Transmittal

To: Dr. Drew McAvoy, Michelle Balz, and Mary Cropenbaker

From: Aaron Tam, Ariana Fox, Cameron Gastaldo, Gianna Cantor, Kathryn Jordan, Mohammed Alsaqri

Re: Composting Infrastructure Recommendation for Hamilton County

Date: April 16, 2024

Dear R3source,

ECOlibrium Solid Waste Solutions is excited to deliver a proposal for an organic waste diversion strategy for Hamilton County.

The following information is detailed in the proposal:

- Scope of Work and Composting Basics
- Site Design of a Covered Aerated Windrow System
- Economic Analysis of Composting Site
- Environmental Analysis of Composting Site
- Recommendations for a Phase Program and Funding

Respectfully,
ECOlibrium Solid Waste Solutions

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R3SOURCE

Covered Aerated Windrow Feasibility for 200,000 tons of Yearly Residential Food Waste

ECOlibrium Solid Waste Solutions

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4-16-2024

Ecolibrium
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Executive Summary

To assist in a Hamilton County Sustainability goal of diverting 50% of residential and commercial food scraps from landfilling, ECOlibrium Solid Waste Solutions proposes a large-scale composting facility. According to the 2020 U.S. Census, the population of Hamilton County is estimated to be 836,700 people (“QuickFacts: Hamilton County, Ohio” 2020). R3Source’s analysis has determined that there are roughly 255,000 tons of organic waste annually being landfilled by its population (Cincinnati Waste Management District Personnel 2016). Organic materials have valuable nutrients and carbon, allowing for the reuse of these materials through composting. Additionally, the USEPA estimates that wasted food was responsible for 58% of landfill methane emissions in the United States (US EPA 2023). Composting provides avenues for market potential, reuse of valuable natural resources. This proposal describes a site design, equipment, a financial analysis, and an environmental analysis for a covered aerated turned windrow system. The process starts with receiving the material from a contracted hauler, shredding, and bulking the feedstock, actively composting the feedstock in an aerated windrow system, curing the compost, screening the compost, and then distributing. The site is 55 acres, which includes space for each element of the process. The active composting pad is the largest portion with 526 windrows in 32 acres. The greenhouse gas emissions are 47.2% less than traditional landfilling.

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1 Introduction

1.1 Project Scope

ECOlibrium Solid Waste Solutions (ECOlibrium) is responding to the request from Hamilton County's solid waste district, R3Source, for a proposal to address the substantial amounts of organic waste that end up in landfills. According to the 2020 U.S. Census, the population of Hamilton County is estimated to be 836,700 people, while the Greater Cincinnati Region's population is estimated to be 2,256,000 (U.S. Census Bureau quick facts: Cincinnati City, Ohio; United States 2022). R3Source's analysis has determined that there are roughly 255,000 tons of organic waste annually being landfilled by its population (Hamilton County Solid Waste Management Plan Update - Draft 2016). The amount of organic waste generated from commercial and residential sources is 62% and 38%, respectively (Figure 1).

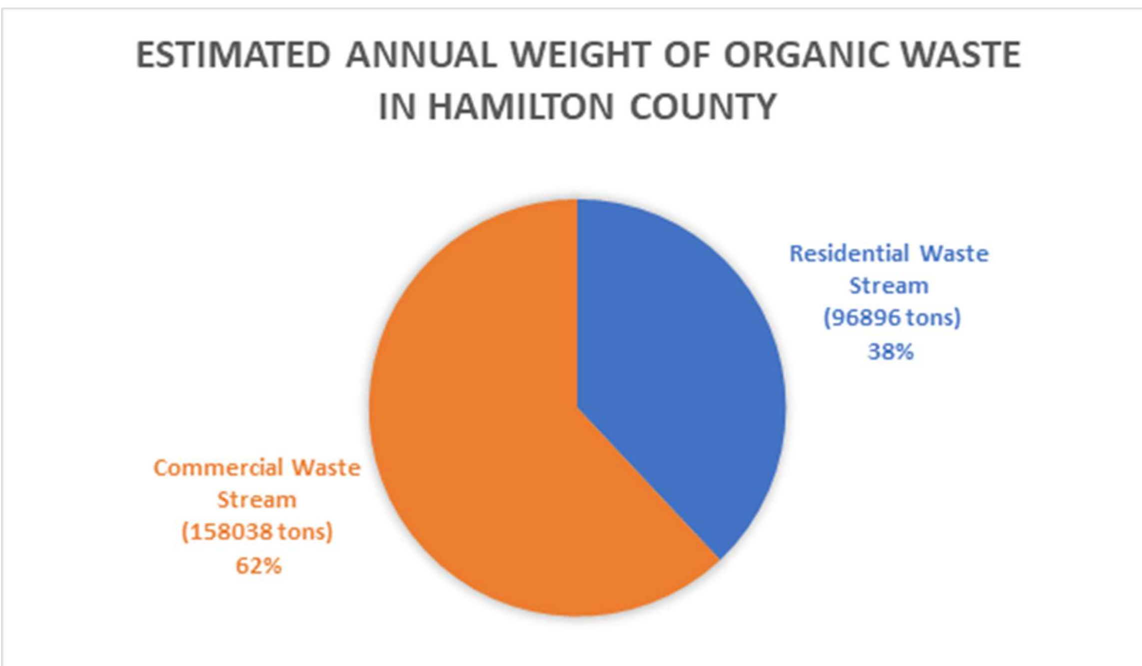

Figure 1: Hamilton County R3Source's analysis plan conclusion of organic waste (Hamilton County Solid Waste Management Plan Update - Draft 2016)

Food scraps and yard waste can be a cause for several problems once landfilled. Food waste can attract birds and pests, both creating operational cost problems and nuisance for the public. Landfills create anaerobic conditions where bacteria break down the organic materials in the landfill, creating methane. This greenhouse gas has significant environmental impacts, affecting the Earth's climate and temperature. The USEPA estimated that wasted food was responsible for 58% of landfill methane emissions in the United States (US EPA 2023). Methane is the second most abundant anthropogenic greenhouse gas behind carbon dioxide (US EPA 2023). Organic waste residing in landfills is a common problem, as shown in Figure 2.

Figure 2: Organic waste in a landfill (Parikh 2021)

There is untapped potential that resides in the food and yard scraps that end up in landfills (Composting 2023). Organic materials have valuable nutrients and carbon, allowing for the reuse of these materials through composting. This provides avenues for market potential, reuse of valuable natural resources, and for energy creation.

The general lack of strong infrastructure for food and yard scraps processing and educational awareness programs demonstrates the need for the establishment of an efficient organics processing system in Hamilton County.

ECOlibrium Solid Waste Solutions will offer recommendations for the support of R3Source's set goal of reducing food waste by 50% by 2030 based on their draft of the 2024-2038 Hamilton County Solid Waste Plan (Hamilton County Solid Waste Management Plan Update 2016). Composting has been identified as the optimal method of processing organic waste in Hamilton County. Based on an alternative analysis, covered aerated turned windrows were deemed the best for Hamilton County. The factors included in this analysis were starting and ongoing operation cost, seasonal variations, the proven success and scalability of the composting method, the class of compost created, greenhouse gases emitted, physical byproducts and environmental implications from the method, and the potential for this solution to create jobs within Hamilton County.

1.2 Organic Waste Hierarchy

The organic waste hierarchy is a tool developed by the United States Environmental Protection Agency for the purpose of ensuring that solid organic waste is managed properly (Figure 3).

Figure 3: The USEPA Waste Management Hierarchy (Courtesy of USEPA)

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This hierarchy ranks the solid waste solutions from the most preferred method to the least preferred method beginning with source reduction. Source reduction means reducing waste at the source, which can take many forms. In its simplest form, it is a method to incentivize producers to produce less and for the consumer to consume less. However, source reduction can also take more complex forms such as “buying in bulk, reducing packaging, redesigning products, and reducing toxicity” (Sustainable Materials Management: Non-Hazardous Materials and Waste Management Hierarchy n.d.). The benefits of source reduction include reduced greenhouse gas emissions, reduced pollution, and monetary savings for both businesses and consumers. According to food specialist, Tony Staubauch, the Food Waste Diversion Sustainable Materials Management: Non-Hazardous Materials and Waste Management Hierarchy Coordinator at Hamilton County R3Source, Hamilton County is one of the top counties to divert food waste from the landfill to provide food insecure residents with food.

Second to source reduction is recycling and composting, the focus of the project. There are beneficial nutrients in organic waste to be recovered. Composting involves the breakdown of organic materials by microorganisms into a nutrient rich soil amendment useful for farming or landscape purposes. The USEPA describes the benefits of compost and recycling as “reducing greenhouse gas emissions that contribute to climate change, supplying valuable raw materials to industry, and stimulating the development of greener technologies’’ (Sustainable Materials Management: Non-Hazardous Materials and Waste Management Hierarchy n.d).

Next in the hierarchy is energy recovery, which is commonly known as waste-to-energy. Waste-to-energy describes the processes in which non-recyclable solid waste is converted into heat, electricity, or fuel. These processes vary but the EPA has distinguished four distinct categories: “combustion, pyrolization, anaerobic digestion and landfill gas (LFG) recovery.” The benefits of waste to energy include reducing carbon emissions via offsetting fossil fuels and reducing methane emissions from anerobic decomposition in landfills (Sustainable Materials Management: Non-Hazardous Materials and Waste Management Hierarchy n.d).

The last method to reduce waste is treatment and disposal. While waste does not require treatment before disposal, it reduces waste volume and potential toxicity. These treatments can be physical, chemical, or biological.

1.3 Compost Basics

The Ohio Environmental Protection Agency defines composting as a "method of solid waste disposal using controlled biological decomposition ("Composting | Ohio Environmental Protection Agency" n.d.). There are two stages in composting; The thermophilic or active stage is the first stage where the decomposition occurs, and the mesophilic stage or maturing stage is the second stage where slower decomposition occurs. The appropriate usage of the compost can be determined after the second stage (Yadav 2014).

The quality of composting is dependent on the feedstock (Table 1). The Composting Handbook describes the best feedstock characteristics for composting (Rynk et al. 2022). From an interview with Jacobs Organic Waste Specialist, Jordan Norris, the best feedstock recipe has a carbon to nitrogen (C:N) ratio of 25:1 to 35:1. Jordan Norris worked at Recology Disposal and Composting as a compliance specialist for composting projects for 11 years. At Jacobs, he designs landfill diversion projects for organic waste. While the composition of incoming organic waste is often inconsistent, the addition of bulking agents allows for considerable control. The Composting Handbook describes bulking agents as carbon-rich materials such as woodchips or straw. Bulking agents are added to change the C:N ratio (Rynk et.al. 2022). After the C:N ratio, Norris says oxygenation, the percentage of oxygen to air, is the second most crucial factor. A free airspace of 12-16% is optimal. Odors are present at oxygenation below 12%. Norris also explained that 50-60% moisture is ideal for large scale composting.

Table 1: Best Feedstock characteristics (Rynk et.al. 2022)

Condition	Acceptable	Ideal
Moisture content	40%–65%	50%–60% by weight
C:N ratio of combined feedstocks	20:1– 60:1	25–40:1
Feedstock particle size	<5 cm (2 in.)	Variable
Bulk density	<700 kg/m^3 (1200 lbs/yd^3)	400–600 kg/m^3 (700–1000 lbs/yd^3)
pH	5.5–9.0	6.5–8.0

1.3.1 Compost Classification

The classification of composting facilities is categorized based on the composition of feedstocks to be accepted ("Composting | Ohio Environmental Protection Agency" n.d.). Ohio has four provisions of composting rated Class I to IV. Class I compost sites accept mixed solid waste. Class II sites accept "yard waste, agricultural plant materials, animal waste, dead animals, and raw rendering material and food scraps." The feedstocks for Class III include "yard waste, agricultural plant materials, animal waste, and dead animals, raw rendering material." Class IV facilities accept only yard waste and agricultural plant materials.

Hamilton County expressed a preference to Class II facilities. Class II sites have the second most variability in feedstock acceptance, but the product can be used commercially. (Class II Composting Facility Requirements n.d.) The Ohio EPA created a Class II Composting Facility Requirements document in 2019.

Finished compost quality also varies based on industry standards. The classification system developed by A1 Organics for finished compost quality consists of four main classes (A1 Organics n.d.). Class I includes fully composted, stable, and matured products. Class II includes fully composted very stable, and mature products made from manure feedstock. Class III includes semi-composted material, while non-composted material made from raw feedstock is Class IV. Class IV has not received the seal of assurance from the US Composting Council (A1 Organics n.d.). Following an industry-recognized compost classification system will ensure reliable and environmentally responsible production of compost.

1.3.2 Regulations

Class II source facilities can use any combination of the following composting methods: windrow, in-vessel, aerated static pile, static pile, or vermicomposting. Class II facilities must follow Rule 3745-560-230 in the Ohio Laws & Administrative Rules. From the Code of Federal Regulations, Title 21, Subpart 1, Subpart B, Part 112, Subpart F, § 112.54 describes the "treatment processes acceptable for a biological soil amendment of animal origin in the growing of covered produce."

There are microbial standards for *L. monocytogenes, Salmonella, and E. coli* 0157:H7. § 112.55 describes each microbial standard. *L. monocytogenes* must be below detection limits "not detected using a method that can detect one colony forming unit (CFU) per 5 gram (or milliliter, if liquid is being sampled) analytical portion." *Salmonella* must "not be detected using a method that can detect three most probable numbers (MPN) per 4 grams (or milliliter, if liquid is being sampled) of total solids." *E. coli*. 0157:H7 must "not be detected using a method that can detect 0.3 MPN per 1 gram (or milliliter, if liquid is being sampled) analytical portion." As stated in § 112.54, static composting must "remain at least 131 degrees Fahrenheit for 3 consecutive days." Compost must be maintained at temperatures greater than 131 degrees Fahrenheit for 15 non-consecutive days and turned at least five times. Both static and turned composting require subsequent curing.

1.3.3 Certifications

The US Composting Council provides a Seal of Testing Assurance (STA) that demonstrates to customers that the compost is regularly tested and free of pathogens and metals. The US Composting Council STA is the highest rated seal of assurance for finished compost. The quality of the compost is essential to ensure the use of safe and effective types of compost that meet all US Composting Council standards. The STA program encourages ecologically conscious composting methods and provides clarity, consistency, and confidence to consumers. The STA program also has an intensified quality program called the Consumer Compost Use (CCUP) (Stehouwer et al. 2022). The CCUP has product standards for three compost uses: lawns, trees and shrubs, and flowers and vegetables. The U.S. Composting Council lists many uses for finished compost, including topdressing for soil lawns and flower beds. Compost also acts as a soil amendment or topsoil mix ingredient.

1.4 Current Composting Infrastructure

Hamilton County is comprised of 48 political jurisdictions with 12 townships, 16 cities, and 20 villages. The district of Cincinnati is the largest political jurisdiction, encompassing 37% of Hamilton County. Hamilton County serves 811,748 people with a 0.1% population growth. According to the 2018 Hamilton County Waste plan, 4.52% of organic solid waste was composted in 2014.

Hamilton County has 13 registered Class IV composting facilities and one Class II facility. While communities have access to composting facilities for their yard waste, little infrastructure exists for composting of other organic waste (Table 2).

Table 2: Composting Facilities in/near Hamilton County (Christmann 2016)

Facility Name	Location		Material Composted (tons)	Percent of all Material Composted
	County	State		
Amberley Village	Hamilton	OH	2,027	4%
Brausch Farms	Warren	OH	535	1%
Bzak Landscaping, Inc.	Clermont	OH	18,418	35%
Columbia Township Compost	Hamilton	OH	150	0%
Evans Landscaping, Inc.	Hamilton	OH	10,013	19%
Village of Fairfax	Hamilton	OH	0	0%
Findlay Market - In-Vessel Compost Facility	Hamilton	OH	147	0%
Glendale Compost Facility	Hamilton	OH	210	0%
Village of Greenhills	Hamilton	OH	395	1%
Grailville Farm	Hamilton	OH	0	0%
H. Hafner & Sons Inc. Construction & Demo Debris Facility	Hamilton	OH	2,181	4%
NPK Compost Facility	Hamilton	OH	9,953	19%
Ohio Mulch	Butler	OH	1,348	3%
Reading Municipal Garage	Hamilton	OH	269	1%
City of Springdale	Hamilton	OH	845	2%
Sycamore Township Compost	Hamilton	OH	1,587	3%
Wyoming WTP Laboratory	Hamilton	OH	1,246	2%
Other out-of-district facilities	N/A	N/A	3,636	7%
Total			**52,960**	**100%**

1.5 Community Insight

To collect residential food waste, the residents must be willing to collect and provide their waste. Since the residents are providing the feedstock, they must be involved in some aspects of the design. To gain community insight, ECOlibrium distributed a ten-question, three-minute, Google form to community members on Facebook, Reddit, and LinkedIn (Appendix 9.2). There were 141 responses with an overwhelming positive support for composting. Most residents claimed to have an average knowledge about composting (Appendix 9.2.8), and to choose sustainable alternatives when available (Appendix 9.2.5).

Of 140 responses, 137 agreed that they would like to see composting in their community (Appendix 9.2.6). Of 109 members that chose to state their neighborhood, most came from the City of Cincinnati (Appendix 9.2.2). There are 48 political jurisdictions in Hamilton County. The City of Cincinnati is the largest by population, and Colerain and Green Townships are the largest by area (Hamilton County Solid Waste Management Plan Update - Draft 2016).

Community members are worried about communication, cost, odor, and noise. ECOlibrium has proposed ways to alleviate these concerns. Residents are most concerned about potential lack of community involvement or communication from a local composting facility (Abstract 9.2.7). Tailoring a composting program to the community needs in each jurisdiction will require proper communication with residents. The survey revealed concerns about the potential costs of a collection bin or other waste collection cost (Abstract 9.2.7). Using grants or having the county shoulder the cost of bins would alleviate this worry. Engineering best management practices and well-informed location selection will alleviate odor and noise concerns. Effective communication with residents will ensure little adversity in program development.

2 Compost Technology

2.1 Covered Aerated Windrow System

Table 3 shows the decision matrix to determine the optimal compost type for Hamilton County. Each criterion is assigned a priority. The criteria from highest to lowest priority are cost, environmental impacts, negative byproducts, greenhouse gas emissions, compost quality, scalability, proven success, seasonal variations, and then potential for job creation. After prioritizing the criteria, each compost type is given a ranking between 1 and 13, for most and least desirable option, respectively. After multiplying the weight by the ranking and summing each category together, a final weighted score was determined. Covered aerated turned piles, covered aerated static windrow, and covered aerated turned windrow had the highest scores.

Table 3: Decision matrix to analytically determine which compost type is best for Hamilton County

Criteria	Priority (high to low)	Scoring by Method Alternative												
		Piles					Windrows				In-Vessel		Vermicomposting	No Compost
		ASP	CASP	ATP	CATP	Circular ATP	ASW	CASW	ATW	CATW	Agitated Bay	Tunnel		
Cost (startup and ongoing)	9	11	10	9	8	3	7	6	5	4	1	2	12	13
Environmental Impacts (air, water, etc.)	8	6	10	5	11	7	4	8	3	9	13	12	2	1
Negative Byproduct (leachate, odor, noise, etc.)	7	2	7	5	9	4	3	8	6	10	12	13	11	1
Greenhouse Gas Emissions	6	5	8	2	8	2	5	8	2	8	12	13	5	1
Compost Classification of Product/ Potential Revenue Streams	5	4	4	7	7	7	10	10	12	12	2	3	5	1
Scalability	4	12	8	10	6	5	13	9	11	7	4	3	2	1
Proven Successful / Case Studies	3	6	6	6	6	3	10	10	10	10	5	4	2	1
Seasonal Variations	2	3	8	6	10	5	4	9	7	11	13	12	2	1
Potential For Job Creation	1	3	9	8	10	7	4	11	12	13	6	5	2	1
Total Score		52	70	58	75	43	60	79	68	84	68	67	43	21
Total Weighted Score		286	362	281	378	204	290	367	283	379	342	351	276	153

(A=Aerated, S=Static, P=Pile, C=Covered, T=Turned, W=Windrow)

Every type of composting has pros and cons. In-vessel composting requires a high capital cost, indicated by the lowest score in the cost criteria. Each agitated bay system received a score of 1 and 2 respectively, as in-vessel options require buildings with all utilities connected. Due to the required surface area, the next highest cost option are windrows. Aeration and covers also increase costs, as they require additional infrastructure for pipes, fans, and applicators. Windrows also require equipment to build the windrows and to move the materials between each area. Table 3 describes that piles would have a higher score compared to windrows, but addition of aeration, turning, or covers increases the cost. Vermicomposting is the most cost-effective option for compost. Minimal equipment is required, and the worms reproduce.

Environmental impacts, negative byproducts, and greenhouse emissions are prioritized similarly and are mitigated in similar ways. Because of environmental regulations and permitting, these criteria would be the least impactful on the environment and neighbors. Some composting options mitigate these problems naturally. Because in-vessel composting is enclosed, most environmental impacts are eliminated through filtering of emissions, leachate, and noise. This yields the highest scores for in-vessel systems in environmental impacts, negative byproducts, and greenhouse emissions. The agitated bay and tunnel received scores of 13 and 12, respectively. Vermicomposting scored 5 for greenhouse gases due to feedstock limitations. Rejected feedstocks would still have to go to the landfill, increasing methane emissions. Covered windrows and piles offer the next best score for environmental impacts and negative byproducts. The cover contains odors and leachate. Vermicomposting scored 2 for environmental impacts due to constant aeration and manual turning of the pile from the worms.

Compost classification and potential revenue stream relate to the quality of compost created. All composting types require a second curing phase, but all in-vessel options require a second curing phase using another composting method. This is why they scored low in this section. The compost requires relocation from one area to another, which requires extra time. Windrows produce higher quality compost than piles because piles tend to decompose unevenly. Vermicomposting produces high quality compost when the feedstock is uncontaminated, resulting in a score of 5 for this category.

Windrows have the highest proven success in a large-scale setting. The Cedar Grove Composting facility is an example of a large-scale windrow composting site (Figure 4).

Figure 4: Model Windrow Facility (Cedar Grove n.d.)

In-vessel composting has been proven successful, but the compost would need a curing time longer than the other methods. Vermicomposting is great for cost, but the feedstock is very narrow. This proves a problem for large scale proven successful projects. The circular aerated turned piles ranked third lowest in this category due to their novelty and limited case studies.

Buildings and covers would increase a compost method's ability to withstand seasonal variation. The composting type that scored the highest with the least seasonal variations is in-vessel. In-vessel received a score of 13 for agitated bay and 12 for tunnel. This is because they are contained systems and will not need to be changed drastically in winter and rain. The covered systems also ranked highly due to weather resistance and heat-trapping capabilities.

