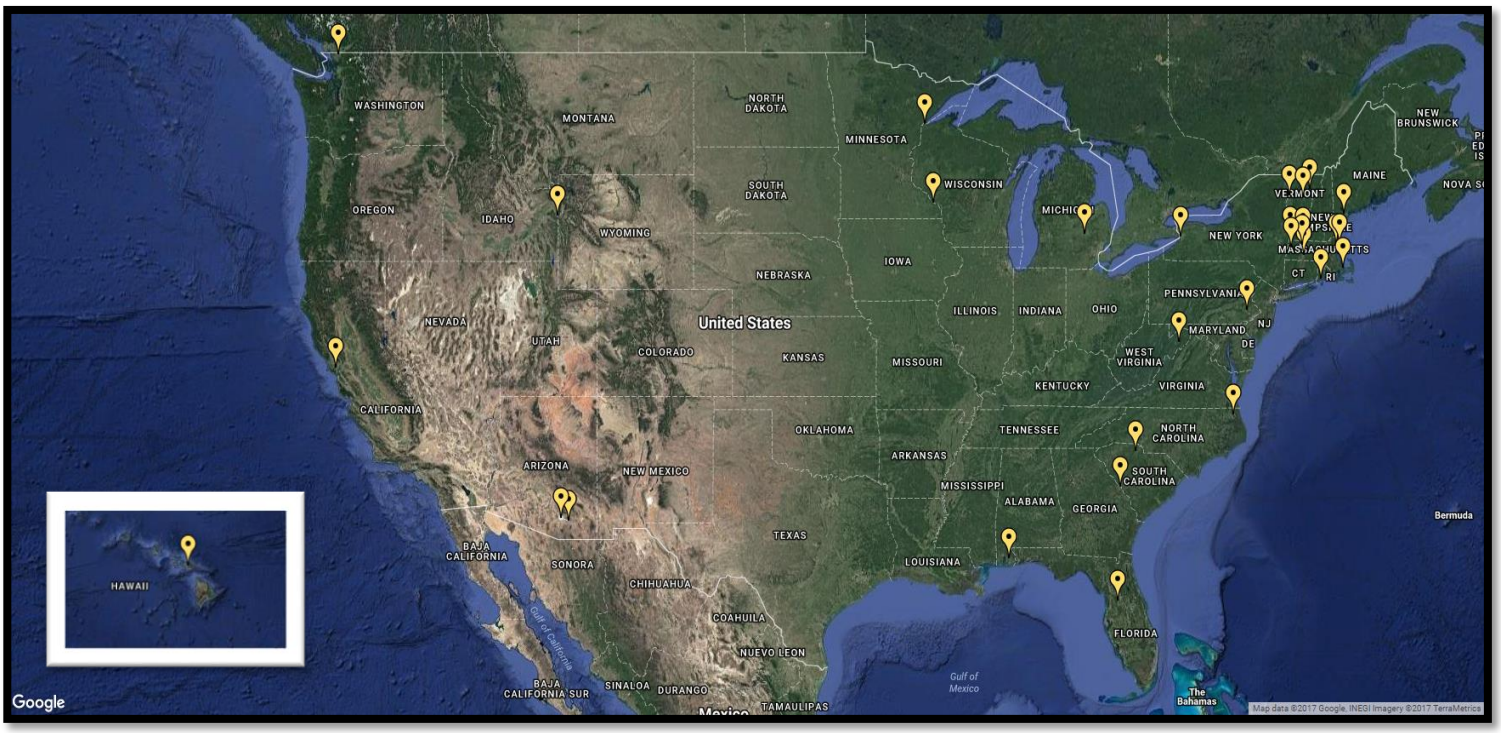
			size of the facility ➢ Requires much less area that typical windrows (i.e. 50 acres of windrows can be reduced to 4 acres using the Gore cover system ➢ Retains moisture ➢ Very limited labor required ➢ Mix ratio for food waste to green waste is 1:3 by or 1:1 by weight (i.e. if you receive fifteen tons of food waste, you only need fifteen tons of green waste for successful composting)
Drawbacks	➢ Should not be used on piles that require frequent access during the winter months	➢ Recommended to use in an aerated static pile system with positive aeration to be effective	➢ While it is heavy duty, the cover can rip which requires repair ➢ Needs to be pressurized for the best results ➢ Requires more construction and planning than just using a compost cover
Notes	➢ The site should have adequate drainage to prevent ponding ➢ The piles should be oriented parallel to the site slope ➢ Should be used only when needed ➢ Best to remove the covers when they are dry ➢ A threading frame can be attached to the tractor-pulled turner which raises and lowers the covers as the turner is pulled through the pile ➢ For larger piles multiple covers should overlap (12”-24”) to cover the entire pile ➢ Store covers dry and away from sunlight	➢ Tested on October 9, 2008 for VOC and ammonia emissions at a bio-solids compost facility in Western Arizona ➢ Testing showed it was 98% effective in reducing VOCs	➢ If this product is used in an urban area, you can build a building for tipping the food and green waste in order to mix the wastes without spreading the odor ➢ This company offers a smaller scale, mobile system in order to try out they process without investing a large amount of money for a full scale version

Appendix N: Compost Runoff/Leachate Management Chart

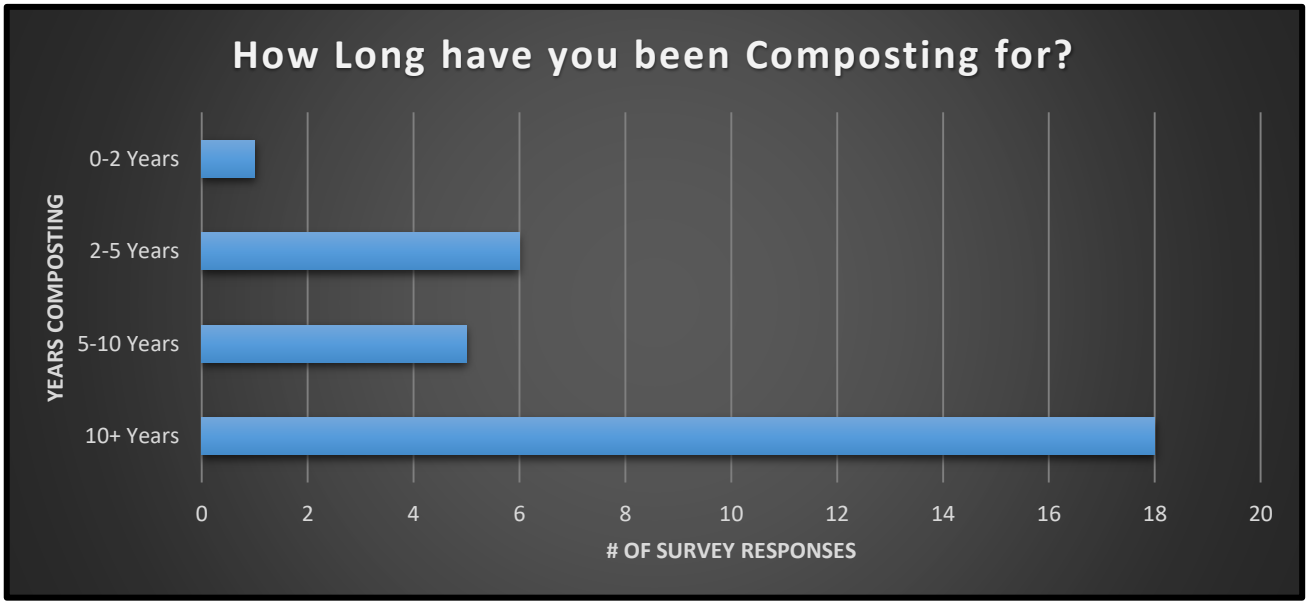
Storm Water Management Type	Description	Benefits	Drawbacks	Companies that offer the products
Compost Filter Tubes/Socks	➢ A mix of compost, wood chips, and other materials are inserted into burlap or mesh tubes ➢ The tubes can be held in place with stakes ➢ Various types of filter tubes for sediment/erosion control, pollutant removal, and storm water management ➢ Sizes range from 8 inch diameter by 10 feet long to 24 inch diameter by 100 feet long ➢ Functional lifespan varies from 6 months to 5 years	➢ They are heavy enough so that they do not need to be trenched in and are easy to install ➢ Filters sediments ➢ Slow the velocity of water and reduces erosion on sloped surfaces ➢ Due to the water holding capacity of the compost, they hold water, reducing flow ➢ Natural additives can be added to the tubes reduce pollutants such as heavy metals, harmful bacteria, phosphorous, nitrogen, and petroleum products ➢ Most are completely biodegradable so they do not have to be removed ➢ Can be used on frozen or compacted soils, paved areas, and around sensitive areas	➢ Performances vary depending on the additives	➢ Filtrexx ➢ Diamond Sock ➢ Silt Snake
Compost Filter Berms	➢ A dike of compost that is placed perpendicular to runoff to control erosion and filter pollutants like heavy metals, nitrogen, phosphorous, oils, and grease ➢ Generally placed along the perimeter of a compost site ➢ Cab be vegetated or unvegetated	➢ Better than regular filter berms because the compost retains a much larger amount of water that helps with erosion prevention and establishing vegetation ➢	➢ Best for sites where flow does not exceed 1 cubic foot per second ➢ The quality of the compost used is very important	➢ Can be homemade
Bioswales (grass swales, vegetated swales, filter strips)	➢ Shallow depressions in landscape where storm water is directed, filtered, slowed, and/or adsorbed	➢ Reduces silt, pollution, etc. ➢ Can be more visually appealing than other options	➢ Have to be careful of flooding the bioswale	➢ Can be homemade ➢ Landscaping companies
Stormwater Treatment Ponds	➢ A manmade pond nearby the composting facility that collects storm water and can then treat the contaminants	➢ Can improve water quality ➢ The water can be recycled	➢ Higher cost ➢ More construction necessary ➢ Requires larger amounts of space ➢ Can attract insects	➢ Construction/ landscaping companies

Appendix O: Information from Composting Farm/Business Survey

Map of Survey responses (Note the variety of locations and the amount in Massachusetts)



(Google Maps imaging, USA)



Sample Survey Data

Farm/ Business Name	Location	Description of Area	Years of Composting	Amount composted	Techniques used and/or researched
Barnside Farm Compost Facility LLC	Schwenksville, PA	Residential, other farms nearby	Over 10	N/A	• Compost Quality Testing • Certified Compost with the US Composting Council
Bear Path Compost LLC	Deerfield, MA	Residential areas nearby	Over 10	Approx. 1200 tons per year	• Compost Quality Testing
Benson Farm, LLC	Gorham, ME	Residential areas nearby	Over 10	5 tons per week	• Compost Quality Testing
Black Dirt Farm	Stannard, VT	Residential areas nearby	Over 10	8-10 tons of food waste per week	• Compost Covers • Anaerobic Digesters • Other Biofilters • Compost Quality Testing • Windrow and Recipe Monitoring
Black Earth Compost	Gloucester, MA	Residential areas nearby	5-10	N/A	• Compost Covers • Anaerobic Digesters • Other Biofilters • Compost Quality Testing • Wood Ash
Brick Ends Farm	South Hamilton, MA	Residential areas nearby	Over 10	N/A	• Anaerobic Digesters • Compost Quality Testing
Bricko Farms Inc.	Augusta, GA	Urban areas nearby	Over 10	Approx. 160 tons per week	• Other Biofilters • Compost Quality Testing
Carolina Compost	Camden, NC	Rural, mostly other farms nearby	5-10	3-4 tons per month	• Compost Quality Testing
Champlain Valley Compost Co.	Charlotte, VT	Residential areas nearby	Over 10	Approx. 1000 tons per year	N/A
Compost Cats	Tuscan, AZ	Urban	2-5	Approx. 13 tons per week	• Compost Quality Testing
CompostUSA of Sumter County	Lake Panasoffkee, FL	Residential/ suburban areas nearby	Over 10	N/A	• Compost Covers • Anaerobic Digesters • Other Biofilters • Compost Quality Testing • MSAP Method
Earth Care Farm LLC	Charlestown, RI	Residential areas nearby	Over 10	20-100 tons per week	N/A