All composting methods provide jobs. Between composting methods, the potential for job creation is ranked based on the minimum required labor to process an equal amount of compost via each method. A composting method received a higher ranking for this criterion if it required more labor to operate. Indicators of increased labor requirements for a composting method include increased pre- and post-processing requirements, frequent agitation (including watering, turning, bulking, etc.), a greater amount of equipment such as covers, large-scale turners, and shredders required, and management complexity. Windrow systems ranked the highest in potential job creation due to the size of land they would operate on. In-vessel operations use many automated systems, minimizing the number of operators required. The static piles and windrows would require the least number of operators due to low waste relocation frequency.

A no-composting method was also included in the analysis. This method scored highest only in cost because there would be no additional cost for Hamilton County. If there were to be no solid waste diversion, the current standards the county has set now would remain.

2.2 Bio-Covers

There are two main benefits of covering a windrow system: heat and moisture control. Other unintended benefits include seeding of beneficial bacteria to begin the composting process, reducing volatile organic compound (VOC) emissions, and shortening the primary composting time. There are four main types of compost covers: impermeable covers, microporous covers, macroporous “fleece” covers, and bio-covers. Impermeable covers do not permit the passage of air and moisture between the windrow and the atmosphere. This often results in the cover forming an inflated bubble around the windrow. Microporous covers are like impermeable covers in that they do not allow moisture passage. However, unlike impermeable covers, microporous covers allow air passage between the atmosphere and the windrow. Additionally, these covers often include per-fluorinated compounds, which decreased their popularity over time. Fleece covers are lightweight covers often used to cover passively aerated piles and turned windrows during rain events to maintain moisture in the pile (Staff E.C.S. 2022). Lastly, bio-covers consist of a 6- to 12-inch layer of finished compost placed on top of the windrow. This compost can be either screened or unscreened.

An alternative analysis was conducted between impermeable covers, microporous covers, and bio-covers. Fleece covers were not considered because of reported issues with effectiveness and tearing (Staff E.C.S. 2022). The alternative analysis categories and their respective weights are as follows: cost (5), lifespan (4), heat and moisture control (2), and proven success (1). Five is the most important and one is the least important.

Cost is the most important criterion for covers because of high associated costs such as cover rollers and routine replacement. Lifespan is the second most important criterion because of its relation to cost. A cover with a short lifespan would need more frequent replacement and would therefore incur more costs over time than a cover with a longer lifespan. Next is the covers’ ability to retain heat and moisture. Heat and moisture control are paramount to ensuring the success of the active compost phase. If the cover does not control heat and moisture effectively, incomplete decomposition and pathogen growth are likely. Least important is the proven success of the compost cover method, due to constant changing of the compost cover market and low variability between cover types. The alternative analysis results are shown in Table 4.

Table 4: Compost Cover Alternative Analysis

Cover Type	Priority (High to Low)	Bio-Cover	Microporous	Impermeable
Cost	5	3	1	2
Lifespan	4	3	2	1
Heat Control	3	3	1	1
Moisture Control	2	1	2	3
Proven Successful	1	2	1	3
Unweighted Score		12	7	10
Weighted Score		40	21	26

For both the cost and lifespan, the bio-cover scored higher than the microporous and impermeable covers because the bio-cover used would be finished compost. This would result in little to no cost besides relocation of the bio-cover. Additionally, since the cover is generated on site for every windrow, replacement cost is of no concern so long as the facility is in operation. Microporous and impermeable covers require replacement from tearing every six to ten years (Staff E.C.S. 2022). The six- to twelve-inch-thick bio-cover is also the best of the three at heat control while also permitting air passage. The thin impermeable and microporous covers poorly insulate the windrow from heat, which can cause negative bacterial growth on the windrow's surface.

When it comes to moisture control, the impermeable cover performs the best, followed by the microporous and the bio-cover. Impermeable covers do not allow moisture to pass between the windrow and the outside atmosphere. The microporous cover allows some moisture to pass through. The bio-cover blocks some moisture, but not as well as impermeable or microporous covers. The last category is proven success. All commercially available systems have instances of success and failure. Many newer compost facilities use impermeable covers to prevent odor emissions. Older and lower-budget facilities tend to use bio-covers, though certain facilities use microporous in specific situations. However, less use microporous covers due to concerns over leaching of per-fluorinated compounds. Due to the low cost, low replacement concern, and heat control, a bio-cover should be selected for the windrows.

The cover recommended in the aerated windrow system will be a six-inch-thick bio-cover of finished compost. This cover will be applied after the shredding and bulking step. Front loaders will move the cover from the finished compost to the windrows. After the primary composting step, the cover is then mixed into the windrow for the curing phase. Mixing the bio-cover into the finished compost defeats the need for a cover roller. High levels of microorganisms contained in the bio-cover will also aid in breaking down the raw compost as soon as it is applied.

3 Compost Process and Design

Figure 5 describes the design components and process of the proposed composting site. The first step is organic waste receiving. The second step is pre-processing, which consists of shredding and bulking. The third step is the active composting phase. Front loaders turn the compost as they move it from the active composting phase to the curing phase. The material is then screened, and subsequently distributed off-site.

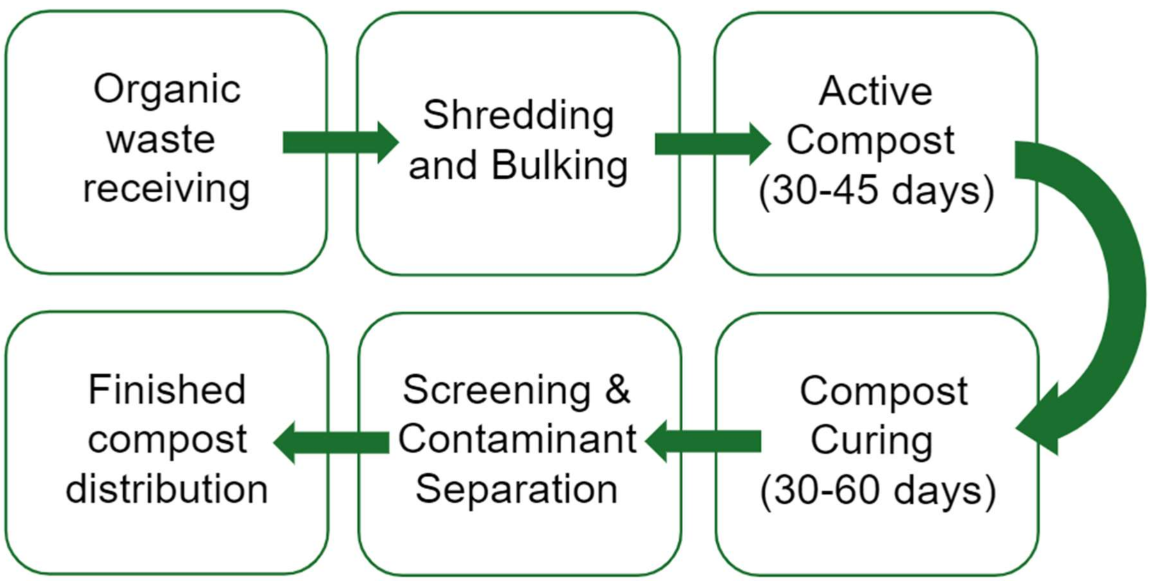

Figure 5: Composting Process

The layout of the compost facility optimizes efficient processing and control of materials handling (Figure 6). ECOlibrium Solid Waste Solutions chose the placements of each area based on a U-shaped layout. This avoids cross-contamination of compost stages and allows for the quickest flow from each process to the next (Pinkerton 2022). Compost facility operators should also avoid prolonged raw feedstock storage to prevent odor or leachate production.

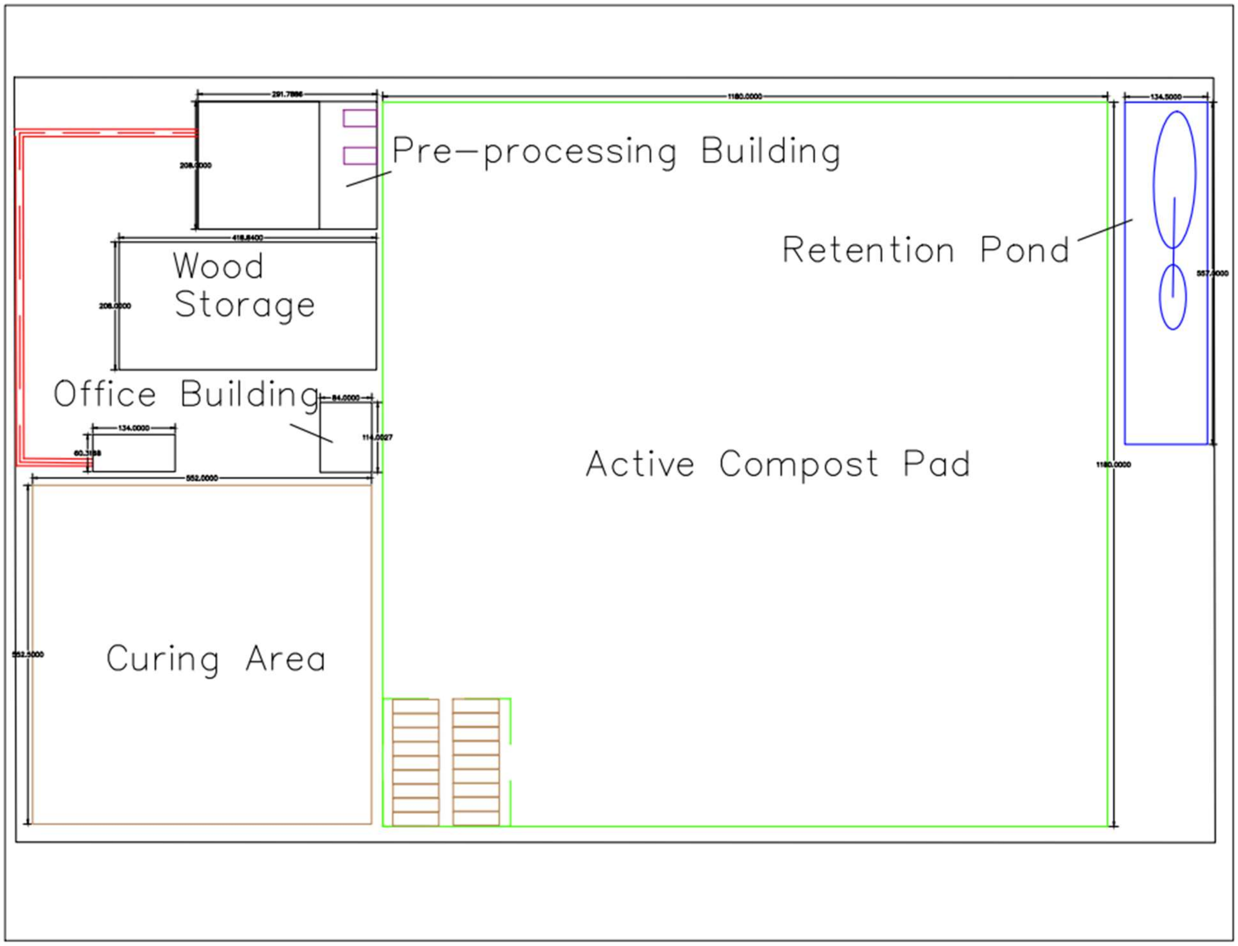

Figure 6: Composting Facility Proposed Design (ECOlibrium)

The preliminary design features an access road that will allow trucks to drop off feedstocks to the receiving and pre-processing building at the entrance. The access road also provides access to the parking area and an office for employees. This road is 12 feet wide as required by the state of Ohio (“800 - Access, R/W Use & Driveways” n.d.). Other components of the composting facility include a receiving and pre-processing area, an active composting pad, a curing area, a retention pond system, and an office and equipment building. Dimensions of each area are in Appendix 9.4.

The curing and pre-processing areas are located up-slope from the active compost area so that these areas do not become contaminated by active compost runoff (Pinkerton 2022). The active composting pad is also positioned up-slope from the retention pond system, so runoff drains to this area (Pinkerton 2022). A separate outdoor area is also designated for carbon-rich feedstock storage as this requires more volume.

3.1 Bins and Pick-Up

The first process in the composting workflow design requires the distribution of collection bins to residential areas around Hamilton County. This will provide residents with a designated collection bin for organic waste and clear separation directions. Separation of materials by residents will reduce feedstock contamination. An organic waste processing model with curbside pickup increases community participation, as organic waste collection is more available to residents. A study analyzing municipal composting programs in Massachusetts showed an effective pick-up model from the town of Dover. It resulted in 57.2 tons of food waste collected and composted in 2017 from 230 total families (Chia Yan Min 2019).

ECOlibrium recommends that Hamilton County distributes at least one 12-gallon bin to household units. According to the Hamilton County Waste Plan, the average person in Cincinnati produces 7.91 lbs/person/day of solid waste, where 20% is food waste. This equates to 1.442 lbs/person/day of food waste. An average household of four people throws away 40 lbs/household/week of food waste. The high density of food waste suggests that a 12-gallon bin is suitable for this amount of waste. Rehrig Pacific Company sells a durable 12-gallon bin with a locking mechanism to prohibit pest access and wheels for easy transport (Figure 7).

Figure 7: Rehrig Pacific Company 12-gallon bin (personal communication 2024)

For the curbside pickup, a contractor will need an agreement with the county or the composting facility. Prior to establishment of a curbside pickup program, drop off locations for residents to bring their waste to are recommended. Section 7.1 describes potential program establishment.

3.2 Receiving

Receiving of organic waste will occur near the entrance of the composting site. Incoming feedstocks will be inspected and weighed at a scale house. Operators must document weight, contents, date, and name of the person or hauler who brought the feedstocks. Feedstocks are then tipped by the trucks inside the receiving area. The receiving area shares a building with pre-processing, which encourages direct material flow and quicker handling speed (Gamble et al. 2022). An indoor pre-processing area mitigates the odors and leachate from raw feedstocks. Feedstocks that contain food must typically be processed within a day (Cotton and Rynk 2022).

Bulky feedstock amendments will be sent to a separate outside storage area. This area is larger because the wood amendment can be stored longer than the raw feedstock without issue. There will be a small amount of wood amendment kept in the receiving and pre-processing building that is readily available for mixing.

3.3 Shredding and Bulking

Pre-processing consists of shredding and bulking the feedstock. Feedstock should exhibit a particle size of 1/8 inch to 2 inches, a bulk density of 1200 lbs/yd^3, and a carbon to nitrogen (C:N) ratio of 25:1 (Oshins and Michel 2022). Smaller particles offer more surface area for microorganisms to decompose the material. Shredding the material also provides a consistent particle size throughout the process. Craig Coker from Coker Consulting and David Matchinga from Maverick Environmental Equipment state that low speed, high torque shredding reduces the feedstock size while also mixing in bulking agents (Personal Communication, 2024).

It was determined Hamilton County produces enough bulking agents for the compost facility if waste is bulked to the recommended ratio of 1:3 by volume of green waste to brown waste. The proposed facility requires 115,000 cubic feet of brown waste per day. Currently, Hamilton County produces 25 tons of solid waste per year from residential and industrial sources. The USEPA published a report in January 2022 that stated wood waste, paper and paperboard, and yard trimmings consist of 60% of organic waste generated (U.S. Environmental Protection Agency 2022). Hamilton County produces an estimated 1,176,618 lbs of brown waste each day. Using the typical density of this waste of 9.67 lb/cfu (Jamal 2020), this equates to 118,043 cubic feet of brown waste per day. This is greater than the required brown waste needed for bulking.

The pre-processing building houses the organic waste feedstock, a portion of required bulking agents, and two shredders used to mix the organic waste with the bulking agents. This design is based on Cedar Grove's pre-processing building, which contains space for incoming waste and a shredder that empties out onto a conveyor belt (Cedar Grove Facility Tour 2018). Craig Coker recommended that the building be constructed of stainless-steel or a material double-coated with epoxy resin (Personal Communication 2024). This design protects the walls and interior of the building from corrosion induced by the organic waste in the building. Figure 8 shows the proposed preprocessing building, designed to house over 5,700 cubic yards of organic waste. This is the estimated daily average of incoming organic waste, calculated in Appendix 9.3.2.3. The height of an incoming organic waste pile should be approximately 4 feet at most (Personal Communication, 2024). This minimizes the risk of organic waste spillage within the building. The determined allowable space for the incoming organic waste is 75-by-75-by-1.333 yards. This space will contain 20% more than the average daily incoming volume of organic waste, which may be necessary in the event of higher incoming daily loads.

Waste haulers should drop off feedstock on the organic waste pad so that older waste sits towards the back of the pad, and therefore closer to the shredders. The necessary clearance for the building is 22 feet to allow garbage trucks to enter. The recommended allowable space between equipment should be 15 feet to accommodate maintenance and movement of other machinery nearby ("Turned Windrow Composting" n.d.). The alley space in between the shredders is 4 yards wide.

The preprocessing building, shown in Figures 8 and 9, should be a pre-engineered building system. The prototype provided by Allied Building Systems (Personal Communication 2024) is made of stainless steel with a polyurethane finish coat.

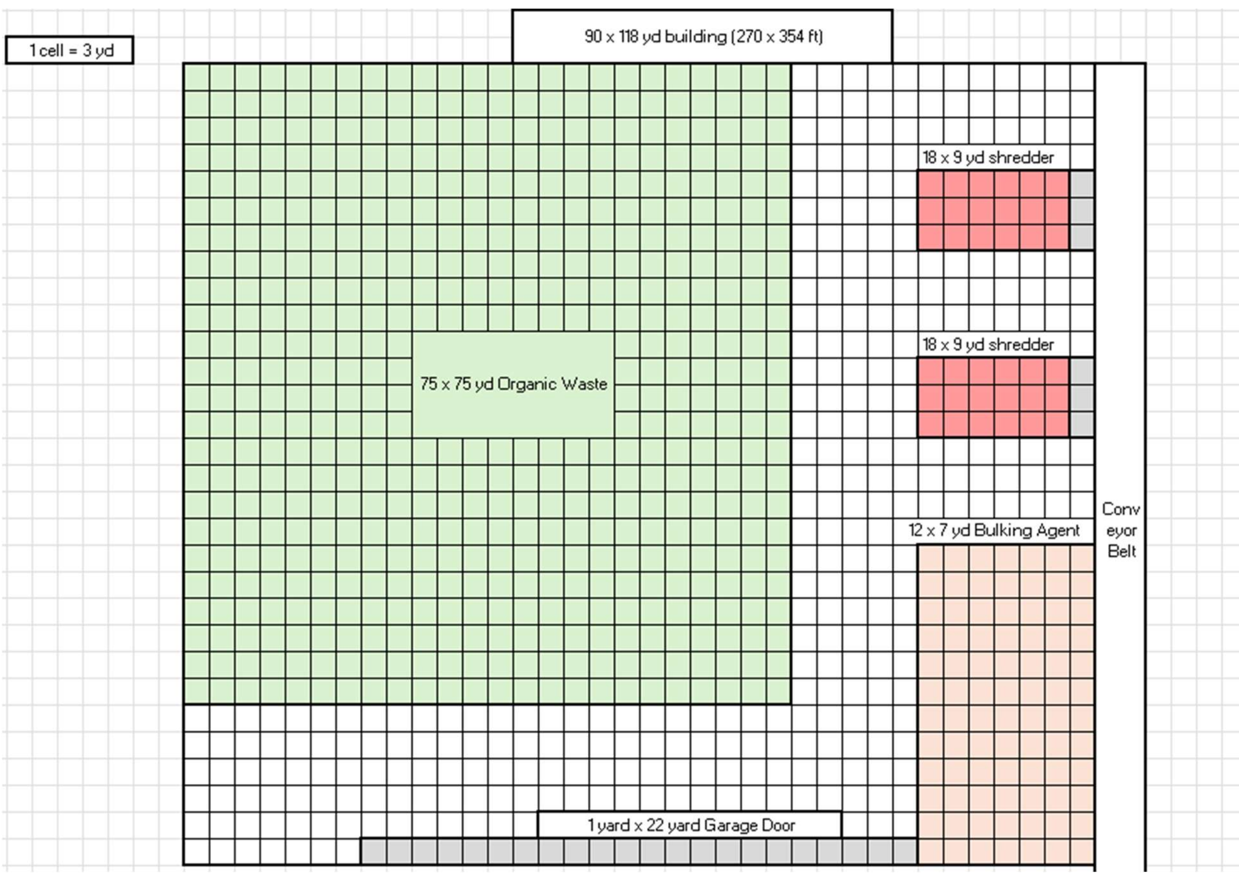

Figure 8: Overhead drawing of pre-processing building with scale

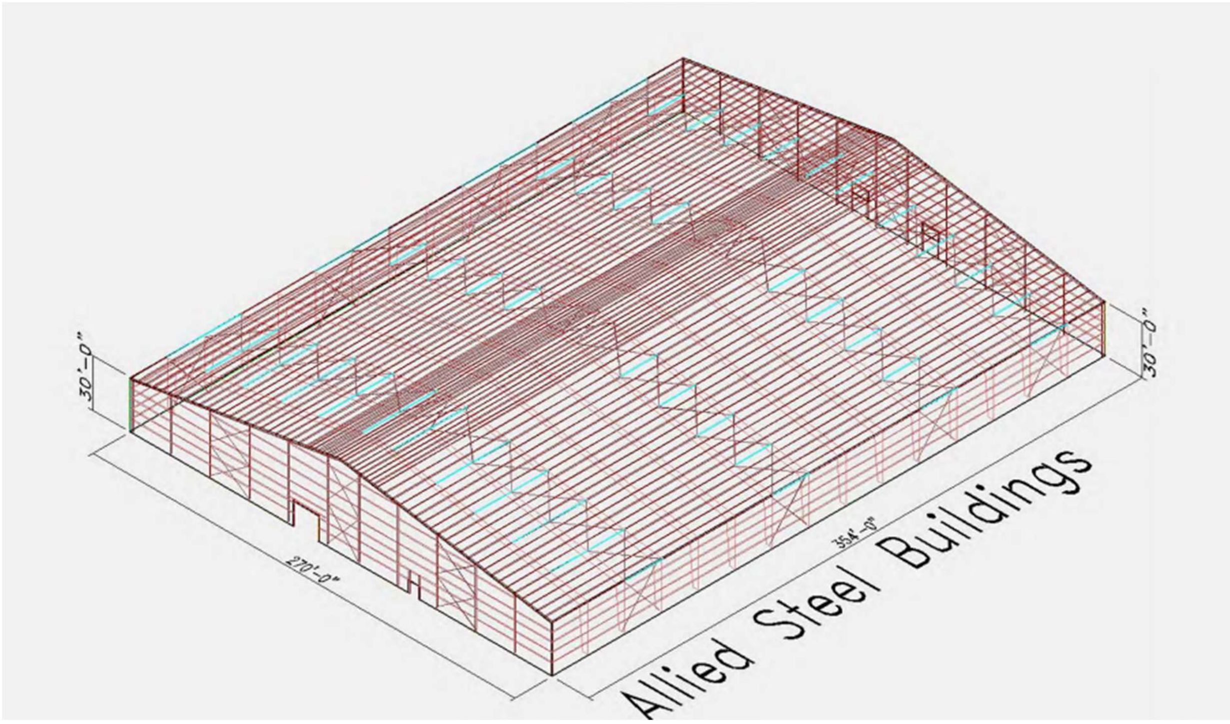

Figure 9: Drawing of proposed pre-processing building by Allied Steel Buildings

3.4 Active Composting

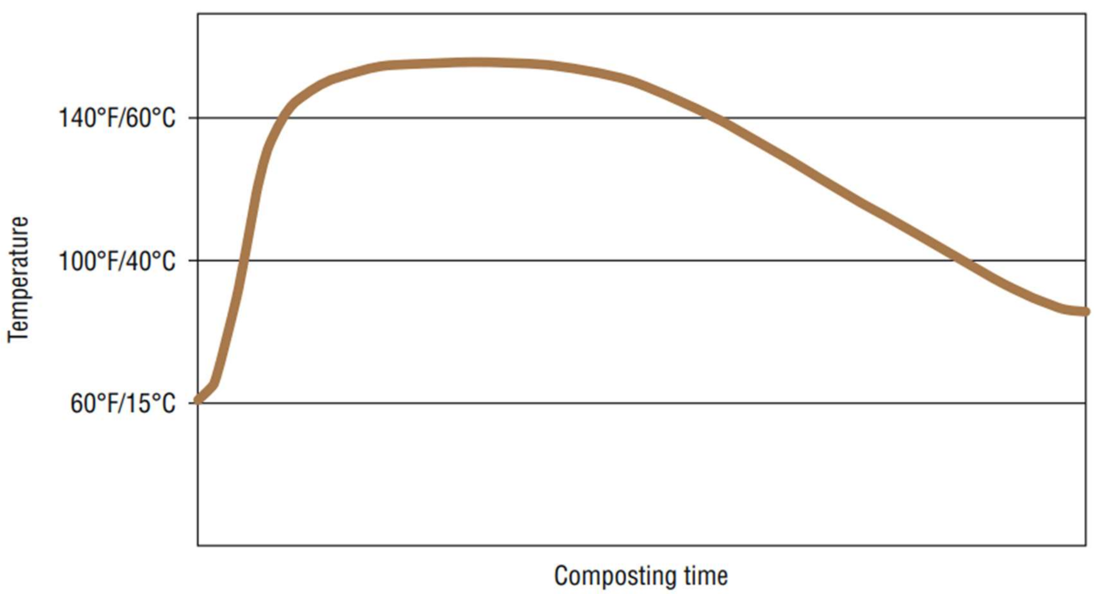

Figure 10: Graph of Composting Temperature Over Time (Oshins and Michel 2022)

In the active composting phase, microbes start to break down the organic waste into a usable soil amendment. The compost will begin to heat up to 120° to 140°F (50° to 71°C) as the microorganisms begin to emit heat from organic decomposition (Gamble et al. 2022). The temperature will often fluctuate in this range as several types of microbes grow and die off. Temperature is the main indicator of the compost's health at this stage (Figure 10). A low temperature can indicate decreased microbial activity, often resulting from improper aeration or moisture. With enough oxygen, the pile temperature can reach above 140°F. A temperature this high can also decrease microbial activity by killing off the beneficial bacteria in the compost. If the compost reaches this temperature, it is cooled via forced aeration or pile size reduction (Gamble et al. 2022). This active composting phase can last 45 days, but only requires 30 days in the correct conditions.

The active compost is situated on the compost pad in windrows. The compost pad is the largest portion of the facility. After shredding, the raw compost will spend 40 days in this composting stage, before being moved to the secondary curing phase. The pad must be impermeable and up-slope from a retention pond system to control leachate drainage. A six-inch-thick layer of crushed asphalt as the compost pad's material will convey more leachate and lower costs compared to other materials.

Four different calculations were performed to determine the acreage needed for the pad. These include two different calculation methods for both trapezoidal- and oval-shaped windrows. The first method followed a set of established steps from the Vermont Agency of Natural Resources (Turned Windrow Composting n.d.). It includes a 20-step process that uses the weight of feedstock and bulk density to calculate the total area of the compost pad. ECOlibrium established the second set of calculations to verify the first set. This method converted the total 200,000 tons of anticipated waste per year into pounds of anticipated waste per day. That waste flow rate was then divided by the desired bulk density of compost, 40 lbs/cfu, to yield an anticipated volume of green waste per day. This was then multiplied by 3 to yield the volume of required bulking agents. Both volumes were added to estimate the total amount of compost volume entering the facility each day. The incoming daily volume divided by the desired cross-sectional area of a windrow then yielded the amount of windrows built per day in terms of windrow length. Dividing this by the set windrow length of 75 feet produced the total number of windrows produced per day. The required acreage for these windrows was then calculated.

The two methods yielded similar results for both windrow shapes. The Vermont Agency of Natural Resources method determined that 29 acres were required for a compost pad with trapezoidal windrows, and 31 acres were required for a compost pad with oval windrows. The method derived by the ECOlibrium determined that 23 acres were needed for a compost pad with trapezoidal windrows, and 31.9 acres were needed for a compost pad with oval windrows. To accommodate the highest potential daily compost volume, 32 acres was selected and used as the required compost pad size. Full compost pad size calculations are in Appendix 9.3.2.

3.4.1 Retention Pond

Stormwater and leachate management is necessary for the proposed compost facility to prevent erosion and water pollution, protect public health, and preserve the site integrity. To reduce discharge of solids and contaminants in stormwater directly to groundwater, it is recommended that leachate treatment is separate from general site stormwater treatment. This would also allow for facility operators to reuse the collected leachate to wet the active compost, reducing overall site water use and stormwater treatment costs. Cedar Grove's Maple Valley and Everett composting sites utilize a four-part stormwater and two-part leachate management system on their combined 52-acre composting sites (Bartlett 2006). The leachate management system consists of three separate drainage systems that empty into a leachate collection tank. The largest drainage system connects to the aeration trenches beneath the windrow, which double as a means for air distribution to the windrows. The stormwater system includes a solids separator, two aerated ponds, a wet pond with plants, and a bioswale. The proposed site for Hamilton County utilizes a similar treatment train.

Leachate collected from the receiving area, preprocessing area, and composting pad is collected and stored in a 60,000 gallon in-ground storage tank at the lower end of the composting pad. The covered tank is lined with impervious material and aerated to minimize odor generation.

To determine the required size of the aerated ponds, the expected water quality volume generated from the serviced site area is required. The Ohio EPA requires that detention pond capacity is increased by 20% of the determined water quality volume to address capacity lost over time due to sediment accumulation (“Chapter 2 Post Construction Stormwater Management Practices 27 2.6 Water Quality Ponds”, n.d.). A watershed imperviousness ratio of 0.9 was used for the 55-acre proposed site. Average rainfall records to cover 0.9 inches of rainfall depth and 90% of average annual runoff depth provided by the Ohio EPA were used, as a specific site location has not yet been selected. The calculated water quality volume required was 4.257 acre-ft, or about 1.4 million gallons. Between two evenly sized aerated ponds, this yields a capacity of 700,000 gallons for each pond. Each will require an acre of site space, with the wet planted pond and bioswale adding an additional acre to the system footprint.

3.4.2 Aeration System

Forced aeration systems supply air to the aerobic bacteria in the active compost mix and maintain lower temperatures in the windrow during active composting. Temperature kept in the mesophilic range during the composting process results in raised pH levels, more frequent conversion of nitrogen to nitrates, reduction in odor emissions, and increased rates of organic matter bio-oxidation (Sundberg 2008). Efficient maintenance of these conditions via a forced aeration system requires reliable, uniform air distribution. Aeration floor systems can accomplish this while acting as a flat working surface and drainage system for water and leachate.

The size of the proposed composting facility and desired compost uniformity and quality dictate the aeration system’s overall design. The most significant design feature is the chosen direction of air flow, which can be positive, negative, or alternating. Negative aeration systems pull air from outside the windrow through the composting mass and into the pipes below (“Aeration Floor Fundamentals.” 2017). The proposed site plan uses a positive aeration system that forces air from the floor to the compost material. Though capture of air emissions and leachate is reduced with positive aeration compared to negative aeration, the selected system is simpler and more cost-effective to implement. Excess leachate collection and buildup beneath the composting mass and in the aeration piping system is avoided with positive aeration (Miller 2017). As a result, this method will also reduce required cleaning and maintenance frequency for the distribution system, which is significant for such a large facility. The aeration system itself will be in-floor to reduce potential damage risk from front loaders and other vehicles compared to the pipe-on-grade (POG) alternative.

Maintaining uniform air distribution and high peak aeration rates in the in-floor system is crucial for temperature and air control in the composting material. Though slightly more expensive, a low friction trench system was selected over a sparger system due to its leachate capture ability, lower blower horsepower requirements, and improved energy efficiency ("Aerated Static Pile Composting Floor Types" n.d.). Low-friction systems maintain a high peak aeration rate using a balanced low-pressure design to evenly distribute air (Miller 2017). To avoid maldistribution of air flow along the trench length, the maximum length was kept to 75 feet for the windrow aeration system. Space between trenches under each windrow was also designed to be two-thirds the height of the pile. From a windrow height of 8 feet, this results in a trench distancing length of about 5.3 feet, or about 3 trenches per 22-foot-wide windrow. Each set of three trenches is connected to the leachate collection system and a centrifugal blower, which is controlled and monitored by the site SCADA system described in Section 4.6.

3.5 Curing

The next stage of composting occurs at a lower mesophilic temperature, as decomposition still occurs (Gamble et al. 2022). For an aerated system, the compost moves from the active compost pad to the curing area once the temperature falls below 40°C or 105°F (Gamble et al. 2022). There is no standard time at which curing should begin, which is why the temperature requires consistent monitoring during the active stage.

During this stage, the compost can be cured in windrows or piles. ECOlibrium recommends that Hamilton County cures compost in piles to conserve space. A separate curing area is recommended to free up room on the active compost pad. Piles can be up to 12 ft tall but must be monitored to prevent overheating. The volume of compost is usually 40-50% less than the original feedstock ("Large Scale Compost" n.d.). The curing process ranges from 30-60 days. To determine the end of the curing phase, composite samples will be tested for maturity levels based on respiration ("Large Scale Compost" n.d.).

The size calculation for the curing area was based on a study and guide for windrow composting from the Vermont Agency of Natural Resources. Modifications were made to cure in piles instead of windrows. An average curing time of 45 days was used to account for the variability of curing being 30-60 days (Gamble et al. 2022). Final calculations yielded 3,461,538.5 cubic yards of compost. This amount was then divided by the 12 ft maximum curing pile height (Gamble et al. 2022). This yielded 288461.5 square feet needed for the curing area. Converted to acres, the resulting curing area was 6.62 acres. This was rounded to 7 acres in the layout of the site to account for extra room for retail, as shown in Appendix 9.6.2.5.

3.6 Screening

Screening occurs after the active composting and curing cycle. Any material outside of the size requirements for composting or that fails to decompose is removed from the compost during this process. Sales representatives from Komptech and Doppstadt, popular composting machinery suppliers, describe that the feedstock at the start of the process is high in moisture and will clog any type of screening machine (Personal Communication 2024). Allowing the compost to stabilize will ensure the screening efficiency at the end of the process. A trommel screen will remove hard debris and an air screener will remove light debris such as plastic.

3.7 Distribution and Retail

Distribution of finished compost material is not currently included in the scope of the existing site design recommendation. Finished compost will be reused on site or stored until it is picked up by compost purchasers or selected hauling services. ECOlibrium recommends that Hamilton County contracts out compost hauling services and potential off-site compost bagging and retail. This is recommended especially for the initial phases of facility operation. Current facility plans do not include equipment for bagging and retail of finished compost except for the sale of bulk compost via an established pick-up area. Space is available for future development of a retail area if desired.

On-site bulk compost purchase and pick-up will provide direct access to agricultural application and landscaping, the largest local markets for finished compost. Beyond these primary markets, finished compost can also be used in construction, green infrastructure, homeowner and community gardens, nurseries, and land reclamation applications. Estimations for compost retail in these secondary markets are not included in this paper's financial analysis. A portion of the compost produced at this facility will also remain on site for reuse in biofilter covers.

4 Equipment

One of the reasons Hamilton County wants to implement composting is to reduce greenhouse gas emissions from the landfill. Choosing electric powered equipment will align with this goal.

4.1 Storage of Equipment

Storage of the equipment is an essential consideration in the site's design. A pre-engineered building system similar to the pre-processing building will protect the equipment from weather conditions and shelter employees. A proposal of the equipment building shown in Figure 11 was also provided by Allied Building Systems, with a stainless-steel build including a polyurethane coating (Personal Communication, 2024). The equipment building houses several vehicles, the screening system, and several rooms for operator and employee use (Figure 12). The building acts as an office for the workers, a monitoring point for the sensor and aeration systems, and a room for potential on-site laboratory testing of compost samples (Figure 12). The on-site laboratory space eliminates the need to outsource lab testing of the compost to commercial labs. Operators at the facility can conduct on-site sampling and testing to determine the quality and characteristics of each windrow.

The building is designed to accommodate 8 vehicles in 8 total 8-by-4 yard parking spaces. These vehicles include trucks (with measurements based on 5.8-by-2.2 yard 2023 Ford F-150), water trucks (with measurements based on 6.75-by-2.637 yard Load King Water Truck), and front loaders (with measurements based on 6.75-by-2.637 yard CAT-950 model). A designated 20-by-9 yard space for a screener (with measurements based on Electric Komptech Crambo 5000) is included in the equipment building to accommodate any required indoor maintenance.

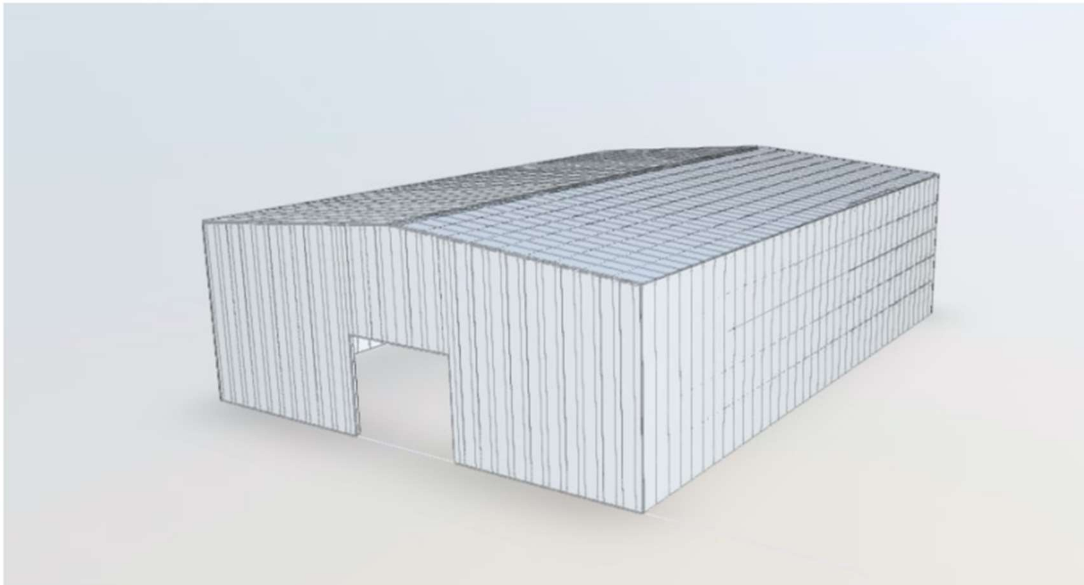

Figure 11: Drawing of proposed equipment and office building by Allied Steel Buildings

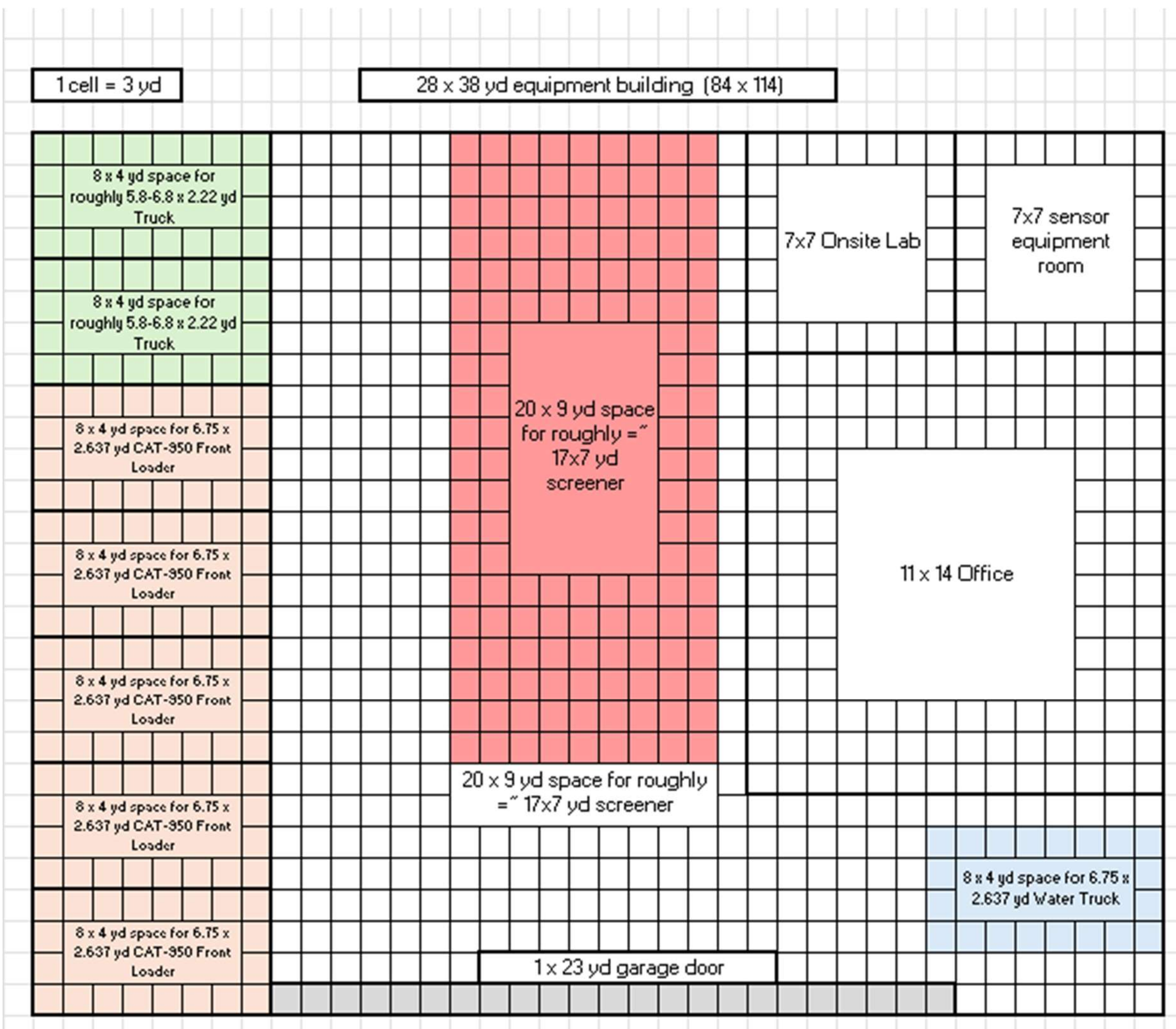

Figure 12: Overhead drawing of equipment building with scale

4.2 Shredder

Maverick Environmental Equipment supplies Komptech composting equipment to Ohio (Figures 13 and 14). Purchasing two Electric Komptech Crambo 5000s with throughputs of 48.14 yds/hour meets the throughput requirements of 200,000 tons yearly of residential food waste. This electric shredder provides 70% energy cost savings and 50% maintenance cost savings compared to diesel. Only one operator per machine is required. Adding residential food waste and bulking agents at the same time also makes this usable as a mixer. The Komptech Crambo 5000 can accommodate a misting system to wet the compost or a magnet to remove metals.

Figure 13: Electric Komptech Crambo 5000

Figure 14: Inside of Electric Komptech Crambo 5000

4.3 Front Loader

The front loader has multiple functions. These include moving feedstock into the shredder, moving feedstock from shredders to windrows, turning windrows, moving compost to the curing area, putting compost into the trommel screen and air screener, and placing compost in the retail space. Monica Rulo, a Construction manager at Moss and Associates, and Craig Coker, from Coker Consultants, describe CAT as the most reliable front loader brand (Personal Communication 2024). Craig Coker recommends the CAT 950, shown in Figure 15 (Personal Communication 2024). At least fifteen are necessary. To decrease the number of required front loaders, oversized buckets can replace the typical buckets that front loaders come with. Buckets on a front loader are designed for heavy material like gravel, but compost is a much lighter substance (Gamble et al. 2022). The electric CAT 950 GC lasts about six hours on one charge. The front loaders can charge overnight in the equipment storage building.

Figure 15: Cat-950

4.4 Water Truck

Construction sites can become very dry. Ohio's regulation, Rule 3745-17-08, describes the restriction of emission of fugitive dust (Ohio Laws & Administrative Rules 2023). Water trucks can suppress dry ground to reduce fugitive dust. Two of them should suffice for this project. Water for the trucks can be drawn from the leachate storage tank.

4.5 Screeners

4.5.1 Trommel-Screen

Trommel screens are the standard screen in organics processing plants (Figure 16). Trommel screens are a type of rotating horizontal screening drum. The drum is tilted, and the material falls down its length as the drum rotates. The smaller material falls through the screen while the larger material goes out the end (Gamble et al. 2022). GoZERO in Ohio and A1 Organics' largest compost facility in Colorado are examples of compost facilities that utilize a trommel Screen (Personal Communication 2024). Star screeners are the second most popular screening type. Corey Shaffstall, Sales Manager at ECOVERSE, states that star screeners accommodate wetter and stickier material. Since the screening will commence after the active composting phase, the material will be dry enough for a trommel screen (Personal Communication 2024). The electric Vermeer TR626EM has a throughput of 200yd^3/hour, an 0.5 inch screen, and can handle a moisture of less than 40% (Personal Communication 2024).