Fairfax Companies, LLC	Tuscan, AZ	Urban	5-10	200 tons per day	• Compost Quality Testing • pH monitoring
Farmer Pirates Compost Crew	Buffalo, NY	Urban areas nearby	2-5	Approx. 50 tons per week	• Compost Covers • Compost Quality Testing
Faulkner Farms	Silverhill, Al	Residential, other farms nearby	5-10	5 tons per week	• Compost Covers • Anaerobic Digesters • Other Biofilters • Compost Quality Testing
Green Earth Technology, LLC	Lynden, WA	Residential areas nearby	Over 10	23,500 tons annually	• Compost Covers • Anaerobic Digesters • Other Biofilters • Compost Quality Testing
Holiday Brook Farm	Dalton, MA	Residential areas nearby	Over 10	N/A	N/A
Kupa'a Farms	Kula, Hawaii	Residential areas nearby	Over 10	N/A	• Non-breathable Compost Covers • Anaerobic Digesters • Compost Quality Testing • Perforated Plastic Pipes
Litchke Farms	Superior, WI	Rural, few neighbors	Over 10	N/A	• Compost Quality Testing • 12 ft. Tunneled Compost Turner
Martin's Farm	Greenfield, MA	Residential areas nearby	Over 10	Over 15 tons per day	• Compost Covers • Compost Quality Testing • Windrow Turner • Perimeter Vapor System • Bio Organic Catalysts/ Inoculants • Weather/Recipe Monitoring
McKay's Compost Farm	Swartz Creek, MI	Residential areas nearby	Over 10	N/A	• Compost Covers • Anaerobic Digesters • Other Biofilters • Compost Quality Testing
Moorefield Regional Compost	Moorefield, WV	Residential areas nearby	2-5	N/A	• Compost Covers • Anaerobic Digesters • Other Biofilters • Compost Quality Testing
Palmetto Supreme Organic Compost, Inc.	McConnells, SC	Residential, other farms nearby	5-10	N/A	• Compost Quality Testing

TAM Organics	Bennington, VT	Residential areas nearby	2-5	Approx. 305 tons per week	• Compost Covers • Other Biofilters • Compost Quality Testing
Teton Full Circle Farm	Victor, Idaho	Residential, other farms nearby	2-5	N/A	• Anaerobic Digester • Compost Quality Testing • Biodynamic Preparations
Vermont Compost Company	Montpelier, VT	Residential areas nearby	Over 10	1,400 tons per year	N/A
Watts Family Farms Inc.	Sandwich, MA	Residential areas nearby	Over 10	N/A	N/A
Windham Solid Waste Management District	Brattleboro, VT	Residential areas nearby	2-5	Approx. 50 tons per week	• Compost Covers • Anaerobic Digesters • Other Biofilters • Compost Quality Testing
Winona Farm	Winona, MN	Residential areas nearby	Over 10	2 tons of food waste per week	• Biochar
WM Earthcare of Marin	Novato, CA	Residential/ suburban areas nearby	Over 10	500 tons per day	• Other Biofilters • Compost Quality Testing • Mechanical Aeration

Summary of Techniques/Strategies Used Column

Strategy to improve Compost Operation	Survey Percent Using
Compost Covers	37.5% (9 sites)
Anaerobic Digesters	8.33% (2 sites)
Biofilters	29.17% (7 sites)
Compost Quality Testing	87.5% (21 sites)
Other	37.5% (9 sites)

*As found from the survey, these composting sites receive their feedstock from a variety of sources including: their community, other businesses, on-site generation, other farms, supermarkets, towns, hotels, restaurants, zoos, parks and others.

*Also found from the survey, the feedstock includes food waste, yard waste, manures, papers, woodchips, hay, bio-solids, fish, seaweeds, mushrooms, coffee grinds, wood ash, and others.

Appendix P: Final Matrix of Strategies to Mitigate Concerns with Food Waste Recycling Operations

Strategies for Addressing Concerns with Food Waste Recycling Operations
Compiled by Nicholas Bograd, Brett Carbonneau, Alex Krasa and Benjamin Preston in May, 2017 to complete a project for partial fulfillment of a degree requirement at Worcester Polytechnic Institute
Each Sheet at the bottom of the page contains details for the methods listed below
Methods
Anaerobic Digesters
Bio-Organic Catalysts
Biofilters on Compost Piles
Bioswales
Community Outreach
Compost Berms
Compost Covers
Compost Quality Testing
Limiting Delivery Hours
Odor Sensors
Stormwater Treatment Ponds
Weather Monitoring
Well Testing
Windrow Turners
Comparison

Anaerobic Digesters

*This matrix does not necessarily recommend any of the companies listed within but simply lists them as sources for further information