Figure 16: Vermeer TR626EM Trommel Screen

4.5.2 Air Separation System

Small plastics are a nuisance to composting facilities. Large plastics are easily handpicked, but handpicking smaller ones would be infeasible. Komptech offers a wind sifter and a pressure-suction system (Figures 17 and 18). The pressure blower first separates the material, so that the lighter material rests on top of the heavier material. A suction blower then sucks up the light plastics (Komptech 2022). The Hurrikan S has a throughput of 78.47 yd^3/hour.

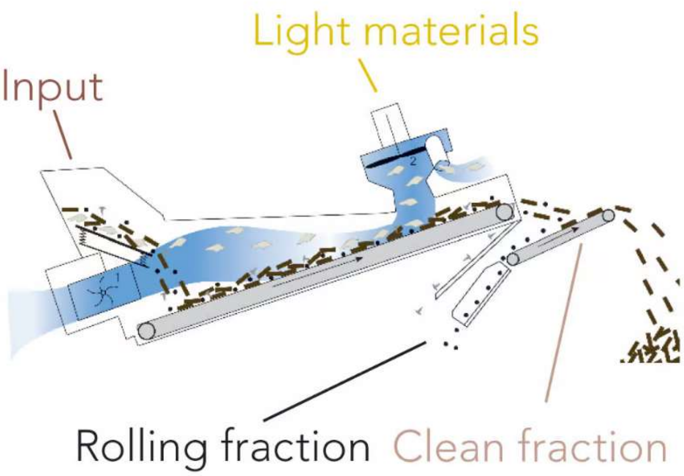

Figure 17: Hurrikan Process (Komptech 2022).

Figure 18: Hurrikan S (Komptech 2022)

4.6 Monitoring System

Monitoring systems for the composting process are common in large-scale composting facilities. These systems consist of computer networks used to monitor and control different parameters within piles and windrows such as moisture, temperature, aeration, and pH. Sensors will be connected through a Supervisory Control and Data Acquisition (SCADA) system, which is used to control and monitor the devices and processes used throughout the facility. A designated computer system has been positioned in the equipment building to house the hub for a trained operator. Temperature and pH probes will be required to be used alongside the SCADA system. They will be placed along the windrows for monitoring throughout the composting process.

A weather station will be included to measure wind speed, wind direction, and rainfall. Inclement weather conditions may have drastic impacts on the characteristics of unsheltered windrows. An accurate weather station would allow on-site operators to make real-time decisions on the compost windrows through the station's results. These often do not require significant space or an individual room to be operated.

4.6.1 Greenhouse gas Monitoring

Greenhouse gases (GHGs) emitted from composting include methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2), and can be monitored and measured using a variety of methods. Closed or open chamber, gradient, integrated horizontal flux (IHF), and funnel methods are most often used to monitor GHGs from composting. The chamber method shown in Figure 19 is the most commonly used to monitor GHGs from large composting facilities. This method works by inverting a box or cylinder over the entire pile and using a variety of specific instrument techniques to measure the emission of GHGs. The main difference between the open chamber procedure and the closed chamber procedure is that the open type allows outside air to continuously flow through the chamber. Large-scale open chamber systems are frequently used because they can be coupled with mobile automated gas analyzers to evaluate emissions directly at the location. This feature enables prompt modifications to the sampling strategy, leading to an increase in gas flux capture because of alterations in the surrounding environment and management actions (Yasmin 2022).

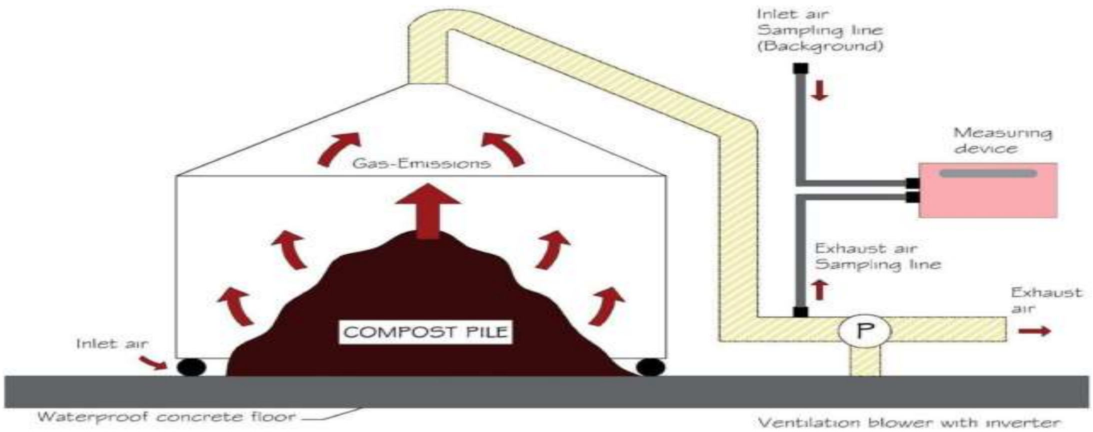

Figure 19: Closed chamber method for the measurement of GHGs (Yasmin 2022)

4.6.2 Temperature Monitoring

Temperature monitoring during the composting process is essential to ensure the quality of the finished compost and control the decomposition rate. Temperature records are required for composting permits and regulations for composting agencies. There are several temperature-measuring devices that are commonly used to monitor windrow temperatures. A mechanical dial thermometer (bimetallic) is one of the most effective, easy-to-use, and inexpensive thermometers that can be used to monitor windrow pile heat (Figure 20). The temperature range of the thermometer must be between 0 to 100°C (0 to 200°F). However, it is difficult to reach reading stability with this device. Electronic temperature probes are also commonly used in the composting industry. This electronic probe produces faster temperature readings compared to the thermometer, has a digital readout, and has the option to transfer the temperature reading into data recording instruments, which is ideal for use with a SCADA system (Rynk et al. 2022).

Figure 20: Bimetallic thermometer with a dial readout with its orange handle (Rynk et.al. 2022)

4.6.3 Moisture Monitoring

Maintaining the level of moisture in compost piles is crucial to ensure the correct recipe. The moisture content of each compost pile can vary depending on the aeration system, weather, and type of feedstock. The level of moisture must be balanced to achieve an effective decomposition process, avoid odor emissions, and produce high-quality finished compost. The best practice for determining the whole pile level of moisture is to get samples from different locations and at different depths. The dry sample's appearance, texture, and weight should also be evaluated. Moisture level determination can be done following basic procedures or using an electronic moisture probe. For the basic process, the wet sample must be weighed before and after drying, and the difference yields the weight of the water. Dividing the weight of water by the wet sample weight will produce the moisture content value. This method is occasionally inaccurate and time-consuming. The electronic moisture probe is the best alternative option to use because of its accuracy, quick result, and ease of use at multiple locations on the pile. Two electrodes pointed at the end of the moisture sensor probe measure the electrical resistance of the materials once the probe is inserted. Because moisture content effects the material's electrical resistance, moisture level can be measured (Rynk et al. 2022).

5 Economic Analysis

5.1 Site Development Costs

Costs for site development were compiled from estimates for permitting and approvals, site clearing and grading, hardscape construction, water management system implementation, utilities extension, and front-end facility component construction. Without an exact site location chosen, land acquisition costs and more accurate estimations for clearing, grading, hardscape construction, and utility extension are not available. Utility extension was thus estimated for an arbitrary distance of 1500 ft, costing $55, $35, and $35 per foot for extension of three-phase power, water, and sewage services, respectively. Initial permitting for composting, air, and stormwater management is estimated at $10,000, $10,000, and $5,000, respectively.

Hardscape construction estimates include several soil borings, silt fence construction, and excavation and backfill for several site components. Construction of the composting pad and asphalt construction for the site includes estimates for the geotextile fabric below the pad and asphalt and crushed aggregate working surfaces. Additional costs for installation of the asphalt-cast in-floor low-friction aeration system in the composting pad include trench and blower purchases. Excavation, backfill, purchase, and installation for the leachate tank, wet detention ponds, solids separator, and bioswale is also included. The addition of pre-engineered buildings for equipment maintenance, receiving, and preprocessing areas brings the total cost for hardscape construction, clearing, and grading to just over $8 million.

Several other site development components were added to the initial investment to cover the front-end areas of the facility. Foundation and construction of a truck weighing station, parking lot, and office trailer added costs of $30,000, $47,880, and $50,000, respectively. In total, site development costs for the proposed composting facility are estimated to be $9.5 million. All site development costs are outlined in Table 5.

Table 5: Cost estimates for composting facility development and construction

Item	Unit Price	Units	Quantity Needed	Total Cost
Permits and Approvals				
Composting Permit	$ 10,000.00	per permit	1	$10,000
Air Permit	$ 10,000.00	per permit	1	$10,000
Stormwater Permit	$ 5,000.00	per permit	1	$5,000
Clearing and Grading				
Clearing	$ 4,094.00	per acre	55	$225,170
Stone Tracking Pad	$ 2,154.00	each	1	$2,154
Fine Grading of Site for Drainage	$ 1,037.00	per acre	55	$57,035
Hardscape Construction				
Geotechnical (8-12 soil borings)	$ 1,250.00	each	12	$15,000
Silt Fence	$ 1.45	LF	6398	$9,277
Geotextile Fabric	$ 1.29	SY	63607	$82,053
Asphalt Working Surface	$ 120.00	CY	25763.23218	$3,091,588
Crushed Aggregate Working Surface	$ 1.25	SF	1001880	$1,252,350
Excavation & Backfill for Leachate Tank	$ 2.02	cy	2463	$4,975
Initial Bio-cover Layer	$ 35.00	CY	26125	$914,375
Equipment Maintenance Building	$ 156,653.00	1	1	$156,653
Receiving & Preprocessing Building	$ 2,251,866.00	1	1	$2,251,866
Water Management				
Vegetative Buffer Perimeter	$ 586,700.00	1	1	$586,700
Pond Excavation	$ 102,000.00	1	1	$102,000
Pond Aeration System Installation	$ 81,000.00	1	1	$81,000
100 mL Pond Liner	$ 16,600.00	100000 Gal	7	$116,200
Runoff Swales	$ 9,000.00		1	$9,000
Solids Separator	$ 58,500.00		1	$58,500
Wet Detention Pond	$ 10,000.00	100000 GAL	14	$140,000
Utilities				
Extension of 3 Phase Power & Data Line	$ 55.00	FT	1500	$82,500
Extension of Sewer from WWTF	$ 35.00	FT	1500	$52,500
Extension of Water from WWTF	$ 35.00	FT	1500	$52,500
Front-end Facility Components				
Truck Weighing Station Foundation	$ 30,000.00	1	1	$30,000
Parking Lot	$ 47,880.00	1	1	$47,880
Office Trailer	$ 50,000.00	1	1	$50,000
Scalehouse	$ 75.00	SF	3600	$270,000
TOTAL				$9,496,276

5.2 Equipment Costs

Equipment purchases for the composting facility are all priced new. Most of the equipment costs estimated for the facility constitute operational equipment and machinery. Several other additions include the leachate collection tank and the purchase of compost collection bins for all of the owner-occupied single family dwelling units in Hamilton County. An insurance coverage cost equal to 0.5% of equipment costs was added to the total. The total initial cost for equipment was $14.2 million. Using average depreciation rates and estimates for replacement periods, equipment costs were annualized to $4.4 million. These costs are listed in Table 6. Joined with site development costs, initial capital investment totals $23.7 million.

Table 6: Cost estimates for initial equipment purchases

Equipment Type	Unit Price	Quantity Needed	Total Cost	Supplier
General Site				
950 GC Electric Medium Wheel Front-End Loader	$ 150,000.000	10	$ 1,500,000.000	Caterpillar Inc
FORD F150 Pick-Up Truck	$ 37,000.000	2	$ 74,000.000	Ford Motor Company
Truck weighing station scale	$ 80,000.000	1	$ 80,000.000	Walz Scales
Water truck	$ 150,000.000	2	$ 300,000.000	Commercial Truck Trader
HOBO RX3000 Remote Weather Station	$ 3,000.000	1	$ 3,000.000	HOBO Data Loggers
SCADA monitoring system	$ 840,000.00	1	$ 840,000.000	Reotemp Compost
Preprocessing and Active Composting				
Electric Komptech Crambo 5000 Shredder	$ 873,000.000	2	$ 1,746,000.000	Maverick Environmental Equipment
Aeration Trenches	$ 3.380	214608	$ 725,375.040	Engineered Compost Systems
Aeration Blowers	$ 3,500.000	526	$ 1,841,000.000	Engineered Compost Systems
CompostWatch Cloud System EcoProbes	$ 2,735,200.000	1	$ 2,735,200.000	Reotemp Compost
Postprocessing and Distribution				
35" Wide Over-Belt Magnet	$ 29,750.000	1	$ 29,750.000	Maverick Environmental Equipment
TR626EM Trommel Screen	$ 531,932.400	1	$ 531,932.400	Vermeer
Hurrikan S Air Screener	$ 368,500.000	2	$ 737,000.000	Maverick Environmental Equipment
Leachate tank	$ 20,000.000	1	$ 20,000.000	Highland Tank
Water pumps	$ 4,000.000	3	$ 12,000.000	Universal Aquatics
12 Gallon Organic Waste container	$ 11.250	263138	$ 2,960,302.500	Rehrig Pacific Company
Total			$ 14,206,237.740	

5.3 Operating Costs

Operating costs for the proposed compost facility include labor, equipment maintenance and upkeep, administrative costs, and use of the stormwater, bio-cover, and compost lab testing systems. Minimum on-site labor was estimated to require one managerial position at a $126,000 annual salary, and 15 full-time operator positions at a $64,625 annual salary. Adding in a $5.97 per ton of accepted organic waste overhead administrative fee and an 0.1% operating insurance cost, administration and labor is estimated to cost $2.3 million annually. Equipment maintenance is estimated at $134.57 per machine per hour of operation, costing $2.8 million annually. Routine compost testing, stormwater management operation, and bio-cover application bring the annual operating costs to $5.8 million. These costs are outlined in Table 7.

Table 7: Annual cost estimates for operation

Item	Unit Price	Units	Quantity Needed	Total Cost
Laborers	$ 64,625.600	1	15	$ 969,384.000
Manager	$126,000.000	1	1	$ 126,000.000
Biocover	$ 3.000	$/ton	200,000	$ 600,000.000
Stormwater treatment	$ 750.000	wk	52	$ 39,000.000
Testing	$ 7,200.000	1	1	$ 7,200.000
Overhead	$ 5.970	/ton	200000	$ 1,194,000.000
Equipment maintenance	$ 134.570	/machine/hr	20800	$ 2,799,056.000
TOTAL				$ 5,791,986.40

5.4 Market Assessment

Potential revenue from the sale of finished compost was generated for landscaping and agriculture, the two largest markets in the Hamilton County area. Of the available finished compost produced annually at the proposed facility, 25% is projected to sell in the landscape market, while 19% is projected to sell to agricultural applications. 40% of the finished compost will be reused on site for the bio-cover and berm maintenance, leaving approximately 16% of the finished compost for all other available markets. These include compost applications in construction, green infrastructure, homeowner and community gardens, nurseries, athletic fields and golf courses, and land reclamation projects. The landscape and agricultural markets were evaluated for Hamilton County and its surrounding counties, including Butler, Clermont, and Warren Counties in Ohio, Franklin and Dearborn Counties in Indiana, and Boone, Kenton, and Campbell Counties in Kentucky.

The residential landscaping market for these areas was estimated based off the number of owner-occupied housing units in each county. The U.S. Census Bureau provided the number of housing units and the percentage of owner-occupied housing units in each county. The percentage of housing units that were detached single family units (SFDUs) was estimated from state reported averages. The number of owner-occupied single-family units in Hamilton County was estimated to be 155,778 ("QuickFacts: Hamilton County, Ohio." 2020).

Bed and turf usage per owner-occupied SFDU was estimated using average bed size of 500 square feet per unit, an average turf area coverage of 6000 square feet per unit, and compost application rates of 3 cubic yards per 1000 square feet per year for bedding and 1.5 cubic yards per 1000 square feet per year for turf. In total, compost usage potential was 2,336,663 cubic yards of finished compost in Hamilton County alone. Potential sales were then estimated assuming that only 10% of available units would participate in compost application. The market share after 3 years of this facility's finished product was assumed to be 30% in Hamilton County and 20% in all neighboring counties. An estimated 70,100 cubic yards of finished compost per year were projected to be sold in Hamilton County alone. A total of 147,920 cubic yards of finished compost is projected to sell in the entire evaluated area annually, as outlined in Table 8. At a retail price of a projected $35 per bulk cubic yard, this would earn the facility operators $5.2 million per year.

Table 8: Estimation of annual compost sales to landscaping applications.

	Hamilton County	Butler County	Clermont County	Warren County	Franklin County	Dearborn County	Boone County	Kenton County	Campbell County	Total
# Housing units (total)	381691	155633	88553	96493	9811	21106	53445	73249	42121	922102
Detached SFDUs of housing units (%total)	68.94	68.94	68.94	68.94	65	65	58.2	58.2	58.2	64.48444
Owner-occupied housing units (%total)	59.2	69.5	73.8	78.9	81.4	83.2	76.2	69.1	71.5	73.64444
# owned SFDUs (detached only)	155778	74569	45054	52486	5191	11414	23702	29458	17528	415179
Avg SF beds (SF/SDFU)	500	500	500	500	500	500	500	500	500	
Application rate (CY/1K SF/yr)	3	3	3	3	3	3	3	3	3	
Bed usage (CY/yr)	233666	111853	67581	78729	7787	17121	35553	44187	26292	622769
Avg SF turf	6000	6000	6000	6000	6000	6000	6000	6000	6000	
Application rate (CY/1K SF/yr)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	
Turf usage (CY/yr)	2102997	1006680	608226	708562	70079	154091	319977	397683	236625	5604919
Total usage (CY/yr)	2336663	1118534	675806	787291	77865	171212	355530	441869	262917	6227688
Percent using (%)	10	10	10	10	10	10	10	10	10	
Market share (%)	30	20	20	20	20	20	20	20	20	
Potential sales (CY/yr)	70100	22371	13516	15746	1557	3424	7111	8837	5258	147920

For the agricultural market, acreages covered by each of the six most common crops in each of the evaluated counties were obtained from the 2017 Agricultural Census. Nationally, agricultural producers purchase between 5% and 15% of compost needed to apply to these crops (Dodson et. al. 2023). Expected purchase of compost needed for agricultural application in this assessment was thus conservatively estimated to be 5% for all crop types. Compost application rate depends on the soil nutrient conditions and crop type (Rittenhouse 2015). For this study, the compost application rate was assumed to be 20 tons of compost per acre per year for soybeans, corn, wheat, and vegetables. Forage, sod, and Christmas tree farming were estimated to use 10 tons of compost per acre per year, while orchards were assumed to use only 5 tons of compost per acre per year. The market share was again projected to be 30% for Hamilton County and 20% for all neighboring counties after the first 3 years. Table 9 illustrates the potential sale calculation for Hamilton County's agricultural market, and similar calculations for other counties can be found in Appendix 9.4.6. Using the same bulk price for finished compost, an estimated $3.9 million is generated annually from the agricultural market.

Table 9: Estimate of annual compost sales in agricultural market in Hamilton County

Hamilton County	Forage (hay/ haylage)	Soybeans for beans	Corn for Grain	Vegetables Harvested	Orchards	Sod/ Nursery	Total
Crop acreage	2099	1920	1893	251	62	67	6292
Percent using compost (%)	5	5	5	5	5	5	
Acreage to cover (ac/yr)	105	96	95	13	3	3	
Compost application rate (tons/ac/yr)	10	20	20	20	5	10	
Compost use (tons/yr)	1050	1920	1893	251	16	34	
Compost use (CY/yr)	1772	3241	3195	424	26	57	
Market share (%)	30	30	30	30	30	30	
Potential sales (CY/yr)	531	972	959	127	8	17	2614

5.5 Financial Analysis

Total capital costs, operating costs, and projected sales were used to estimate total annual revenues and a breakeven point for the facility investment. Total capital costs and annual operating costs were $23.7 million and $5.8 million, respectively. Using an annual throughput of 200,000 tons, operating costs average $28.92 per ton. Total capital expense was annualized using depreciation and replacement rates for equipment costs, yielding $30.01 per ton per year. Revenue generated from projected annual compost sales of $11.2 million and a $20 per ton tipping fee resulted in a total annual revenue of $3.0 million. Table 10 summarizes these values.

Table 10: Financial analysis for proposed composting facility

Characteristics	Total	
Throughput (tons/yr)	200000	
Total Site Area (acres)	55	
Total Composting Pad Area (acres)	32	
Staff - Full time	16	
Costs	**Total**	**Annualized**
Equipment Capital ($)	$ 14,206,237.74	$ 4,454,765.21
Site Development Capital ($)	$ 9,496,276.25	$ 1,564,745.08
Total Cost of Capital ($)	$ 23,702,513.99	$ 6,019,510.29
Total Cost of Capital ($/ton)		$ 30.10
Annual Operating Cost ($)	$ 5,791,986.40	
Total Operating Cost ($/ton)	$ 28.96	
Waste Disposal ($/ton)	$ 2.00	
Tipping Fee ($/ton)	$ 20.00	
Compost Sales ($/ton)	$ 55.81	
Total Annualized Revenue ($/ton)	$ 14.75	
Total Annual Revenue ($)	$ 2,950,668.54	

Revenue generation from tipping was assumed to begin after 1 year of site construction, while revenue generated from sale of compost was expected to begin after an additional 3 months. Market share was expected to gradually increase from 0 to 30% in the first 3 years. The site's breakeven point was thus projected to occur after 5 years (Figure 21).