Concerns Addressed	Sources for Further Information*	Description	Costs	Implementation Time	Monetary Benefits	Additional Benefits	Drawbacks
~Health Risks ~Odors ~Wildlife Attraction ~Insect Attraction ~Noise (other than truck traffic)	~BioCycle ~RCM Digesters ~Vanguard Renewables	~Anaerobic digesters are large-scale, expensive biogas producers that use food waste and other composting inputs as a feedstock. Digesters are enclosed systems to reduce odor, noise, and potential health hazards. These systems can range in size with most in the United States being large-scale digesters with tanks upwards of a few hundred thousand gallons. In addition to biogas that can be used for power production, digesters also produce liquid and solid digestate that can be used for fertilizer, cow bedding, etc. There are also a wide variety of digester designs depending on the kind and amount of inputs. Dry and wet digesters are the two major categories with dry digesters tending to be smaller as the wet digesters need to be large to hold the vast amount of liquid involved. There are also different options within these categories such as complete mix digesters, which mix their contents continuously and are constantly running while batch digesters are reset every cycle with new inputs. While there is great variability depending on design, most digesters have a cycle of around 25-35 days for input material to produce its maximum gas and digestate.	~The costs of an anaerobic digester can vary widely depending on the system's size, inputs, and design. ~These costs include hard costs such as construction, connecting to the grid, and setup, as well as soft costs such as permitting fees. ~Initial cost of digesters are generally in the millions of dollars for the larger digesters seen in the United States. ~A digester designed to produce up to 800 kilowatts of power could cost between 3 and 5 million dollars. ~A digester designed to produce between 1 megawatt and 1.5 megawatts of power would be more sophisticated and cost between 5 and 8 million dollars. ~Maintenance costs can vary widely depending on the design of the digester and components used.	~A large-scale anaerobic digester will generally take between and 18 and 24 months to reach a fully operational status depending on the digester type (shorter time for a smaller or dry digester). -6 months: permitting and testing site -6-8 months: construction -6-12 months: build microbe populations and sustain digester cycle (wet, continuous digester)	~If digester is solely owned by the operator: -digester produces heat that can heat homes and the rest of the site -biogas that can be used to power the rest of the site as well as sold back to the grid -fertilizer from end products can be used or sold ~If digester land is rented to outside company (ex. Vanguard): -above monetary benefits -rent -touring fees from leaser should they wish to give a group a tour	~Faster process than average compost (normal compost process lasts between 3 and 6 months depending on the process used, while a digester cycle is 25-35 days). ~Technological process can draw community to site for educational purposes or interests. ~Reduces leachate, or water that has percolated through a compost pile and been contaminated.	~Possible trucking increase as more feedstock is necessary to run digester ~Large initial costs with possibly high maintenance costs ~Large space needed if using a larger digester ~Long time to implement

Bio-Organic Catalysts

*This matrix does not necessarily recommend any of the companies listed within but simply lists them as sources for further information

Concerns Addressed	Sources for Further Information*	Description	Costs	Implementation Time	Monetary Benefits	Additional Benefits	Drawbacks
~Odor ~Health Risks ~Wildlife Attraction	~BioCycle ~Bio-organic Catalyst ~Ecoverse ~Martin's Farm Greenfield, MA ~Global Odor Technologies ~U.S. Composting Council	~Bio-organic catalysts are compounds that either enhance the efficiency of the microbes within a compost pile or reduce odorous compounds in the air around a compost pile. The first are inoculates that are sprayed on or turned in a compost pile. These compounds act similar to a steroid for the microbes within the pile, allowing them to more efficiently use the oxygen at their disposal. This increased efficiency helps to reduce odors and pathogens through regulating temperature and oxygen levels in the pile, thus also speeding up the compost process and producing a better quality final product. The topical or turned-in catalyst is a liquid that is diluted in water generally at a 100 parts water to 1 part catalyst ratio. Bio-organic catalysts are additionally used for odor mitigation in the air surrounding compost. For instance, the Martin's Farm in Greenfield, MA. uses a perimeter vapor system from Global Odor Control Technologies. This system spreads a vapor in the air that around the compost operations that either makes an odor compound denser than the air forcing it to drop to the ground, alters the compound to neutralize the odor, or destroys the odors compound.	~A topical or turned-in catalyst can cost around $35 per gallon ~Perimeter vapor system can cost upwards $25,000 with a monthly operational cost of about $1,500 dollars.	~A topical or turned-in catalyst can be added during typical turning operation thus requiring very little extra time for its use ~A vapor system can require further setup in the form of the delivery system, this could require a few days to a few weeks to fully set up the system.	~The higher quality compost resulting from catalyst use can serve as a reason to increase final product prices	~Reducing odor and health risks can increase community support for the operation ~A higher quality compost product ~Many, if not all have no harmful effects to your health and environment	~Application can require extra time or machinery use

Biofilters on Compost Piles

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Concerns Addressed	Sources for Further Information*	Description	Costs	Implementation Time	Monetary Benefits	Additional Benefits	Drawbacks
~Health Risks ~Odors ~Wildlife Attraction	~Bar-Way Farm Inc. Deerfield, MA. ~BioCycle ~Martin's Farm Greenfield, MA. ~U.S. Composting Council ~Vanguard Renewables	~Biofilters are materials that absorb odorous or harmful compounds from the air. For instance, certain woods naturally, or after treatment, have an ability to attract and neutralize particles. One anaerobic digester in Deerfield, Massachusetts uses this method. In the top of the anaerobic digester tank there is a deck of treated wood that absorbs hydrogen sulfide gases. The gases solidfy on the wood as stalagmites before falling to the bottom where they can be scrubbed away. ~Another method is to use materials such as wood chips and finished compost product on top of existing piles with the effect of reducing odor compounds, this practice is used by the Martin's Farm in Greenfield, Massachusetts	~There is no extra cost for using a portion of compost generated on site or woodchips generated on site. ~Though if bought elsewhere, materials for this type of system, for example wood chips, could cost between $20 and $80 per cubic yard.	~Spreading the materials over a windrow pile can take some time on the order of hours. ~Installing a setup similar to that seen in the Deerfield anaerobic digester would take longer though depending upon the system it is used it.	~These filters can help to reduce odors and health risks, possibly eliminating the need for other, more costly mitigation methods.	~These systems can show a community that the operation is making strides to mitigate address their concerns while needing a smaller budget.	~Biofilters are not generally a sole solution, they are usually applied within or in combination with another system.