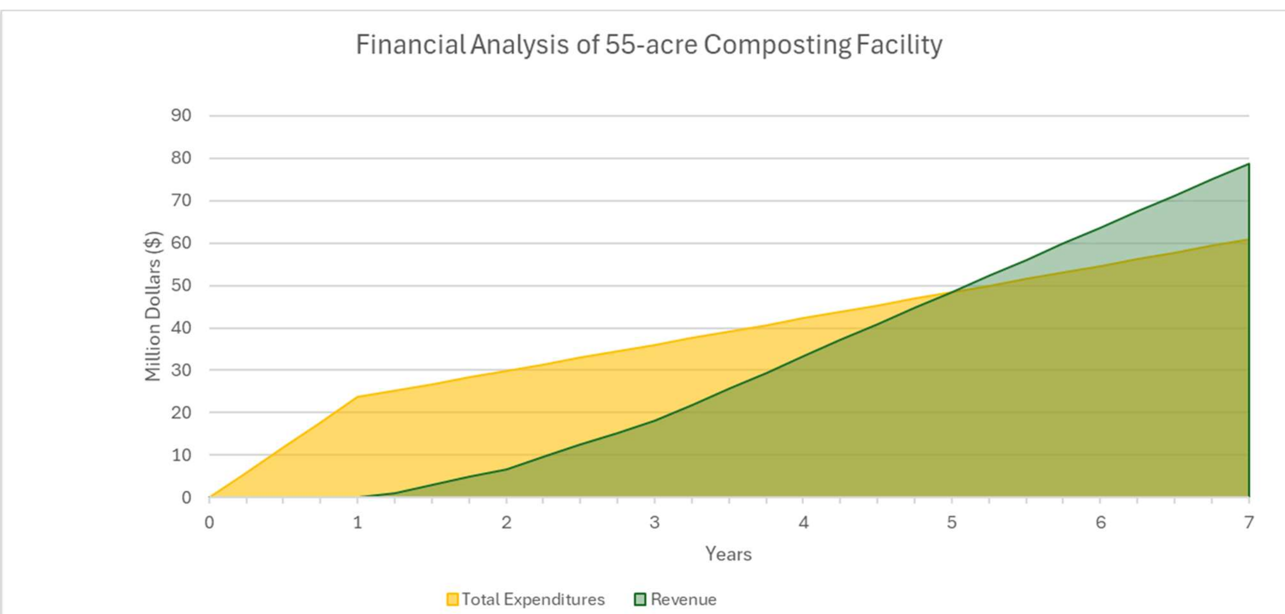

Figure 21: Projected expenditures and revenues for proposed composting facility

6 Environmental

Several environmental factors including selecting the site, managing GHG emissions, controlling odor, mitigating noise, and addressing wildlife, need to be carefully considered before the establishment of the composting facility. Each factor plays a crucial role in the success of the facility in terms of obtaining a high-quality product while adhering to stringent environmental standards. This comprehensive approach not only protects the facility's success but also contributes to sustainable practices and responsible environmental management.

6.1 Greenhouse Gases

The composting of materials can generate different greenhouse gas emissions that contribute to environmental issues. However, the amount of emissions generated from composting is lower than that of landfilling organic waste materials. The greenhouse gas emissions that composting processes produce are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (Yasmin 2022).

Methane (CH_4) has greater negative impacts on the environment. The emission of CH_4 during the composting process depends on organic material composition, composting method types, diffusion of the gas at the top of the piles, and aeration rate. Additionally, the CH_4 is released from areas with reduced airflow. The second gas is nitrous oxide (N_2O), which is released during the breakdown of the compost's nitrogen contained in the compost. Usually, when the organic materials are in the process of decomposition, the available carbon will be used as the source of energy to convert nitrate or nitrite to nitrous oxide (Yasmin 2022).

To calculate emissions, the amount of methane (CH_4) and nitrous oxide (N_2O) were converted to their respective air emission equivalents (CO_2-eq), as provided in Tables 11 and 12 (Zhu 2014). The sum of CH_4 and N_2O in CO_2-eq was then multiplied by the amount of food waste generated annually in kilograms to obtain the total annual site emissions. For composting, emission factors for CH_4 and N_2O reported by Zhu (2014), were 9.70E-04 and 2.10E-07, respectively. These values were multiplied by 1000 and by their CO_2-eq equivalents, 25 kg eq. CO_2 and 310 kg eq. CO_2, respectively, and then by the 181,436,948 kg of food waste generated. The same process was applied for landfilling using the landfill emission factors from the provided tables, including 4.7E-02 for CH_4 and 3.60E-08 for N_2O. The total emissions of CH_4 and N_2O in CO_2-eq from composting were calculated as 4.517 × E+09, while those from landfilling amounted to 2.132× E+11. Calculations are provided in Appendix 9.3.1.

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Table 11: Air emission factors for the three food waste treatment options (Zhu 2014).

Pollutants	Emissions (kg/kg)		
	Landfilling[a]	Aerobic composting[b]	Anaerobic Digestion[c]
CO_2	1.26E-01	2.50E-01	6.00E-03
CH_4	4.70E-02	9.70E-04	1.64E-05
NH_3	3.70E-04	6.00E-04	1.65E-07
N_2O	3.60E-08	2.10E-07	8.15E-05
NO_2	4.70E-05	6.90E-05	4.50E-05
SO_2	1.00E-05	1.10E-04	3.20E-05

Table 12: Air emission equivalents (Zhu 2014).

Gases	Equivalents
CH_4	25 kg eq. CO_2
N_2O	310 kg eq. CO_2
NH_3	1.6 kg eq. SO_2
NO_2	0.7 kg eq. SO_2
NH_3	0.35 kg eq. PO_4
NO_2	0.13 kg eq. PO_4

CML data base

Methane (CH_4) capture in landfills can significantly reduce greenhouse gas emissions. According to Shahi (2023), with a 75% capture rate, only 25% of the previous emission value would be released. The total amount of greenhouse gases emitted would thus be reduced. These calculations are provided in Appendix 9.3.1.

The graph below illustrates greenhouse gas (GHG) emissions, including CH_4 and N_2O, from landfill and composting sites. The blue bar represents emissions from landfills without CH_4 capture, exhibiting the highest GHG emissions. In contrast, the orange bar represents emissions from landfills with CH_4 capture, and the gray bar signifies emissions from composting. Notably, composting demonstrates the lowest emissions among the three sources. Food waste composting is preferred over landfilling due to its lower greenhouse gas emissions, thereby helping to mitigate global warming (Figure 22).

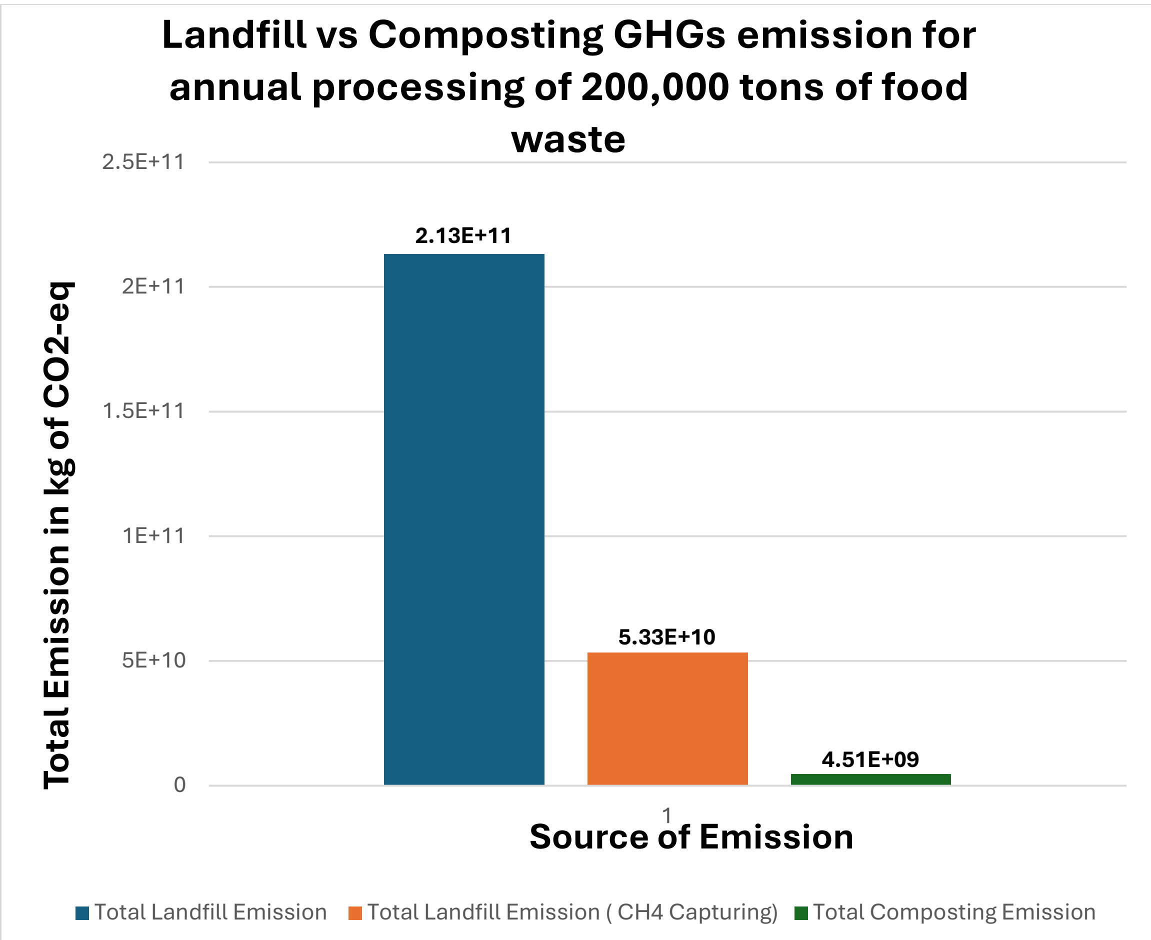

Figure 22: Landfill Vs Composting GHGs emission for annual processing of 200,000 tons of food waste

6.2 Wildlife

Compost can attract various wildlife species, particularly when there is a spread of odor. Wildlife such as rats, deer, bears, and flies often find compost piles as warm nesting places and sources of food (Krop 2020). A study conducted to monitor wildlife activity at a compost pile on the campus of Geneseo, NY, revealed that cameras captured various animals passing by the compost site, including cats, foxes, and birds (Krop 2020). While most animals captured were herbivores or scavengers, some animals view the compost pile as a hunting ground for other organisms. The presence of wildlife at compost sites can indicate poor management practices (Krop 2020). A study examining the frequency of coyote visits to compost piles and urban natural areas found a higher rate of coyotes visiting compost sites. These coyotes are more likely to exhibit visible signs of mange and other ectoparasite infections. Many compost piles contain high concentrations of mycotoxins, which can cause diseases and facilitate transmission to other organisms (Murray 2016).

There are some preventative habits that can be taken before building any composting facility that play a significant role in eliminating or reducing wildlife attraction. Existing physical barriers like fences and walls around the facility would help reduce the number of wildlife visitors. Controlling the compost moisture and ammonia odors would keep flies away from the compost area as ammonia is a known attractant for flies (Chardoul 2015).

6.3 Site (Neighbors)

The location of the composting area plays a significant role in its impact on the environment and surrounding areas. Several environmental issues, including groundwater and runoff pollution, odor, and noise can arise if proper criteria for selecting a composting site are not followed. According to the Composting Handbook, selecting a site with a slope of 0% to 5% and situated away from the 100-year floodplain can help protect groundwater and surface water leachate (Rynk et al. 2022). Additionally, it is crucial for the site to be distant from sensitive residential areas. Sensitive population areas include schools, hospitals, homes, and living areas. Composting facilities must be isolated from those areas where environmental justice is a relevant concern (Rynk et.al. 2022).

Measurements for determining distance often begin from the edge of the composting pad, although some regulations may specify measurements from the boundaries of the facility. Moreover, the type of feedstock being composted can influence distance measurements. Limitations and buffers must always be considered when selecting a suitable composting site, as outlined in the Composting Handbook. In open windrow composting, the active composting site should be greater than 1000 meters from the nearest residential area. Composting facilities should not be situated within 150 meters of drinking water supplies or surface water and should maintain a distance of 50 meters from bodies of water such as rivers or streams (Locke 2010). Table 13 illustrates common distances in the United States between composting activities and their surroundings. Although these distances may vary depending on city or state regulations, they collectively serve to protect the environment. Additionally, the composting facility must be 3 km away from airports, as most composting facilities that handle food waste attract a variety of wildlife that might pose hazards to the aircraft (FAA 2007). Adhering to these distance regulations ensures a safe living environment for residents, shielding them from unpleasant odors, noise, and polluted water.

Table 13: Common minimum setback in the United States for composting activities (Rynk et al. 2022)

Sensitive land use	Minimum separation distance (m)	Minimum separation distance (ft)
Property line	15–30	50–100
Residence or place of business	60–150	200–500
Private well or other potable water source	60–150	200–500
Wetlands or surface waters (streams, ponds, lakes)	30–60	100–200
Subsurface drainage pipe or drainage ditch discharging to a natural water course	8–10	25–30
Water table; (seasonal high)	1–2	2–6
Bedrock	1–2	2–6

6.3.1 Grading

Land grading is a crucial step to reaching good land topography and avoiding environmental issues. A land slope of between 0% to 5% is recommended to achieve a good positive drainage system. If the slope of the site is above 5% it could cause stormwater and runoff management challenges, muddy the site, and increase the feedstock materials' level of moisture. A proper drainage system is required which starts from choosing the site based on soil and land topography. Composting site development items that help control the drainage and runoff include berms, infiltration areas, and sedimentation and filtration devices (Rynk et.al. 2022).

6.4 Odor

Odor generation in composting facilities occurs due to the anaerobic decomposition of organic materials. Most odors are feedstock-related, but several arise from the process itself. For example, hydrogen sulfide, a compound with the odor of rotten eggs, is produced under anaerobic conditions (Rynk et al. 2022). During the decomposition process of organic materials, bioaerosols and VOCs are also produced (Ward 2018). Facility management, oxygen level, temperature, site selection, and types of feedstocks can all play significant roles in odor production. For example, compost temperature has a major impact on odor emissions, either directly or indirectly. Overheated compost piles tend to produce more odor compared to cold compost piles (Rynk et al. 2022). Exposure to compost odors is offensive and might have health implications for nearby residents and can attract wildlife to the facility. According to Ward (2018), a study conducted in various locations showed how odor emissions impact residents and cause various diseases (Table 14).

Poor processing of organic feedstock can emit 50 to 200 times more odor compared to a well-designed process. To minimize and control odor emissions from compost facilities, several strategies help reduce or eliminate odor generation. Minimizing odor from the beginning of the process by mixing materials off-site, following handling methods (first in, first out), and adding wood or other alkaline materials to mitigate the smell are effective strategies (Rynk et al. 2022). Furthermore, maintaining a proper balance of aeration, pH, moisture, and temperature would manage odor generation. Additionally, managing stormwater at the site can reduce odor generation. These methods are more efficient and cost effective than capture technologies. Capturing methods include bio- and fabric covers, pile surface irrigation, and enclosed processing areas. It is recommended in the site design to have an indoor pre-processing area and have a bio-cover on top of the windrow.

Table 14: Studies on health impacts to residents from compost emissions (Ward 2018)

Location and Study	Odour Measure	Increased Risk of Symptoms
Finland – waste treatment centres with composting plants.16	Residents <1.5 km vs. 3 or 5 km	cough/phlegm, nose irritation/stuffy nose, hoarseness/dry cough, fever/shivering
	Perceived Odour vs. none	hoarseness/dry cough, headache, diarrhoea
	Odour Annoyance vs. none	unusual shortness of breath, eye irritation, dry throat, toothache, unusual tiredness, fever/shivering, joint pain, muscular pain
Germany – large-scale composting site.6	<200 m from site, highest (to >105 CFU/m3) bioaerosols vs. near background levels	shortness of breath (following exertion and while at rest), bronchitis, coughing (waking up or on rising/during the day), sore eyes, diarrhoea, excessive tiredness, shivering
	Odour annoyance vs. none	Smarting eyes, itchy eyes, joint trouble, muscular complaints

6.5 Noise

Most operations involved in the composting process can generate significant noise levels that may adversely affect the surrounding environment and nearby communities. This noise is considered an environmental concern that requires mitigation and control measures to maintain a natural noise level. The primary sources of noise in composting facilities are the process machines, including shredders, turners, aerators, and other vehicles. According to OSHA, the maximum allowable noise exposure for an employee over an eight-hour period is approximately 90 decibels (dBA). High noise levels can lead to stress and psychological effects in humans and disrupt wildlife and their ecological systems (Rynk et al. 2022). To mitigate the impact of high noise levels on employees and nearby residents, several measures must be implemented. Regular equipment maintenance is essential to prevent excessive noise caused by malfunctioning parts. Selecting composting equipment with lower noise emissions designed for quieter operation is also crucial.

Site selection and modification can contribute to noise reduction. There are two main types of barriers including natural such as trees and dense vegetation and artificial such as solid fences and walls (Figure 23). The barriers are extremely helpful in isolating the facility from its surroundings and keeping other environmental impacts away. Natural barriers are more effective and preferred compared to artificial ones due to their contribution to air circulation, enhanced site visibility, and low cost (Figure 23) (Rynk et.al. 2022). Additionally, employees should be provided with appropriate personal protective equipment for hearing protection and must adhere to OSHA standards regarding noise exposure. Building a positive relationship with nearby residents is vital. This can be achieved by providing them with a contact number to report noise complaints and collaborating to identify sensitive times when they prefer composting operations to cease (Chardoul 2015).

Figure 23: A row of fast-growing poplar trees and more slowly growing evergreen trees (Rynk et.al. 2022)

7 Recommendations

7.1 Phases

With Hamilton County's population and number of townships, it is recommended to facilitate a phase plan. This roll-out plan mimics pilot programs from New York City and Minneapolis and promotion in schools like Franklin County, Massachusetts.

New York City has launched the largest composting roll out program in the United States. That roll out program started with a successful pilot in Queens (Ford 2022). New York City chose Queens because it is the most diverse township in the city. There are areas with large yards and multifamily units. Queens was also successful because residents did not have to opt in. Residents could use any bin they chose or could request a bin from the New York City Department of Sanitation (DSNY). The pilot proved successful when three times the amount of organic waste was collected compared to other pilot studies the DSNY implemented in the past. Minneapolis, with a population of 400,000, introduced a pilot program to their residents in 2016. Wastedive reported that “43% of eligible single-family homes and small multi-unit buildings” opted into the program. The city anticipated a 40% participation. To fund the pilot, every resident had a minor increase in their monthly bills (Rosengren 2017). Extensive education was provided to any resident who opted into the program (Pierron 2022). On average, only about 0.5% of material was contaminated (Rosengren 2017), but if there is contamination in a bin the waste haulers will leave a tag and not take the waste (Pierron 2022).

A comprehensive study of composting strategies in various counties of Massachusetts offered several instances of successful drop-off and pick-up. The community of Franklin County, MA, was shown to have had a strong record of engagement with municipal composting programs and drop-off programs. Despite Franklin County’s median income being $57,307, which is much lower than the state median of $74,167 (U.S. Census Bureau 2019), its public participation in providing composting materials is remarkably high. Franklin County’s public outreach efforts and culture of composting and food waste collection contribute to the active contributions from its community. A notable statistic from this study was that all 25 public schools in Franklin County practice food waste separation.

Additionally, the town of Dover, MA analyzed the success of its curbside pick-program. In Dover, curbside pickup for compost is conducted weekly for no cost. Here, residents must contact the program to enroll and must purchase their own pails or bins from the Dover transfer station to store their food scraps. Statistics of this program displayed that 230 families were enrolled in the curbside collection program in 2019, and that 57.2 tons of food waste were collected and composted from this program in 2017. Although Dover seemed to have a high emphasis on the education of composting and its importance, it should be noted that Dover has a high median housing income. With Dover being a wealthy region, it allows for the funding of a free curbside food waste pick-up program (Chia Yan Min 2019).

A recommended phase program is represented in Figure 24.

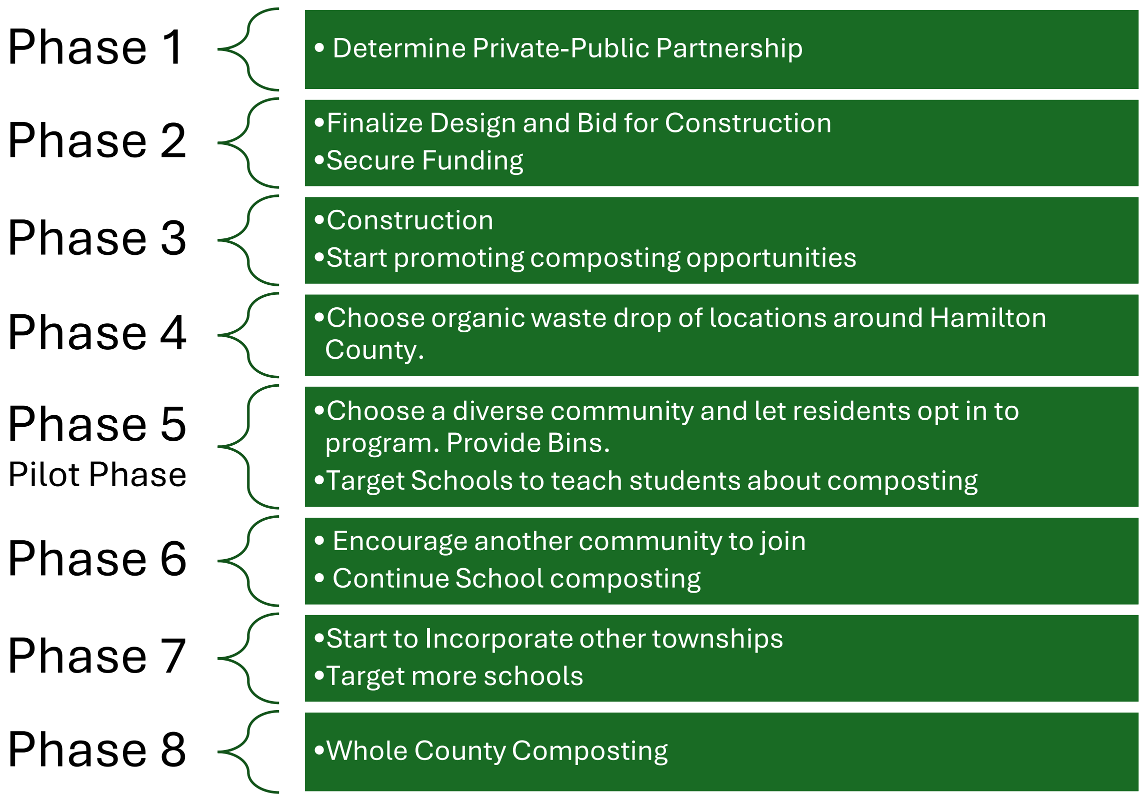

Figure 24: Recommended Phase Program (ECOlibrium)

Phase 1:

Hamilton County presented an interest in a public-private partnership (P3). A P3 is a "collaboration between a government agency and a private-sector company that can be used to finance, build, and operate projects" (Brown and Kazel 2024). The private role is to finance the project and participate in designing, completing, and implementing the project. The public role is to provide payments, ensure goals are being met, and monitor compliance. There are four types of P3: Build-Operate-Transfer, Build-Operate-Own, Design-Build, and Buy-Build-Operate. In a build-operate-transfer (BOT) agreement, the government gives the public sector the operations and construction of a project for a set time. After a contracted time, the facility is given back to the government. A build-operate-own agreement is similar to the BOT agreement, but the private company does not have to give back the facility. A design-build project is when the government has a private entity design and construct a project. The public side then can choose to operate the facility or find a company to run it. Lastly, the buy-build-operate agreement is when the public entity sells the constructed facility to a private entity (Brown and Kazel 2024).