Bioswales

*This matrix does not necessarily recommend any of the companies listed within but simply lists them as sources for further information

Concerns Addressed	Sources for Further Information*	Description	Costs	Implementation Time	Monetary Benefits	Additional Benefits	Drawbacks
~Leachate ~Health risks ~Odor	~Agri Service Inc. ~BioCycle ~Filtrexx Sustainable Technologies ~US Composting Council	~Bioswales are shallow depressions in the landscape with various filters such as stones, sand, etc. where stormwater is directed, filtered, slowed, and/or adsorbed These depressions allow for filtering of leachate to prevent the contaminated runoff from entering water systems that are used by people for crop growth or drinking water. Thus, these systems help to prevent large issues from arising if contaminated water were to enter an existing water system.	~Cost of these systems depends on the size of the depression and materials used within it. ~If constructed by a landscaping company these depressions can cost tens or hundreds of dollars while they can also be homemade for the lower cost of materials.	~Implementation time depends on who is constructing the system and the size of the system to be constructed.	~Bioswales can aid other, inexpensive methods in mitigating odor and leachate so that a more expensive system may not be necessary.	~Systems reduce silt, pollution, etc. ~Bioswales can be more visually appealing than other options. ~They can be used as pre-treatment and/or post-treatment for detention ponds. ~They can help improve runoff water quality.	~Due to their smaller size an operator needs to be careful of flooding in bioswales. ~These systems may require more planning and construction than other leachate management techniques.

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Community Outreach

Concerns Addressed	Sources for Further Information*	Description	Costs	Implementation Time	Monetary Benefits	Additional Benefits	Drawbacks
~Community inclusion and communication ~Potential to assist in addressing all other concerns	~BioCycle ~Martin's Farm Greenfield, MA.	~Community outreach can take many forms. The method revolves around the idea that communication and inclusion allow all stakeholders to feel invested in the operation and to better understand its importance and operation. This strategy can include regular communication with a nearby community, participation in town meetings, and on-site events. In terms of on-site events success has been noted with farms that hold events regularly such as monthly or on a specific date each year. Such a practice allows for neighbors and community members to know ahead of time that an event will be occurring so they can plan for it and increase attendance. Events of this nature that we have found effective include operation tours and education days, events geared towards children, and events that include the rest of the operation (if it is a farm for example) to better understand how the operation fits in the larger scope of the site.	~The costs of this strategy can vary depending on the types of outreach. ~Events such as a compost education day may have very little costs other than advertisement. ~Events involving children or the rest of the farm may require extra attractions that could have a cost.	~The implementation time for such outreach is essentially solely as long as is needed for advertising and setup. ~Other events may take more time to implement in the idea that making an event well-known or common place may take several iterations of the event itself which will take time.	~The main goal of these practices is to increase positive relations with nearby communities however, accomplishing this goal can lead to increased business at a site especially regarding sale of the final compost product.	~Positive community relations can help to prevent concerns before they arise as communication lines are already open to discuss operations and worries. ~These positive relations can also allow for more input and understanding from neighbors in mitigating existing concerns as well. ~We found positive relations and community support to be two of the most important aspects of successful operations.	~Additional time and possibly resources need to be spent and diverted to these types of outreach that could have been used elsewhere

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Compost Berms

Concerns Addressed	Sources for Further Information*	Description	Costs	Implementation Time	Monetary Benefits	Additional Benefits	Drawbacks
~Leachate ~Health Risks ~Odor	~BioCycle ~Diamond Sock ~Filtrexx Sustainable Technologies ~Silt Snake ~U.S. Composting Council	~Compost berms are piles or tubes of materials that are used to reduce leachate and odors from a compost operation. The tubes are made of a burlap or mesh material that holds the materials to a cylindrical form that allows easy stacking and placement. Materials inside the tubes can range from woodchips to finished compost product to special additives to remove certain pollutants. These tubes are dense and heavy enough that they do not need to be trenched in place but can simply be placed, staked, and left where they are without fear of movement. Piles are similar to these tubes but are simply piled instead of contained in a tube. Both of these barriers are placed perpendicular to runoff tracks and around a site in general to block and screen leachate, or contaminated runoff liquid from the site. In addition to contaminants that can affect health such as bacteria, phosphorus, and nitrogen, additives to these screens can also filter odors, sediments, heavy metals. Berms solely comprised of compost or a majority of compost have the added benefits of compost's ability to hold five times its weight in water. Thus, the barriers can deal with large amounts of leachate.	~Cost of these berms can vary depending on the materials they are comprised of and the size of the berm. -400 linear feet of 12 inch diameter compost filter sock costs about $3,000. -This cost includes materials, installation, regular inspection, sediment removal, and repair, replacement, and disposal costs. -Just materials and installation would cost between $3.00 and $3.50 per linear foot (installation and materials) ~Berms piled without a tube or sock can cost essentially nothing as they are made with existing compost or other materials	~There is little implementation time associated with compost berms other than the piling of the material	~Can aid other, inexpensive methods in mitigating odor and leachate so that a more expensive system may not be needed	~Can last from 5 to 6 years ~Sediment is filtered out of runoff ~Views of compost piles can be blocked if piles present an unwanted sight ~Special additives can be added to the berms/tubes in order to screen for specific pollutants ~They can be bought/made in various sizes	~Added piles of compost can add further concerns if not also monitored ~Quality of the used compost is also very important ~Will eventually have to replace

Compost Covers

*This matrix does not necessarily recommend any of the companies listed within but simply lists them as sources for further information