Phase 2:

Phase 1 and 2 may be completed simultaneously. Phase 2 of a composting problem would be to finalize the design and bid for construction. Hiring a reputable contractor is necessary to ensure all parts of the plan are executed correctly.

Phase 3:

During the construction, Hamilton County will promote their goals in reducing food waste to residents. This initiative is ideally demonstrated through online materials, at large public events, on the news, etc.

Phase 4:

Once construction is near completion, it is recommended that the county choose compost drop off locations in each community. The residents that choose to bring their organics would likely be interested in the process. The waste will also likely be exceptionally clean.

Phase 5:

It is recommended that the fifth phase is a pilot program in a diverse housing community. A diverse community means a place where there are residents in apartment buildings, but also residents with large yards. While the county cannot mandate a waste collection service upon a community, they can provide the facts and resources to encourage a community to participate. Once a community has opted in, bins should be provided for residents and education must commence. Implementing composting programs at schools and teaching kids the proper way to practice compost promotes informational dispersion in their homes.

Phase 6:

During phase 6, other townships should be included in the composting program. Bins and school participation should be continued.

Phase 7:

By phase 7, the whole county should be participating in organic waste diversion. Education should be consistent with high communication from the facility.

7.2 Education

7.2.1 Public Education

Educating the public on the composting process and proper separation of waste when throwing away organics is imperative to receive a proper feedstock. According to an interview with Ryan Green, co-founder, and lead composter at Happy Trash Can Composting in Montana, public education is essential in controlling and limiting contamination (Personal Communication 2024). A widespread education program would allow for contamination to be minimized at the source, as residents would be fully informed on what waste is considered compostable. Additionally, educating the public would increase residential turnout and participation in programs, as this would provide the community with clear instruction and incentives for managing organic waste.

Implementation of a proper education plan is necessary to reach the community and to properly inform the public. Franklin County, Massachusetts, exhibited all 25 public schools within its county practicing food waste separation due to an educational plan being implemented within their schools (Chia Yan Min, 2019). This also potentially increases community participation outside of the schools, as the children attending the schools may bring home their food-separation practices, therefore educating their families on the importance of composting. Hosting and providing community workshops for its members to get hands-on learning with compost could be an effective way to educate the public. Utilizing social media platforms to inform the public could be effective as well, as this could provide information on the importance of composting, as well as pictures and videos of the processes themselves. Clearly labeled instructions would also be included with each bin, as this would provide a clear guide on what organic waste residents should include in their collection bins, reducing the risk of contamination.

7.2.2 Industry Education

Industry education is also necessary to expand the composting market in Hamilton County. Industry education will help promote the benefits of composting and its products (Table 15).

Jessica Anderson from A1 Organics Composting in Colorado provided insight on the composting marketability for farmers in Colorado (Personal Communication, 2024). It was stated that there is a general stigma about using compost from farmers across Colorado. Properly educating farmers on the available nutrients in compost would increase the willingness of agricultural organizations and groups to utilize compost for their products. During ECOlibrium's research, a list of companies and groups around Hamilton County that could benefit from the facility's finished compost was created (Table 15). Composting uses include agriculture and horticulture, landscaping and nursery, vegetable and flower gardens, sod production, roadside projects, wetlands creation, green infrastructure, soil and land remediation, and stormwater management. This list of companies are suggested as potential clients to educate about the benefits of compost and to potentially sell the finished bags of compost to.

Table 15: Compiled list of potential clients and customers for education and compost purchasing

Composting Purpose	Company/Group
Agriculture/horticulture	ADM Cincinnati
Agriculture/horticulture	CGB Enterprises Cincinnati
Agriculture/horticulture	Cargill Cincinnati
Agriculture/horticulture	Bartlett Tree
Landscape/nursery	Garden Path Landscaping
Landscape/nursery	Schill Grounds Management
Landscape/nursery	K&R Landscaping
Vegetable and flower gardens	Civic Garden Center
Sod production	Motz Turf Farms
Sod production	Green Prairie Turf
Sod production	Turpin Sod Farms
Roadside projects	City of Cincinnati
Roadside projects	Ohio DOT Cincinnati
Roadside projects	Eastern Corridor Cincinnati
Wetlands creation	Clermont Shor Park Wetland Restoration
Green infrastructure	City of Cincinnati
Green infrastructure	MSD
Green infrastructure	Green Corps Cincinnati
Soil remediation	City of Cincinnati Brownfield Redevelopment
Land reclamation	City of Cincinnati Brent Spence Bridge Corridor
Stormwater management	Strand Associates Lick Run Greenway
Stormwater management	Stantec Lick Run Greenway
Stormwater management	City of Cincinnati Stormwater Management Utility (SMU)

7.3 Funding

The use of government funding through various grants will allow Ohio to grow their compost infrastructure. There are various funding opportunities and sources that Hamilton County can pursue for this proposed composting facility. The larger funding opportunities are offered on a federal level. Smaller grants and funding opportunities are offered on the state level. Hamilton County can apply for these grants and use them for costs related to composting infrastructure.

One of the large sources of funding is the USDA Office of Urban Agriculture and Innovation Production who offers funding under the Composting and Food Waste Reduction cooperative agreements. The City of Cleveland received $340,961 from the USDA as a Compost and Food Waste Reduction cooperative agreement ("Cleveland awarded $340,000 USDA grant for composting and food waste reduction project | City of Cleveland Ohio" n.d.). Cleveland will be utilizing these funds to help the city expand residential compost drop-off locations, increase waste diversion and accessibility to compost, and provide subsidized services for SNAP-eligible households.

Another source for funding is through the Climate Pollution Reduction Grants from the EPA. These grants are being awarded to multiple industries in an effort to reduce GHG emissions. The CPRG provides up to $5 billion in grants to states, local governments, and tribes ("Priority Resiliency Plan" 2024). The State of Ohio recently addressed composting as one of its goals in its Priority Resiliency Plan to receive funding via this grant for multiple sectors.

8 Conclusion

Overall, a large-scale composting facility is not only feasible, but can be very successful. Hamilton County would be able to construct an organic waste composting site for 200,000 tons per year for the estimated costs of $23.7 million in capital and $5.8 million in yearly operating cost. The site's breakeven point was projected to occur after 5 years. The site should operate with a covered aerated windrow system containing 526 windrows that are 75 ft long and 22 ft wide. These windrows will reside on a compost pad spanning 32 acres. The entire site including the receiving area, equipment and office building, receiving and pre-processing building, curing area, and retention pond, would bring the size of the site to 55 acres. In case of available space restrictions, the same process produces a smaller footprint using a smaller feedstock.

Residential composting will not be successful without proper education to the residents and the market that will be using the compost. Additionally, the compost facility needs to be maintained by trained staff to ensure that ideal composting conditions are met throughout the windrow. Lastly, it is imperative that the compost meets regulations for the success of the facility.

9 Appendices

9.1 References

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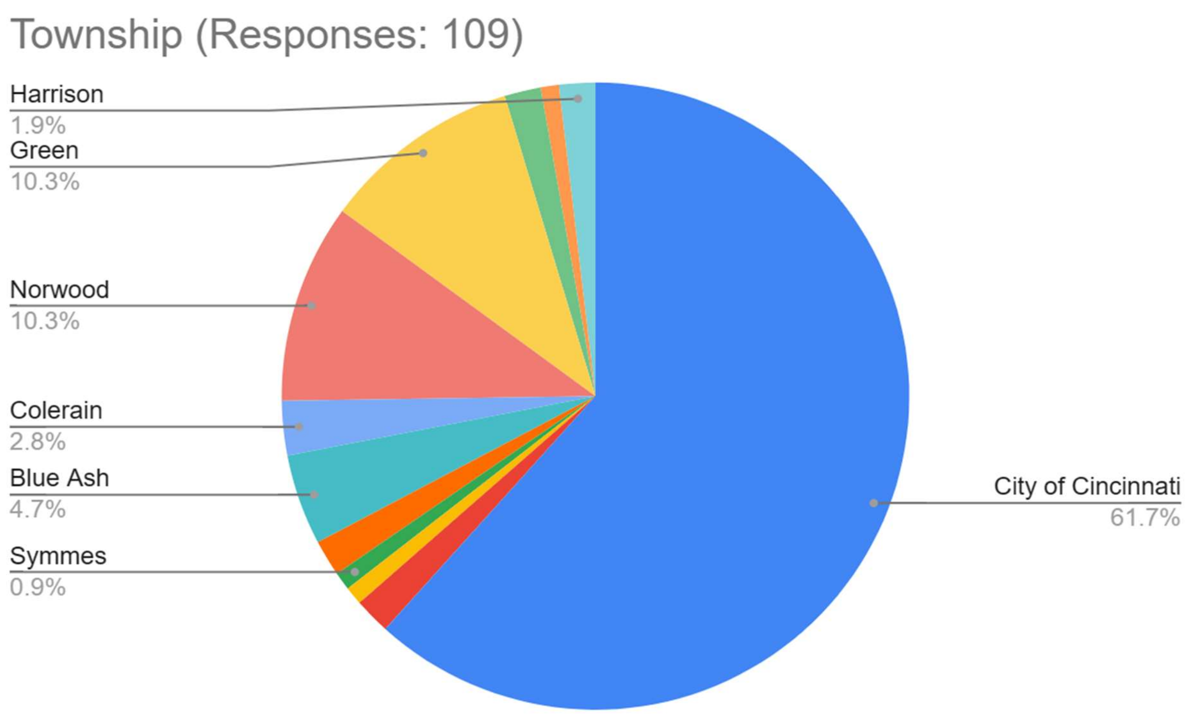
9.2 Google Form Questions and Responses

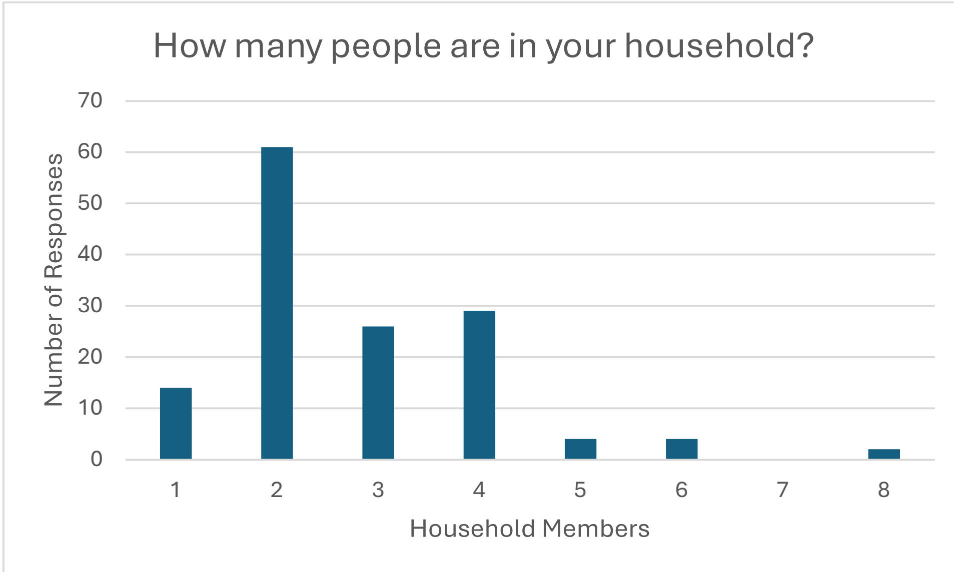
9.2.1 Name? (Responses: 71)

Names will be provided upon request.

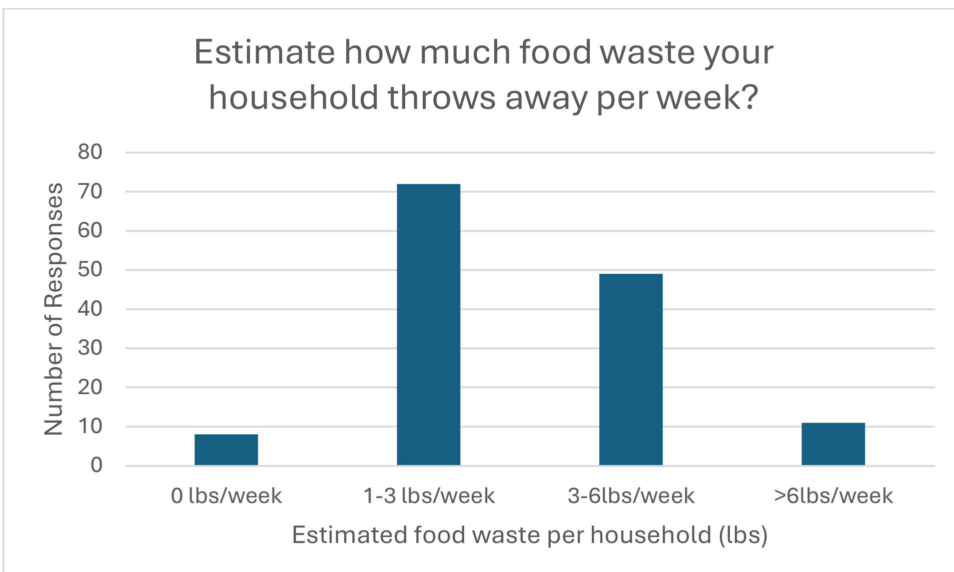
9.2.2 Neighborhood? (Responses: 109)



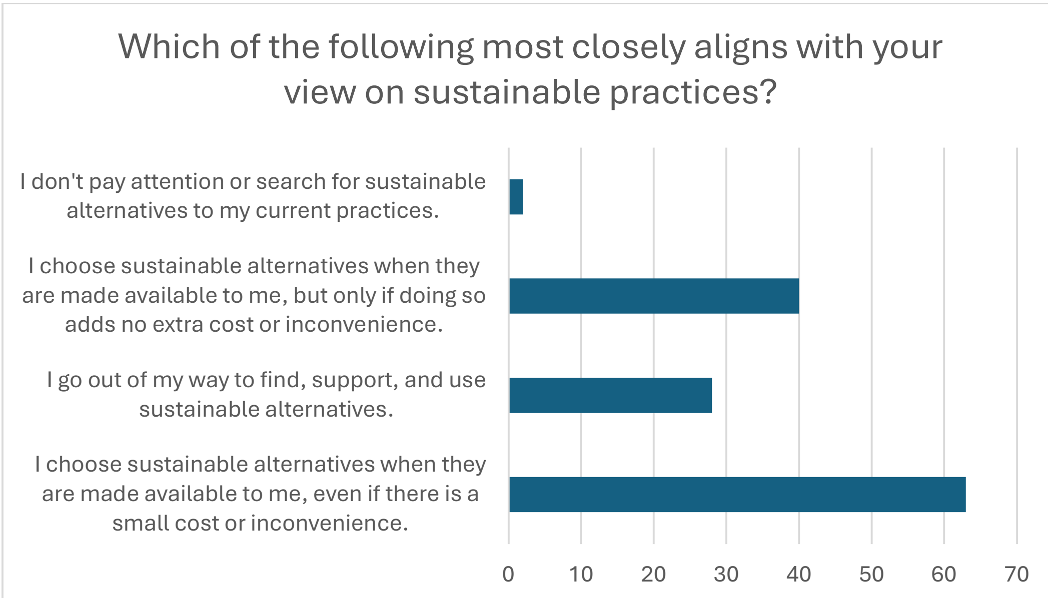
9.2.3 How many people are in your household? (Responses: 140)



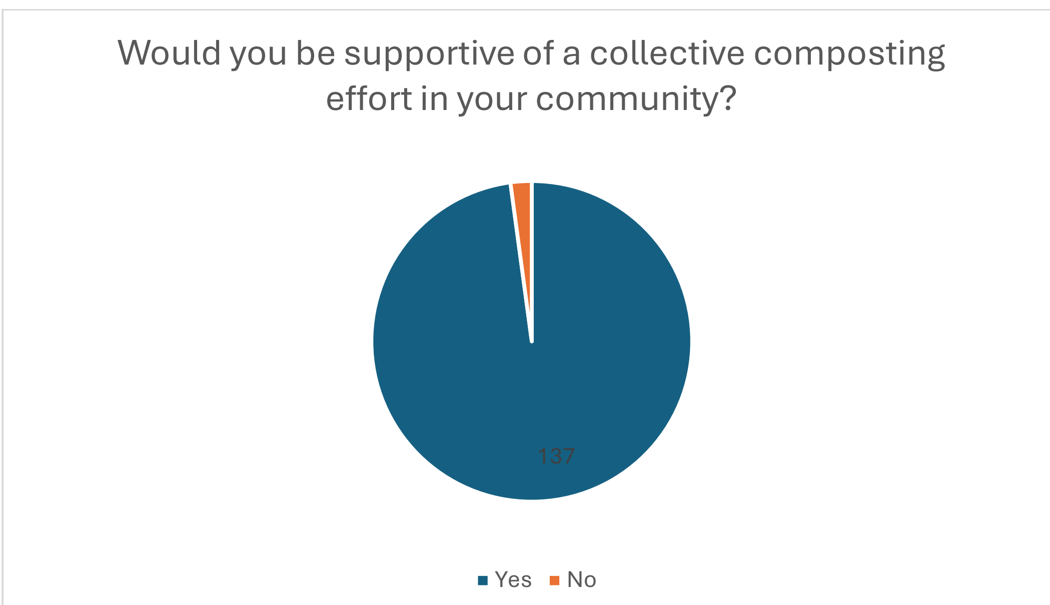
9.2.4 Estimate how much food waste your household throws away per week? (Responses: 140)



9.2.5 Which of the following most closely aligns with your view on sustainable practices? (Responses: 133)



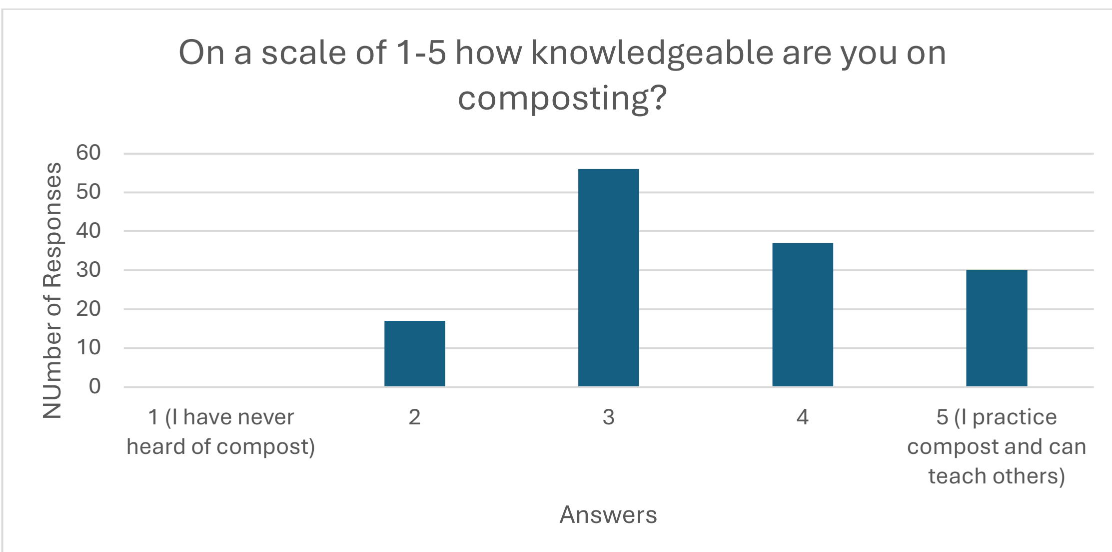
9.2.6 Would you be supportive of a collective composting effort in your community? (Responses: 141)



9.2.7 What are your reservations or preferred alternatives to reduce food waste? (Responses: 141).

Response	# of Responses
I am concerned about a decrease in property value in my neighborhood if a	9
I am concerned about how much effort would have to get put into it and whether the results would be beneficial enough to the community to make it worth it.	1
I am concerned about potential competition with food donation and animal feed	5
I am concerned about potential health risks from compost or compost byproducts	5
I am concerned about potential lack of community involvement or communication	39
I am concerned about the potential costs of a collection bin or other waste collection cost	36
I am concerned about animals.	2
I am concerned about odor and/or noise from a composting site in my	23
I have no reservations.	4

9.2.8 How Knowledgeable are you on composting (Responses: 140)



9.2.9 Do you have any other thoughts to share on composting or food waste? (Responses: 65)

Responses
composting is great for Hamilton county. I am so excited
Compost much of our own waste at home. Wouldn't want to pay for a service.
We have a drop off in Northside that I just joined, which is nice. But a pickup would be even better.
There is a paid service called Compost Now that covers this area, but they charge for pick and up and otherwise you have to take them the bin.
As homeowners with a yard, we compost for our own use, but there are a lot of apartments around us and I think it'd be great if they had the opportunity to get rid of food waste in a more responsible way.
We don't even have a garbage disposal, put all scraps in milk cartons - have tried composting but our urban yard is not ideal for sun/size.
I currently compost through Queen City Commons, but I think it would be more accessible if it was more widely available & cheaper/free.
Wyoming has a community location for compost dropoff, but I find that the 10gal bucket we use fills up and we don't always have the time to drop off when it's full. Having a larger bin and curbside would mean 100% composting for us. (Instead of 25-50%)
Queen City Compost was once looking at a pilot program in Northside involving a subscription service and centralized collection points.
We take our compost to Queen City Compost and love what they do, but curbside would be so convenient
We need this!!! They've been doing this in California for years. All my friends who live out there have a green waste can, which is all compost! We had a compost in our backyard for years but I couldn't keep my dogs, and other wildlife out of it and had to abandon. I would absolutely love to see this!
Don't think out household would generate enough compostable material that would require a weekly pickup