Concerns Addressed	Sources for Further Information*	Description	Costs	Implementation Time	Monetary Benefits	Additional Benefits	Drawbacks
~Odor ~Wildlife Attraction	~BioCycle ~CVCompost CompostTex ~Gore® Cover System ~Odour Stop™ ~U.S. Composting Council	~Compost covers are specially designed nonwoven fabric that is breathable, waterproof, and UV resistant. Some are designed to be incorporated with an aeration system in order to further increase the efficiency of oxygen use within a compost pile. The covers ensure optimum aerobic compost conditions while preventing anaerobic conditions that produce unpleasant odors and nutrient-laden leachate, or contaminated compost runoff. They do this by aiding in the control of oxygen, temperature, and moisture levels of the piles. Their ability to keep a pile's heat levels during wet weather and moisture levels during dry weather are invaluable in pile management. Compost covers also protect against wind pattern variability by reducing odors and keeping variable levels constant within each pile.	~Ranging from $2-$50 per square yard ~With an added aeration system included, costs can be upwards of $500,000 ~Their lifespan can range from 6 months to over ten years depending on the type and the weather	~Minutes for the covers alone depending on the scale ~A few months may be necessary for covers with aeration systems and other systems	~Faster processing time ~Better quality compost	~A threading frame can be attached to the tractor-pulled turner which raises and lowers the covers as the turner is pulled through the pile ~Other add-ons available such as an aeration/blower system, temperature/oxygen sensor probes, winder system, computer operating software ~Some can reduce process time to require only 6 to 8 weeks from start of composting to the finished compost ~Greatly reduced VOCs, ammonia, dust, and other emissions ~Up to 95% odor reduction ~Protection from ground water contamination so there is not a need for a large retention pond ~Can reduce labor required for composting significantly ~For the Gore® Cover System the mix ratio for food waste to green waste is 1:3 by or 1:1 by weight (i.e. if you receive fifteen tons of food waste, you only need fifteen tons of green waste for successful composting) ~Can last from 4 to 10+ years	~Some should not be used on piles that require frequent access during the winter months although some can withstand subfreezing temperatures ~The site should have adequate drainage to prevent ponding ~Some are recommended to use in an aerated static pile system with positive aeration to be effective ~While they are heavy duty, the covers can rip which requires repair

Compost Quality Testing

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Concerns Addressed	Sources for Further Information*	Description	Costs	Implementation Time	Monetary Benefits	Additional Benefits	Drawbacks
~Health Risks	~Baystate Organic Certifiers ~BioCycle ~Martin's Farm Greenfield, MA. ~U.S. Composting Council	~Compost quality testing refers to the practice of having compost materials tested prior to, during, and after processing. Testing generally is performed by a third party that has the technology to do so. These quality tests generally refer to analyzing the compost down to a molecular level so that an operator knows the exact composition of his compost or other tests that look for hazardous compounds. For instance, the Martin's Farm in Greenfield, Massachusetts has its compost analyzed two to three times per year at Penn. State University. This type of test is the first discussed, the more in-depth analysis. Other tests can be performed more often though and on a simpler scale. For example, other sites test for hazardous compounds throughout their process more often. These tests are searching for things such as E. Coli and Salmonella among other health concerns.	~These test have a wide range of costs from well under $100 for a self-testing kit while sending samples to a lab to perform tests can cost hundreds or thousands of dollars due to their more in-depth analysis.	~The implementation of compost quality testing can be a very short process from purchasing test kits to setting up a schedule with an outside lab. However, receiving results from tests when samples are sent away to third-party labs can take days or weeks.	~Quality tested compost could possibly be sold for more should the tester be a reputable lab or research institution. ~Some farming associations and organizations even require testing to be a part of the group, thus inclusion in these groups could allow for higher prices of final compost products.	~These tests verify that a compost operation is producing a high quality product, which lends support to their methods and practices. ~This verification of an operation's care for their site and process can also increase support from neighboring communities.	~Added time and costs

Limiting Delivery Hours

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Concerns Addressed	Sources for Further Information*	Description	Costs	Implementation Time	Monetary Benefits	Additional Benefits	Drawbacks
~Noise from trucking ~Traffic from trucking	N/A	~One of the resultants of large-scale composting is the need to bring large quantities of organic matter to the compost site. This requires large trucks to haul and deliver the organic matter to the operation. When compost operations exist in residential areas, the trucks that deliver organics have to travel down roads that are usually not wide enough for multiple cars, not to mention large 18 to 22 wheel trucks. This traffic places a burden on residents and commuters who have to pull off the road to let these large trucks pass. Additionally, large trucks can also be a source of noise pollution that disturb neighbors during sleeping hours. To address these concerns, it can be beneficial to limit trucking deliveries to hours during times when neighbors will be away from their homes and not on the road. For instance, limiting deliveries to not taking place before 10am or after 4pm could help with this type of issue.	~It is possible that some deliveries may be delayed and this could cost some level of profit.	~Time required to discuss and agree on best hours.	N/A	~Will result in less complaints from neighbors with regards to truck traffic and noise. ~Some level of control over delivery hours can aid a site in the timing of its operation, ensuring that the site is prepared to receive deliveries.	~If delivery times are changed some deliveries may not be able to be made or could be postponed.

Odor Sensors

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Concerns Addressed	Sources for Further Information*	Description	Costs	Implementation Time	Monetary Benefits	Additional Benefits	Drawbacks
~Odors ~Health Risks	~BioCycle ~Boston Environmental ~CHANGE ~Geotech Environmental Equipment Inc. ~Nasal Ranger ~SHINYEI Technology ~Sensigent	~An odor sensor or e-nose (electronic nose) is a device that determines the chemical compounds present in air during testing and quantifies the prevalence or strength of those compounds. Most of these sensors are electronic although a few are manual in operation. These gas sensors quantify odor from different gases such as hydrogen sulfide and methane, VOC's (Volatile Organic Compounds) and other chemical compounds by ppm (parts per million) of air particles. However, for odor testing to be more accurate and verified it is necessary to find an environmental hygienist or environmental health consultant to take the readings for you.	~Odor sensors can either be rented or bought. Prices for renting an odor sensor range from around $100 per day, $200-$500 per week and $800-$1200 per month. Prices for buying an odor sensor range from around $100 for single gas detectors to prices in the thousands of dollars for multi-gas and VOC detectors. Readings from certified environmental health consultants cost more as they are qualified businesses and are usually decided between the consultant and customer, but an example would be a $7,500 flat fee for odor testing on-site.	~Time varies depending on whether you are trying to learn how to use the odor sensor or whether a consultant is contacted.	~Can improve community relations and thus increase profits from compost sales.	~Knowledge of what chemical compounds are in the air and at what strength so that you know if they are harmful or present a danger.	~These sensor can be very costly. ~For a more verified, professional reading, testing needs to be performed by a consultant. ~Test air in a single spot so for data to represent an entire site, multiple readings will need to be taken.