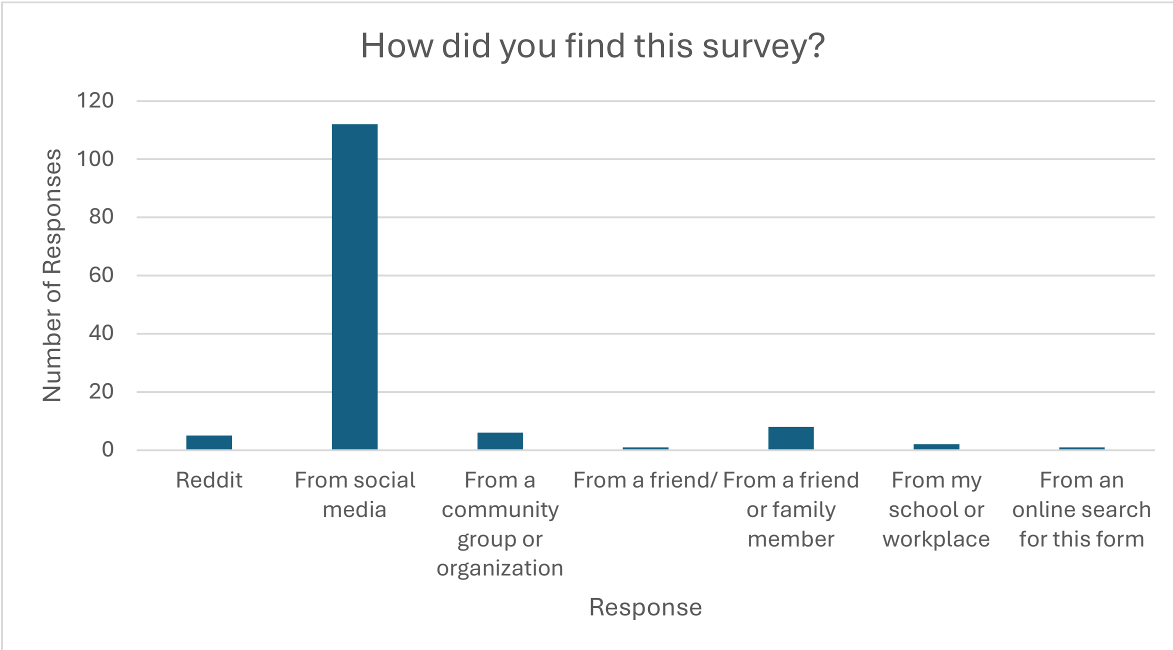
I hope you know about the "Make Soil" initiative here in Cincinnati. A city employee is here at our College Hill rec center every Tuesday afternoon 3p-5p, to collect compost for the bio-reactor at the Rec Center. I save all my compostable kitchen scraps and drive it over to the Rec Center about every other week. As a single person very minimal "scratch-cook," I generate about 5-6 lbs. a month of compostable scraps. I can forsee a ton of problems with individual bins at single-residence homes. Hope you are talking to a lot of home OWNERS to assess those risks. I would definitely NOT mix FOOD SCRAPS with compostable yard-generated compost into a single bin collection system. MakeSoil does not accept yard compostable materials that may be contaminated with chemical applications such as Round Up type products. While I don't use Round Up anymore, my plants I buy at local garden centers MAY have been commercially grown with nonorganic methods, so annuals, shrub cuttings etc. - I have no way to compost that material at the MakeSoil site at Rec Center. Also from experience with a 2-bin system years ago in our suburban (Oxford) yard, I learned there is a fair amount of maintenance associated. So I quit composting yard stuff since my single years. I would much more rather see a multiple NODE SYSTEM of collection points, more accessible than what I have access to right now. Makes more sense to set up the regular collects from the multi-nodes versus a very expensive collection and NECESSARY SORT from single household locations. GOOD LUCK WITH YOUR PROJECT. Thank you for your research.
Need to make it easy, not gross to handle, and cheap or free for people to do it
I think this is a great idea!
I would be great if this were a citywide service available to all citizens. The cost of private composting makes it unaffordable to many.
I live in Mt. lookout and there is no local affordable option, I have to travel to compost for a reasonable price.
I believe composting should be standard practice
I think yard composting is a great alternative that people reject b/c of concerns about odor & attracting rodents.
None at this time
I think if composting were made more readily available I would be more inclined to participate, but specifically when living in a city trying to figure out how to get my compist collected poses as the largest challenge.
n/a

We compost and home and are please with the resulting product. I love the idea of community composting, but I think the educational process will be an uphill battle.
Where & what type will composting effort be? How will waste be collected?
love the work your capstone group is doing!
I save all my food scrapes and throw them in the woods for critters to eat
No
If compared water could be made available to purchase for garden enrichment, that would be a plus! (Maybe helping defray the cost of the program)
I already compost at home, so I probably would not utilize a bin service but would encourage others too. My concern would be a non-zero amount of folks still can't get the right items in recycling bins so the odds of folks using composting bins right is also low
I think it’s a great idea and if concerns can be addressed would be a good addition
We need to do it
I've been composting since childhood - in the past, diverting fresh scraps to chicken feed while composting the rest with various slow/fast methods. We now process all waste organics, including animal products (with bones, which can later be buried or converted to char), grease and compost-safe/nonrecyclable paper and cardboard, with BSFL (black soldier fly larvae/Hermetia illucens) from spring until single digit temperatures in mid/late winter. BSFL are remarkable helpers, eating about twice their own mass per day, self-cleaning, quiet, and repellent to other decomposers while effectively managing odor. In addition to composting, I strongly support food waste prevention, and a straightforward, tax-supported municipal composting system is necessary to support both individual households and small nutrition support organizations that are often saddled with unusable and excess food from diversion sources. The Tikkun model is wonderful, but not an option for many orgs serving dense communities. BSFL process most organic waste within 24 hours while dramatically reducing bulk (estimated at 90% - ime, well over) and methane generation. The system I would most like to see would host BSFL to process organics and then feed their leachate/frass into a biodigester to harvest remaining energy. This would divert far greater nutrient flows from landfill, eliminate much uncertainty for front-end users, and reduce contamination concerns that plague traditional composting systems.

STOP!
I'd be excited about the option in Hamilton Co.
I currently pay for Rumpke to pick up my garbage and have to take my recycling to a local community bin. Would Green Township residents have access to something like that (a free option) or would we have to pay extra to Rumpke?
i would love to compost on an individual level and on a community level just don't know how to get started
I have considered starting a similar program, I hope your capstone is a success!
Well aware of the problems of leachate in landfills and feel people need to be educated no matter how gross.
It's gold! I'm keeping mine for myself! But on other cities they have this service and it's great for apartment dwellers or people who don't grow their own food and need to amend their soil
We need to do much more of it.
It would be great if ppl could go to the collection site and pick up dirt once the items have been composted
I did a study abroad in Ireland and they had compost bins in university housing. If UC doesn't have that already, that could be a good thing to try to start as well! I would love to just have a bin I can throw compost in without having to have the land dedicated to my own pile.
Institutional and business partnerships offer low-hanging fruit! If you are given the opportunity to compost at work, and shown how it works, it'll be more likely that at least a fraction of those employees bring what they learn home, and compost there as well (Provided there are services in place to support them at home as well).
Would like an easy, free, not smelly solution that DOES NOT draw animals, esp. raccoons
I love to be sustainable whenever I can.
I think everyone should do it
I believe many households (including ours) maintain a compost in their own yard. I think this would be a great initiative for people who live in apartments or homes without outdoor space.
I think this a great idea, especially if there can be a way to receive the compost once it's ready for gardening. We are great about composting on our own in the summer but less so in the winter, this would be a nice way to continue with it.
Please do this.

Where would the compost go- who would use it for what?
Great idea, use the created compost in public areas and sell
Currently, in my neighborhood, we have trouble with Rumpke consistently leaving both regular trash and recycling behind. There seems to be no rhyme or reason to why some trash/recycling us picked up or left behind. I would not want a third bin that have to drag back in because it was left behind.
We backyard compost almost all our food waste but make more scraps than we can really compost or use with the space we have so this would be a beneficial complementary program for us.
Would love leaf and yard waste collection to get composted and would love to be able to get soil for gardening
No thoughts other than I love this idea! You probably know already, but there are some existing compost drop off sites around (for a cost), though I can’t remember exactly where they are. They could be a good partner, though!
A city progressing includes a city wide compost! It’s cyclical… the compost can be used in city projects and be sold back to the community.
I would like an easy system for composting on a neighborhood level.
Fully supportive
If it is suitable for composting shouldn't it be suitable for yard waste pickup? I don't get the need for a composting pickup unless you are going to do bokashi composting which can deal with anything.
Would the community have access to the compost for gardening?
I would love for this to happen!
There should be a category above, asking if we already compost, which we do.
We did a dropoff compost program for a while but having to drive our compost to drop it off each week got to be too much once we had our second kid. We would love another composting option.
Food waste is obscene in this country.
Would love to exclude meat

9.2.10 How did you find this survey? (Responses: 135)



9.3 Calculations

9.3.1 Greenhouse gas emissions calculations for landfill and composting process

For the landfill:

CH_4: 47 kg CH_4 per ton of food waste (FW) * 25 kg eq. CO_2 = 1175 kg CH_4 in CO_2 eq

N_2O: 0.00036 kg N_2O per ton of FW * 310 kg eq. CO_2 = 0.1116 kg N_2O in CO_2 eq

Total emission = 1175 + 0.1116 * (181,436,948 kg - food waste generation)

= 2.13209 × E+11 kg CO_2 eq/ kg FW

For Composting:

CH_4: 0.97 kg CH_4 per ton of food waste (FW) * 25 kg eq. CO_2 = 24.25 kg CH_4 in CO_2 eq

N_2O: 0.0021 kg N_2O per ton of FW * 310 kg eq. CO_2 = 0.651 kg N_2O in CO_2 eq

Total emission = 24.25 + 0.651 * (181,436,948 kg - food waste generation)

= 4.517961442 × E+09 kg CO_2 eq/ kg FW

If there is a 75% capture of CH_4 in the landfill, then only 25% of the CH_4 emissions would be released into the atmosphere. Therefore, the calculation for the total emission in CO2 eq from the landfill would be:

CH_4: 47 kg CH_4 per ton of food waste (FW) * 25 kg eq. CO_2 * 0.25 = 293.75 kg CH_4 in CO_2 eq

N_2O: 0.00036 kg N_2O per ton of FW * 310 kg eq. CO_2 = 0.1116 kg N_2O in CO_2 eq

Total emission = 293.57 + 0.1116 * (181,436,948 kg - food waste generation)

= 5.33174E +10 kg CO2 eq/ kg FW

9.3.2 Compost Site Components

9.3.2.1 Compost Pad (Vermont Method, Trapezoidal Windrows) - (Turned Windrow Composting n.d.)

Step 1	200,000	tons
	1	year
	4E+08	lbs/year
Step 2	1080	(lb/cyd)
	370370.4	cyd/year
Step 3	370370.4	cyd/year
	4	Ratio
	1481481	cyd/year additional feedstock
Step 4	1851852	Total cubic yards raw feedstock per year
Step 5	1851852	
	0.4	volume retained
	740740.7	Total cyd finished compost per year
Step 6 is unecessary		
Step 7	1851852	Total cubic yards per year raw feedstock
	0.21	Volume primary feedstock of total mix
	388888.9	cyd primary feedstock / year
Step 8		
	388888.9	cyd primary feedstock / year
	1080	lbs/cyd
	4.2E+08	lbs primary feedstock per year
Step 9	4.2E+08	lbs primary feedstock per year
	2000	lbs per ton
	210000	tons primary feedstock per year

Note: Skip Step 1 if already using pounds.

	Formula	Example
Step 1	( ) Tons Primary Feedstock /( ) Time Period X 2000 (Lbs/Ton) ( ) Pounds/( ) Time Period	(10) Tons Primary Feedstock/(Week) Time Period X 2000 (Lbs/Ton) (20,000) Pounds/(Week) Time Period
Step 2	( ) Pounds/( ) Time Period ÷ ( ) Primary Feedstock Bulk Density (Lbs/Yard³) ( ) Total Yards³ Primary Feedstock/( ) Time Period	(20,000) Pounds/(Week) Time Period ÷ (1,000) Primary Feedstock Bulk Density (Lbs/Yard³) (20) Yards³ Primary Feedstock/(Week) Time Period
Step 3	( ) Yards³ Primary Feedstock/( ) Time Period X ( ) Ratio Additional Feedstock to Primary Feedstock (By Volume, Typically 3-5) ( ) Yards³ Additional Feedstock/( ) Time Period	(20) Yards³ Primary Feedstock/(Week) Time Period X (4) Ratio Additional Feedstock to Primary Feedstock (By Volume, Typically 3-5) (80) Yards³ Additional Feedstock/(Week) Time Period
Step 4	( ) Yards³ Primary Feedstock/( ) Time Period + ( ) Yards³ Additional Feedstock/( ) Time Period ( ) Total Yards³ Raw Feedstock/( ) Time Period	(20) Yards³ Primary Feedstock/(Week) Time Period + (80) Yards³ Additional Feedstock/(Week) Time Period (100) Total Yards³ Raw Feedstock/(Week) Time Period
Step 5	( )Total Yards³ Raw Feedstock/( )Time Period X ( )% Volume Reduction (Assume 60% so use .4) ( )Total Yards³ Finished Compost/( )Time Period	(100) Total Yards³ Raw Feedstock/(Week) Time Period x (.4) % Volume Reduction (Assume 60% so use .4) (40) Total Yards³ Finished Compost/(Week) Time Period
	Formula	**Example**
Step 6	( ) Total Yards³ Finished Compost/( ) Time Period ÷ ( ) % Volume Reduction (Assume 60% so use .4) ( ) Total Yards³ Raw Feedstock/( ) Time Period	(40) Target Yards³ Finished Compost/(Week) Time Period ÷ (.4) % Volume Reduction (Assume 60% so use .4) (100) Total Yards³ Raw Feedstock/(Week) Time Period
Step 7	( ) Total Yards³ Raw Feedstock/( ) Time Period X ( ) % Volume Primary Feedstock of Total Mix (Typically 17-25% or .17-.25) ( ) Yards³ Primary Feedstock/( ) Time Period	(100) Total Yards³ Raw Feedstock/(Week) Time Period X (.2) % Volume Primary Feedstock of Total Mix (Typically 17-25% or .17-.25) (20) Yards³ Primary Feedstock (Week) Time Period
Step 8	( ) Yards³ Primary Feedstock/( ) Time Period X ( ) Primary Feedstock Bulk Density (Lbs/Yard³) ( ) Pounds Primary Feedstock/( ) Time Period	(20) Yards³ Primary Feedstock/(Week) Time Period X (1,000) Primary Feedstock Bulk Density (Lbs/Yard³) (20,000) Pounds Primary Feedstock/(Week) Time Period
Step 9	( ) Pounds Primary Feedstock/( ) Time Period ÷ 2000 (Lbs/Ton) ( ) Tons Primary Feedstock/( ) Time Period	(20,000) Pounds Primary Feedstock/(Week) Time Period ÷ 2000 (Lbs/Ton) (10) Tons Primary Feedstock/(Week) Time Period

Step 10	1851852	Total cubic yards per year raw feedstock
	260	Operational days per year
	40	days in active compost
	284900.3	Total cubic yards raw feedstock processessed
Step 11	284900.3	Total cubic yards raw feedstock processessed
	0.8	Blending shrink factor
	27	cfu/cyd
	6153846	Total cfu on active windrow pad
Step 12a	75	ft long
	156	Cross sectional area Trapezodial
	11700	Ft3 / windrow
Step 13	6153846	Total cfu on active windrow pad
	11700	Ft3 / windrow
	526	Windrows on active pad
Step 14	526	Windrows on active pad
	22	width
	11571.33	feet combined width of windrows
Step 15	524	work alleys
	3	ft width
	1571.909	Feet width of work Alleys
Step 16	11571.33	feet combined width of windrows
	1571.909	Feet width of work Alleys
	10	feet width of additional perimeter
	13153.24	Feet total pad width
Step 17	75	feet windrow length
	20	feet width additional perimeter
	95	feet total pad length
Step 18	13153.24	Feet total pad width
	95	feet total pad length
	1249558	ft^2 Total Active Pad Area
Conversions		
	1249558	ft^2 Total Active Pad Area
	43560	ft^2 / acre
	28.68591	Acres needed for composting pad

	Formula	Example
Step 10	( ) Total Yards^3 Raw Feedstock/( ) Time Period X ( ) # of Time Period ( ) in Active Composting ( ) Total Yards^3 Raw Feedstock Processed	(100) Total Yards^3 Raw Feedstock/(Week) Time Period X (32) # of Time Period (Weeks) in Active Composting (3,200) Total Yards^3 Raw Feedstock Processed
Step 11	( ) Total Yards^3 Raw Feedstock Processed X ( ) % Blending Shrink Factor (Assume 20% so use .8) X 27 (Feet^3 Per Yard^3) ( ) Total Feet^3 on Active Windrow Pad	(3,200) Total Yards^3 Raw Feedstock Processed X (.8) % Blending Shrink Factor (Assume 20% so use .8) X 27 (Feet^3 Per Yard^3) (69,120) Total Feet^3 on Active Windrow Pad
Step 12a	( ) Feet Windrow Length X ( ) Feet Windrow Height X ( ) Feet Windrow Width (Assume Height X 2) X .66 Cross Sectional Area (Assume .5 if Conservative) ( ) Average Feet^3/Windrow	(90) Feet Windrow Length X (6) Feet Windrow Height Feet X (12) Feet Windrow Width (Assume Height X 2) X .66 Cross Sectional Area (Assume .5 if Conservative) (4,277 or call it 4,300) Average Feet^3/Windrow
Step 13	( ) Total Feet^3 on Active Windrow Pad (Step 11) ÷ ( ) Average Feet^3/Windrow (Step 11a or 11b) ( ) # of Windrows on Active Pad (Round)	(69,120) Total Feet^3 on Active Windrow Pad (Step 11) ÷ (4,300) Average Feet^3/Windrow (Step 11a or 11b) (16) # of Windrows on Active Pad (Round)
Calculating the Width of the Pad		
Step 14	( ) # of Windrows X ( ) Feet Width of Windrows ( ) Feet Combined Width of Windrows	(16) # of Windrows X (12) Feet Width of Windrows (192) Feet Combined Width of Windrows
Step 15	( ) # of Work Alleys X ( ) Feet Width of Work Alleys ( ) Feet Combined Width of Work Alleys	(16) # of Work Alleys X (20) Feet Width of Work Alleys (320) Feet Combined Width of Work Alleys
Step 16	( ) Feet Combined Width of Windrows + ( ) Feet Combined Width of Work Alleys + ( ) Feet Width of Additional Perimeter ( ) Feet Total Pad Width*	(192) Feet Combined Width of Windrows + (320) Feet Combined Width of Work Alleys + (10) Feet Width of Additional Perimeter (522 or call it 530) Feet Total Pad Width
Calculating the Length of the Pad		
Step 17	( ) Feet Windrow Length + ( ) Feet Width of Additional Perimeter & Travel Lanes ( ) Feet Total Pad Length*	(90) Feet Windrow Length + (20) Feet Width of Additional Perimeter & Travel Lanes (110) Feet Total Pad Length*
Calculating the Pad Area		
Step 18	( ) Feet Total Pad Width X ( ) Feet Total Pad Length ( ) Feet^2 Total Active Pad Area*	(530) Feet Total Pad Width X (110) Feet Total Pad Length (58,600) Feet^2 Total Active Pad Area*
Calculating Curing & Storage Windrow Dimensions		
Step 19	( ) Total Yards^3 Raw Feedstock/( ) Time Period X ( ) # of Time Period ( ) in Curing and Storage ( ) Total Yards^3 Raw Feedstock Processed	(100) Total Yards^3 Raw Feedstock/(Week) Time Period X (26) # of Time Period (Weeks) in Curing and Storage (2,400) Total Yards^3 Raw Feedstock Processed
Step 20	( ) Total Yards^3 Raw Feedstock Processed X ( ) % Shrink Factor (Assume 60% so use .4) X 27 (Feet^3 Per Yard^3) ( ) Total Feet^3 in Curing and Storage Area	(2,600) Total Yards^3 Raw Feedstock Processed X (.4) % Shrink Factor (Assume 60% so use .4) X 27 (Feet^3 Per Yard^3) (28,080) Total Feet^3 in Curing and Storage Area

Sizing Your Composting Pad 10

9.3.2.2 Compost Pad (Vermont Method, Oval Windrows) - (Turned Windrow Composting n.d.)

Step 1	200,000	tons
	1	year
	4E+08	lbs/year
Step 2	1080	(lb/cyd)
	370370.4	cyd/year primary feedstock
Step 3	370370.4	cyd/year primary feedstock
	4	Ratio
	1481481	cyd/year additional feedstock
Step 4	1851852	Total cubic yards raw feedstock per year
Step 5	1851852	
	0.4	volume retained
	740740.7	Total cyd finished compost per year
Step 6 is unecessary		
Step 7	1851852	Total cubic yards per year raw feedstock
	0.21	Volume primary feedstock of total mix
	388888.9	cyd primary feedstock / year
Step 8		
	388888.9	cyd primary feedstock / year
	1080	lbs/cyd
	4.2E+08	lbs primary feedstock per year
Step 9	4.2E+08	lbs primary feedstock per year
	2000	lbs per ton
	210000	tons primary feedstock per year
Step 10	1851852	Total cubic yards per year raw feedstock
	260	Operational days per year
	40	days in active compost
	284900.3	Total cubic yards raw feedstock processessed
Step 11	284900.3	Total cubic yards raw feedstock processessed
	0.8	Blending shrink factor
	27	cfu/cyd
	6153846	Total cfu on active windrow pad
Step 12a	75	ft long
	138.2301	Cross sectional area semi-circle
	10367.26	Ft3 / windrow
Step 13	6153846	Total cfu on active windrow pad
	10367.26	Ft3 / windrow
	594	Windrows on active pad
Step 14	594	Windrows on active pad
	22	width
	13058.87	feet combined width of windrows
Step 15	592	work alleys
	3	ft width
	1774.755	Feet width of work Alleys
Step 16	13058.87	feet combined width of windrows
	1774.755	Feet width of work Alleys
	10	feet width of additional perimeter
	14843.62	Feet total pad width

Note: Skip Step 1 if already using pounds.