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Stormwater Treatment Ponds

Concerns Addressed	Sources for Further Information*	Description	Costs	Implementation Time	Monetary Benefits	Additional Benefits	Drawbacks
~Leachate ~Health Risks	~BioCycle ~U.S. Composting Council ~Various construction/ landscaping companies	~Stormwater treatment ponds are manmade collection ponds nearby a composting facility that gather stormwater. These ponds can range in size depending on the amount of stormwater and runoff that is expected in an area. Generally they can range from about 25 feet by 50 ft. to 100 ft. by 300 ft. though larger ponds exist for larger runoff areas. The ponds can then be treated to neutralize contaminants or simply allow heavy contaminants such as sediments, heavy metals, and bacteria to sink to the bottom while the clean water exits through a pipe close to the surface. This practice allows for runoff to be decontaminated and reused for other purposes without the need of runoff prevention technology or a larger wastewater treatment system.	~Cost of these ponds depends on the amount of runoff present and thus the size of pond desired. The cost of these ponds is essentially just construction and treatment materials if necessary. The construction of a pond though can be very expensive needing thousands of dollars. ~Though more effective than other methods, stormwater treatment ponds represent one of the more expensive options for leachate control.	~Implementation time depends on the construction and permitting processes. These can take months though.	~The water that is treated in these ponds can then be used for other practices on the site to save money. For instance, treated water on a farm can be used to water crops, plants, etc. so that further water does not need to be purchased.	~This method can improve water quality ~Leachate control can prevent further, more extensive issues from arising.	~Higher cost ~More construction necessary ~Requires larger amounts of space ~Can attract insects

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Weather Monitoring

Concerns Addressed	Sources for Further Information*	Description	Costs	Implementation Time	Monetary Benefits	Additional Benefits	Drawbacks
~Health Risks ~Odors	~AcuRite ~BioCycle ~Davis Instruments ~U.S. Composting Council ~WeatherShack	~Monitoring weather conditions can be vital to a successful composting operation and positive community relations. In monitoring weather data on-site, any change in wind direction, humidity, or temperature can be noted and accounted for in the composting process. For instance, if rain is noted as imminent, compost covers can be placed over the piles to control their moisture content. Similarly, if a day is extremely windy or there are high temperature, turning the piles could be postponed until the following day. Like-wise, if weather conditions prove to be too extreme to reasonably manage the composing operation, the operation can be halted in order to minimize health risks/increased odors. ~Weather monitoring can take two forms, those being either simple attention to weather and third-party reports or installing a weather monitoring station on site.	~Costs of the equipment necessary to implement a monitoring station on site can range from $130 to $1000. This is accounting for weather monitors that include wind sensors. ~There are virtually no costs with simply monitoring weather or using third-party reports.	~Minimal time is required for installation of most weather monitoring devices.	~Through monitoring weather a composting site can be operated more efficiently and thus increase positive relations with communities and possible profits as a result.	~More timely and accurate weather data can be received from on on-site station. ~Data from weather monitoring can be used to control the temperature and moisture of the compost pile to make a higher quality compost.	~Initial cost of an on-site system can be high. ~The time necessary to learn how to operate an on-site system.

Well Testing

*This matrix does not necessarily recommend any of the companies listed within but simply lists them as sources for further information

Concerns Addressed	Sources for Further Information*	Description	Costs	Implementation Time	Monetary Benefits	Additional Benefits	Drawbacks
~Health Risks	~BioCycle ~MassDEP ~Northeast Waterwells, Inc	~Well testing is the practice of analyzing the content of the water within wells near an operation to gauge if runoff could be an issue. If water contamination is unchecked, it can cause serious health risks for those drinking the water. Well testing can be carried out either on one's own with a personal-well test kit or by sending samples to an environmental agency such as the Massachusetts Department of Environmental Protection. The differences lay in the depth of testing and the time for results. While personally testing a well with an at-home kit can take very little time to receive results, it can take days to weeks to receive test results back from an independent lab. However, these times are due to the level of testing each style gives. For instance, a personal test kit may only test for one contaminant such as arsenic, while a lab can test for any number of different compounds and contaminants.	~The cost of a well test can vary depending on the goal of the tests. ~Personal test kits can range from $20 to $300 depending on what compounds the test is searching for. ~A third-party or independent lab test can cost about the same as, or higher than, an expensive personal test kit.	~A personal test kit simply needs to be bought and then testing can be done in a day. ~An off-sight lab test may take a few days to a few weeks to be fully completed and test result received.	N/A	~The knowledge (and record) of the content of the water onsite can be used to improve the health of the residence using the tested wells. ~Possible contamination can be spotted early and addressed.	~Well testing can be expensive and possibly time consuming.

Windrow Turners

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Concerns Addressed	Sources for Further Information*	Description	Costs	Implementation Time	Monetary Benefits	Additional Benefits	Drawbacks
~Odors ~Health	~BACKHUS Compost Turners ~BioCycle ~Compost-turner.net ~Frontier Industrial Corp. Windrow Turners ~Midwest Biosystems ~Scarab ~U.S. Composting Council	~Windrow turners are machines specifically designed to turn windrow compost piles. These machines are either attachments dragged behind tractors and other farm equipment or independent pieces of equipment with their own powered motion. The turners pass over the windrow piles turning them from within as an agitator is passed through them. This machine is set on wheels so that it can travel the entire length of the windrow turning it. Additions to these turners can also be made, such as application devices that inoculate piles with bio-organic catalysts. Compost turners are able to cut down on the time needed to turn piles as well as turn each pile fully and uniformly.	~Cost of the turners depends on their design. ~A windrow turner attachment for an existing tractor can cost between $20,000 and $90,000. -Additional costs would include maintenance ~A self-sufficient windrow turner can cost upwards of $300,000. -Additional costs would include fuel and maintenance	~Once a windrow turner is purchased, the only setup time is attaching it to another piece of equipment if it is an attachment design and then turning the rows. ~We have noted turners being able to turn a compost windrow at about 0.5 ft./sec.	~Being able to quickly and uniformly turn windrow piles can open vast reserves of time that can be spent on other aspects of an operation to increase profits and decrease labor hours. ~More aerated compost piles will produce a better quality final product, which can then be sold at a greater price.	~These turners provide a delivery system for other concern mitigation methods such as bio-organic catalysts. ~Being able to turn piles quickly means that the turning process can be timed more easily so that if there is a long weekend, turning can wait and be done quickly the following week so as not to create odor for neighbors during a long weekend.	~Turners represent another piece of machinery that could break down and need repair.

Method	Concerns Addressed	Costs	Implementation Time	Benefits	Drawbacks
Anaerobic Digester	~Health Risks ~Odors ~Wildlife Attraction ~Insect Attraction ~Noise	~$3 - 8 million for initial setup ~Widely varying maintenance costs -Depends on sophistication of design	~18 to 24 months ~Begins digesting before, but takes time to reach a fully operational status	~"Free" heating ~Biogas to power site/sold back to grid ~Fertilizer ~Faster cycle than composting	~Possible increase in trucking ~High initial cost & possible upkeep cost ~A lot of land needed for a large digester
Bio-Organic Catalysts	~Odor ~Health Risks ~Wildlife Attraction	~ Vapor system initial: $25,000 -Cost per month $1,500 ~Liquid system: $35 per gallon	~A few days or a few weeks to setup ~Minimal time to add during composting process	~Higher quality compost ~Less odor	~More time ~Another expense
Biofilters	~Health Risks ~Odors ~Wildlife Attraction	~Offsite material: $20 - 80 a cubic yard	~A few hours	~Odor reduction ~Reduces health risks	~Meant to be used in conjunction with other methods
Bioswales	~Leachate ~Health risks ~Odor	~Do it Yourself: Range in the hundreds of dollars ~Professional: Range in the hundreds to a few thousand dollars	~Variable time depending on size and who is installing it	~Reduces pollution ~Visually more appealing ~Improve water quality	~Risk of flooding ~Possibly more planning and construction needed
Community Outreach	~Community inclusion & communication ~Potential to assist in addressing other concerns	~Varying cost depending on approach used/types of events ~Costs of advertisement	~Varying time depending on type of outreach. Planning and advertisement for events can generally take place in a few weeks	~Increase positive reputation of site ~Possible increase in business	~Time and money could be spent elsewhere
Compost Berms	~Leachate ~Health Risks ~Odor	~With tube/sock : $3.00 and $3.50 per linear foot ~Varying cost depending on size and material	~There is little implementation time associated with compost berms other than the piling of the material	~Can last from 5 to 6 years ~Sediment is filtered out of runoff ~Views of compost piles can be blocked if piles present an unwanted sight	~Added piles of compost can add further concerns if not also monitored ~Quality of the used compost is also very important
Compost Quality Testing	~Health Risks	~Do it Yourself : Under a hundred dollars ~Professional : Range in the hundreds to a few thousand dollars	~A few days or a few weeks for professional testing	~Higher quality compost sells for more ~Proof of high quality composting site	~Added time and money
Limiting Delivery Hours	~Noise ~Traffic	~Delaying trucks could affect profit	~Time to discuss best hours	~Less traffic and noise complaints	~May lose some money due to traffic changes

Appendix Q: Informed Consent Form to be Used Prior to Interviews

Informed Consent Agreement for Participation in a Research Study

Investigator:
Benjamin Preston
Alex Krasa
Brett Carbonneau
Nick Bograd

Contact Information:
Email: chandleriqp@wpi.edu
Advisors: Derren Rosbach: drosbach@wpi.edu,
Corey Dehner: cdehner@wpi.edu

Title of Research Study:
Chandler Composting Policy

Sponsor:
Massachusetts State Senator Harriette Chandler

Introduction:
You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

Purpose of the study: The Purpose of this study is to better understand the views and opinions of different parties in Northborough, Massachusetts regarding composting at the Davidian Bros. Farm and the concerns the community has with it.

Procedures to be followed: We will be interviewing participants if they choose to participate, only asking questions regarding the situation of the town and the farm.

Risks to study participants: Participants may not feel comfortable talking about their concerns of the community, talking to students not from the community, and may not feel comfortable talking about those involved within the situation.

Benefits to research participants and others: Benefits for participating in the research study may include participants gaining a feeling of inclusion during the study and participation in the effort to obtain a solution to the issue.

Record keeping and confidentiality: Records of your participation in this study will be held confidential so far as permitted by law. However, the study investigators, the sponsor or it's designee and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify you by name. Any publication or

presentation of the data will not identify you by name. You do not give up any of your legal rights by signing this statement.

For more information about this research or about the rights of research participants, or in case of research-related injury, contact: If you wish to contact the investigators for further information, our contact information is located at the top of this document. In addition, here is the contact information for the WPI IRB Chair: Professor Kent Rissmiller, Tel. 508-831-5019, Email: kjr@wpi.edu, and the University Compliance Officer Michael J. Curley, Tel. 508-831-6919, Email: mjcurley@wpi.edu.

Your participation in this research is voluntary: Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit. Should a participant wish to withdraw from the study after it has begun, the following procedures should be followed: email the investigators at chandler@wpi.edu that you wish to have your participation stricken from record. There are no consequences for early withdrawal for the subject and the research.

By signing below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

_____ Date: _____

Study Participant Signature

_____

Study Participant Name (Please print)

_____ Date: _____

Signature of Person who explained this study