	Formula	Example
Step 1	( ) Tons Primary Feedstock /( ) Time Period X 2000 (Lbs/Ton) ( ) Pounds/( ) Time Period	(10) Tons Primary Feedstock/(Week) Time Period X 2000 (Lbs/Ton) (20,000) Pounds/(Week) Time Period
Step 2	( ) Pounds/( ) Time Period ÷ ( ) Primary Feedstock Bulk Density (Lbs/Yard^3) ( ) Total Yards^3 Primary Feedstock/( ) Time Period	(20,000) Pounds/(Week) Time Period ÷ (1,000) Primary Feedstock Bulk Density (Lbs/Yard^3) (20) Yards^3 Primary Feedstock/(Week) Time Period
Step 3	( ) Yards^3 Primary Feedstock/( ) Time Period X ( ) Ratio Additional Feedstock to Primary Feedstock (By Volume, Typically 3-5) ( ) Yards^3 Additional Feedstock/( ) Time Period	(20) Yards^3 Primary Feedstock/(Week) Time Period X (4) Ratio Additional Feedstock to Primary Feedstock (By Volume, Typically 3-5) (80) Yards^3 Additional Feedstock/(Week) Time Period
Step 4	( ) Yards^3 Primary Feedstock/( ) Time Period + ( ) Yards^3 Additional Feedstock/( ) Time Period ( ) Total Yards^3 Raw Feedstock/( ) Time Period	(20) Yards^3 Primary Feedstock/(Week) Time Period + (80) Yards^3 Additional Feedstock/(Week) Time Period (100) Total Yards^3 Raw Feedstock/(Week) Time Period
Step 5	( )Total Yards^3 Raw Feedstock/( )Time Period X ( )% Volume Reduction (Assume 60% so use .4) ( )Total Yards^3 Finished Compost/( )Time Period	(100) Total Yards^3 Raw Feedstock/(Week) Time Period x (.4) % Volume Reduction (Assume 60% so use .4) (40) Total Yards^3 Finished Compost/(Week) Time Period

	Formula	Example
Step 6	( ) Total Yards^3 Finished Compost/( ) Time Period ÷ ( ) % Volume Reduction (Assume 60% so use .4) ( ) Total Yards^3 Raw Feedstock/( ) Time Period	(40) Target Yards^3 Finished Compost/(Week) Time Period ÷ (.4) % Volume Reduction (Assume 60% so use .4) (100) Total Yards^3 Raw Feedstock/(Week) Time Period
Step 7	( ) Total Yards^3 Raw Feedstock/( ) Time Period X ( ) % Volume Primary Feedstock of Total Mix (Typically 17-25% or .17-.25) ( ) Yards^3 Primary Feedstock/( ) Time Period	(100) Total Yards^3 Raw Feedstock/(Week) Time Period X (.2) % Volume Primary Feedstock of Total Mix (Typically 17-25% or .17-.25) (20) Yards^3 Primary Feedstock (Week) Time Period
Step 8	( ) Yards^3 Primary Feedstock/( ) Time Period X ( ) Primary Feedstock Bulk Density (Lbs/Yard^3) ( ) Pounds Primary Feedstock/( ) Time Period	(20) Yards^3 Primary Feedstock/(Week) Time Period X (1,000) Primary Feedstock Bulk Density (Lbs/Yard^3) (20,000) Pounds Primary Feedstock/(Week) Time Period
Step 9	( ) Pounds Primary Feedstock/( ) Time Period ÷ 2000 (Lbs/Ton) ( ) Tons Primary Feedstock/( ) Time Period	(20,000) Pounds Primary Feedstock/(Week) Time Period ÷ 2000 (Lbs/Ton) (10) Tons Primary Feedstock/(Week) Time Period

	Formula	Example
Step 10	( ) Total Yards^3 Raw Feedstock/( ) Time Period X ( ) # of Time Period ( ) in Active Composting ( ) Total Yards^3 Raw Feedstock Processed	(100) Total Yards^3 Raw Feedstock/(Week) Time Period X (32) # of Time Period (Weeks) in Active Composting (3,200) Total Yards^3 Raw Feedstock Processed
Step 11	( ) Total Yards^3 Raw Feedstock Processed X ( ) % Blending Shrink Factor (Assume 20% so use .8) X 27 (Feet^3 Per Yard^3) ( ) Total Feet^3 on Active Windrow Pad	(3,200) Total Yards^3 Raw Feedstock Processed X (.8) % Blending Shrink Factor (Assume 20% so use .8) X 27 (Feet^3 Per Yard^3) (69,120) Total Feet^3 on Active Windrow Pad

	Formula	Example
Step 12a	( ) Feet Windrow Length X ( ) Feet Windrow Height X ( ) Feet Windrow Width (Assume Height X 2) X .66 Cross Sectional Area (Assume .5 if Conservative) ( ) Average Feet^3/Windrow	(90) Feet Windrow Length X (6) Feet Windrow Height Feet X (12) Feet Windrow Width (Assume Height X 2) X .66 Cross Sectional Area (Assume .5 if Conservative) (4,277 or call it 4,300) Average Feet^3/Windrow

	Formula	Example
Step 13	( ) Total Feet^3 on Active Windrow Pad (Step 11) ÷ ( ) Average Feet^3/Windrow (Step 11a or 11b) ( ) # of Windrows on Active Pad (Round)	(69,120) Total Feet^3 on Active Windrow Pad (Step 11) ÷ (4,300) Average Feet^3/Windrow (Step 11a or 11b) (16) # of Windrows on Active Pad (Round)

Calculating the Width of the Pad

	Formula	Example
Step 14	( ) # of Windrows X ( ) Feet Width of Windrows ( ) Feet Combined Width of Windrows	(16) # of Windrows X (12) Feet Width of Windrows (192) Feet Combined Width of Windrows
Step 15	( ) # of Work Alleys X ( ) Feet Width of Work Alleys ( ) Feet Combined Width of Work Alleys	(16) # of Work Alleys X (20) Feet Width of Work Alleys (320) Feet Combined Width of Work Alleys
Step 16	( ) Feet Combined Width of Windrows + ( ) Feet Combined Width of Work Alleys + ( ) Feet Width of Additional Perimeter ( ) Feet Total Pad Width*	(192) Feet Combined Width of Windrows + (320) Feet Combined Width of Work Alleys + (10) Feet Width of Additional Perimeter (522 or call it 530) Feet Total Pad Width

Calculating the Length of the Pad

Step 17	75	feet windrow length
	20	feet width additional perimeter
	95	feet total pad length
Step 18	14843.62	Feet total pad width
	95	feet total pad length
	1410144	ft^2 Total Active Pad Area
Conversions		
	1410144	ft^2 Total Active Pad Area
	43560	ft^2 / acre
	31.93789	Acres needed for composting pad

Step 17	( ) Feet Windrow Length +( ) Feet Width of Additional Perimeter & Travel Lanes ( ) Feet Total Pad Length*	(90) Feet Windrow Length +(20) Feet Width of Additional Perimeter & Travel Lanes (110) Feet Total Pad Length*
Calculating the Pad Area		
Step 18	( ) Feet Total Pad Width X( ) Feet Total Pad Length ( ) Feet² Total Active Pad Area*	(530) Feet Total Pad Width X(110) Feet Total Pad Length (58,600) Feet² Total Active Pad Area*

58,600 ft² is the area of the active pad

9.3.2.3 Compost Pad (ECOlibrium Method, Trapezoidal Windrow)

Total Waste (tons/ yr)			Chosen Height (ft)		Chosen Base (ft)			Chosen Base 2 (ft)	Cross Sectional Area (ft2)	
200,000	**Step 1**		8		22			17	156	**Step 6**
lb per year										
400000000	**Step 2**			Total length of windrows (per day taken in)			**Step 7**			
				986.1933 ft						
lb per day										
1538461.538	769.230769	**Step 3**		Windrow Length			**Step 8**			
				75 ft						
Density of Compost										
40	(lb/cfu)	**Step 4**		New Windrows per day						
				13.14924						
		Step 5			1 acre = 43560 ft^2		**Step 9**			
Volume of Compost (ft3)		"Greens" Volume per day								
153846.1538		38461.54			perfect square means that the length					
					208.7103 ft					
Volume of Compost (cyd)		"Browns" Needed Volume per day								
5698.005698		115384.6			25	Total Windrow accomidation width				
						(Width + 2 * Distance Between)				
Distance between windrows					2.782804	Total Windrows allowed per acre (length)				
3	ft				8.348413	Total windrows allowed per acre (width)				
					Total Windrows per Acre					
					23.232					
							Step 10			
				Amount of days from Compost to exit						
				40						
				Amount of new windrows for compost life						
				525.9698						
				Amount of Acres needed for 40 day lifespan						
				22.63988						

9.3.2.4 Compost Pad (ECOlibrium Method, Oval Windrow)

Total Compost (tons/ yr)				Semi Circle Radius 1		Radius 2 (Height)		Cross Sectional Area	
200,000		**Step 1**		11	ft	8		138.23	**Step 6**
lb per year									
400000000		**Step 2**				Total length of windrows (per day taken in)			**Step 7**
						1391.21	ft		
lb per day									
1538461.538		**Step 3**				Windrow Length			**Step 8**
						75	ft		
Density of Compost		**Step 4**							
40						New Windrows per day			
				Step 5		18.5495			
Volume of Compost (ft3)			"Greens" Volume per day			1 acre = 43560 ft^2			**Step 9**
192307.6923			38461.5						
						perfect square means that the length			
Volume of Compost (cyd)			"Browns" Needed Volume per day			208.71	ft		
7122.507123			153846						
						25	Total Windrow accomidation width		
Distance between windrows						2.7828	Total Windrows allowed per acre (length)		
3	ft					8.34841	Total windrows allowed per acre (width)		
						Total Windrows per Acre			
						23.232			
						Amount of days from Compost to exit			**Step 10**
						40			
						Amount of new windrows for compost life			
						741.981			
						Amount of Acres needed for " day lifespan			
						31.9379			

9.3.2.5 Curing Area - Vermont Agency of Natural Resources Method (Turned Windrow Composting n.d.)

	Formula	Example
Calculating Curing & Storage Windrow Dimensions		
Step 19	( ) Total Yards³ Raw Feedstock/( ) Time Period X ( ) # of Time Period ( ) in Curing and Storage ( ) Total Yards³ Raw Feedstock Processed	(100) Total Yards³ Raw Feedstock/(Week) Time Period X (26) # of Time Period (Weeks) in Curing and Storage (2,400) Total Yards³ Raw Feedstock Processed
Step 20	( ) Total Yards³ Raw Feedstock Processed X ( ) % Shrink Factor (Assume 60% so use .4) X 27 (Feet³ Per Yard³) ( ) Total Feet³ in Curing and Storage Area	(2,600) Total Yards³ Raw Feedstock Processed X (.4) % Shrink Factor (Assume 60% so use .4) X 27 (Feet³ Per Yard³) (28,080) Total Feet³ in Curing and Storage Area

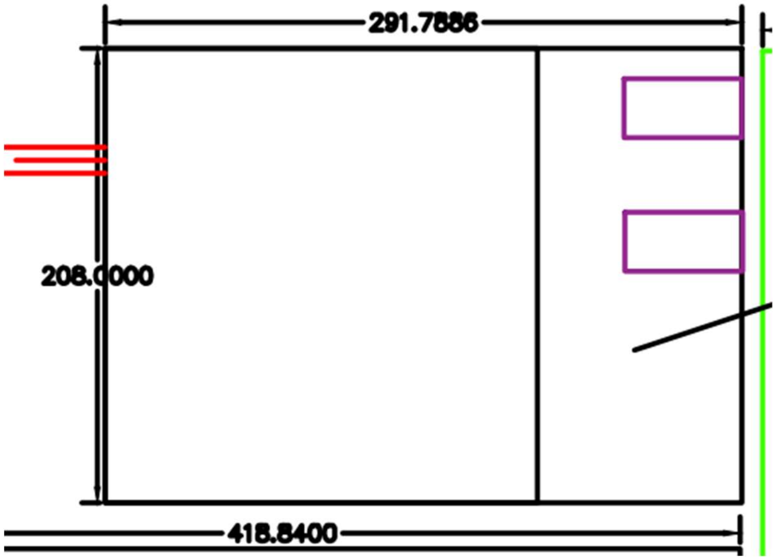
FOOD SCRAPS

Sizing Your Composting Pad 10

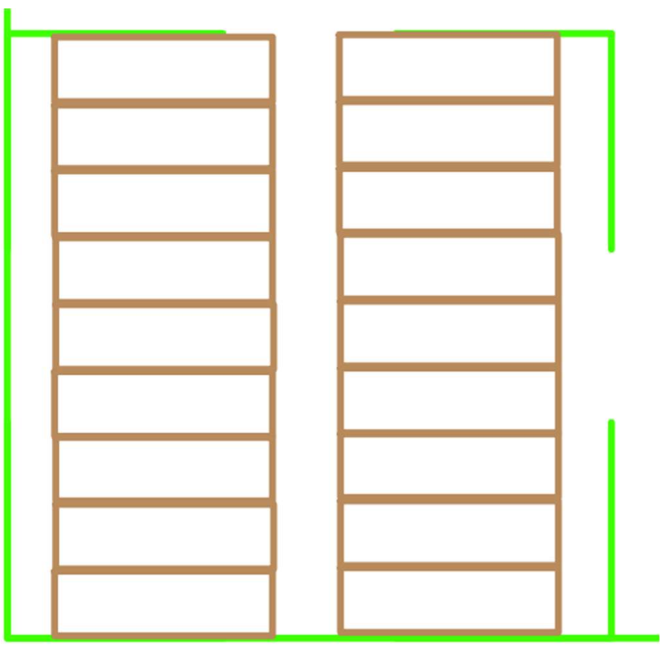
Curing and Storage Windrow Area			
Step 19		1851851.9	Total cubic yards raw feedstock per year
		260	Operational days per year
		45	Days in curing and storing
		320512.82	Total cy raw feedstock processed
Step 20			
		0.4	Shrinkage factor (assuming 60% shrinkage)
		27	Feet^3 per yard^3
		3461538.5	Total cu ft in curing and storing area
		12	max pile height for curing area (ft)
		288461.54	Total square ft in curing and storing area (at 12 ft high)
		288461.54	curing area in square feet
		43560	
		6.6221657	acres for curing and storing

9.4 Composting Facility Layout Components

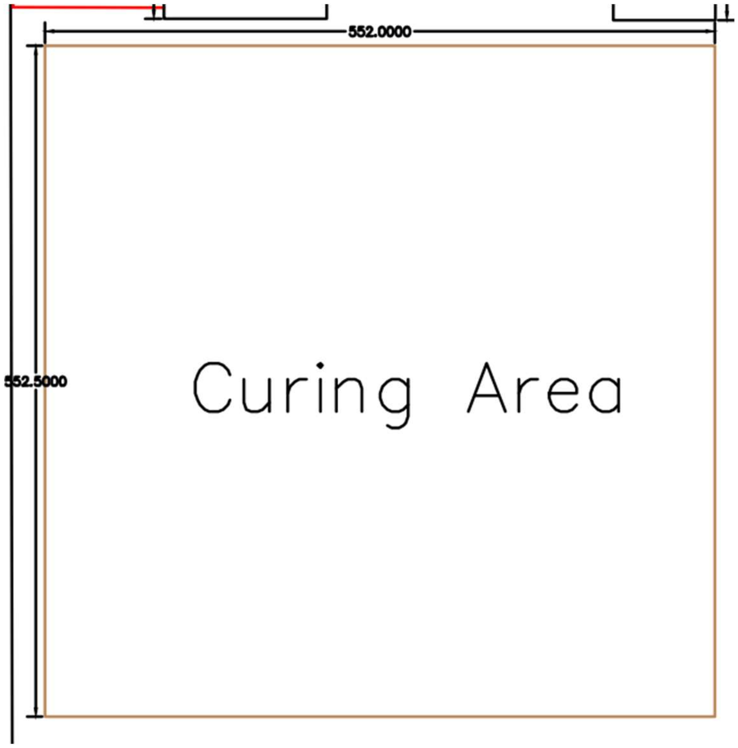
9.4.1 Receiving and Pre-Processing



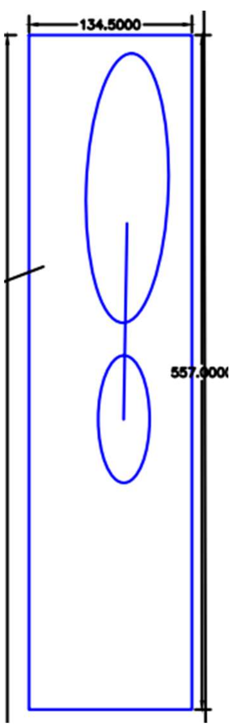
9.4.2 Active compost Pad – Example of 1 Acre of Windrows



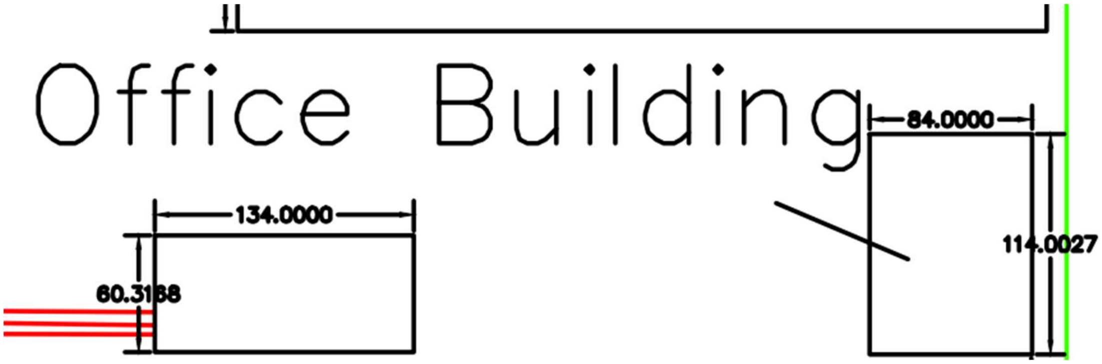
9.4.3 Curing Area



9.4.4 Retention Pond



9.4.5 Office Area



9.4.6 Agricultural market analysis for Hamilton County's neighboring counties

Butler County	Forage (hay/ haylage)	Soybeans for beans	Corn for Grain	Wheat for Grain	Corn for Silage	Sod/ Nursery	Total
Crop acreage	12819	41127	28997	2552	548	0	86043
Percent using compost (%)	5	5	5	5	5	5	
Acreage to cover (ac/yr)	641	2056	1450	128	27	0	
Compost application rate (tons/ac/yr)	10	20	20	20	20	10	
Compost use (tons/yr)	6410	41127	28997	2552	548	0	
Compost use (CY/yr)	10819	69422	48947	4308	925	0	
Market share (%)	20	20	20	20	20	20	
Potential sales (CY/yr)	2164	13884	9789	862	185	0	26884

Clermont County	Forage (hay/ haylage)	Soybeans for beans	Corn for Grain	Wheat for Grain	Christmas trees	Sod/ Nursery	Total
Crop acreage	8742	36854	12807	1345	211	0	59959
Percent using compost (%)	5	5	5	5	5	5	
Acreage to cover (ac/yr)	437	1843	640	67	11	0	
Compost application rate (tons/ac/yr)	10	20	20	20	10	10	
Compost use (tons/yr)	4371	36854	12807	1345	106	0	
Compost use (CY/yr)	7378	62210	21618	2270	178	0	
Market share (%)	20	20	20	20	20	20	
Potential sales (CY/yr)	1476	12442	4324	454	36	0	18731

Warren County	Forage (hay/ haylage)	Soybeans for beans	Corn for Grain	Wheat for Grain	Christmas trees	Sod/ Nursery	Total
Crop acreage	6472	39785	17825	1550	0	471	66103
Percent using compost (%)	5	5	5	5	5	5	
Acreage to cover (ac/yr)	324	1989	891	78	0	24	
Compost application rate (tons/ac/yr)	10	20	20	20	10	10	
Compost use (tons/yr)	3236	39785	17825	1550	0	236	
Compost use (CY/yr)	5462	67157	30089	2616	0	398	
Market share (%)	20	20	20	20	20	20	
Potential sales (CY/yr)	1092	13431	6018	523	0	80	21144

Franklin County	Forage (hay/ haylage)	Soybeans for beans	Corn for Grain	Wheat for Grain	Christmas trees	Sod/ Nursery	Total
Crop acreage	10036	37122	32691	0	0	0	79849
Percent using compost (%)	5	5	5	5	5	5	
Acreage to cover (ac/yr)	502	1856	1635	0	0	0	
Compost application rate (tons/ac/yr)	10	20	20	20	10	10	
Compost use (tons/yr)	5018	37122	32691	0	0	0	
Compost use (CY/yr)	8470	62662	55182	0	0	0	
Market share (%)	20	20	20	20	20	20	
Potential sales (CY/yr)	1694	12532	11036	0	0	0	25263

Dearborn County	Forage (hay/ haylage)	Soybeans for beans	Corn for Grain	Corn for silage	Christmas trees	Sod/ Nursery	Total
Crop acreage	11157	10425	3990	170	0	0	25742
Percent using compost (%)	5	5	5	5	5	5	
Acreage to cover (ac/yr)	558	521	200	9	0	0	
Compost application rate (tons/ac/yr)	10	20	20	20	10	10	
Compost use (tons/yr)	5579	10425	3990	170	0	0	
Compost use (CY/yr)	9417	17597	6735	287	0	0	
Market share (%)	20	20	20	20	20	20	
Potential sales (CY/yr)	1883	3519	1347	57	0	0	6807

Boone County	Forage (hay/ haylage)	Soybeans for beans	Corn for Grain	Vegetables	Christmas trees	Sod/ Nursery	Total
Crop acreage	18355	4899	4199	195	0	165	27813
Percent using compost (%)	5	5	5	5	5	5	
Acreage to cover (ac/yr)	918	245	210	10	0	8	
Compost application rate (tons/ac/yr)	10	20	20	20	10	10	
Compost use (tons/yr)	9178	4899	4199	195	0	83	
Compost use (CY/yr)	15492	8270	7088	329	0	139	
Market share (%)	20	20	20	20	20	20	
Potential sales (CY/yr)	3098	1654	1418	66	0	28	6263

Kenton County	Forage (hay/ haylage)	Soybeans for beans	Corn for Grain	Corn for silage	Tobacco	Sod/ Nursery	Total
Crop acreage	10670	210	243	61	168	165	11517
Percent using compost (%)	5	5	5	5	5	5	
Acreage to cover (ac/yr)	534	11	12	3	8	8	
Compost application rate (tons/ac/yr)	10	20	20	20	10	10	
Compost use (tons/yr)	5335	210	243	61	84	83	
Compost use (CY/yr)	9005	354	410	103	142	139	
Market share (%)	20	20	20	20	20	20	
Potential sales (CY/yr)	1801	71	82	21	28	28	2031

Campbell County	Forage (hay/ haylage)	Soybeans for beans	Corn for Grain	Corn for silage	Vegetables	Sod/ Nursery	Total
Crop acreage	12521	365	324	162	79	165	13616
Percent using compost (%)	5	5	5	5	5	5	
Acreage to cover (ac/yr)	626	18	16	8	4	8	
Compost application rate (tons/ac/yr)	10	20	20	20	20	10	
Compost use (tons/yr)	6261	365	324	162	79	83	
Compost use (CY/yr)	10568	616	547	273	133	139	
Market share (%)	20	20	20	20	20	20	
Potential sales (CY/yr)	2114	123	109	55	27	28	2455

9.5 Equipment Suppliers

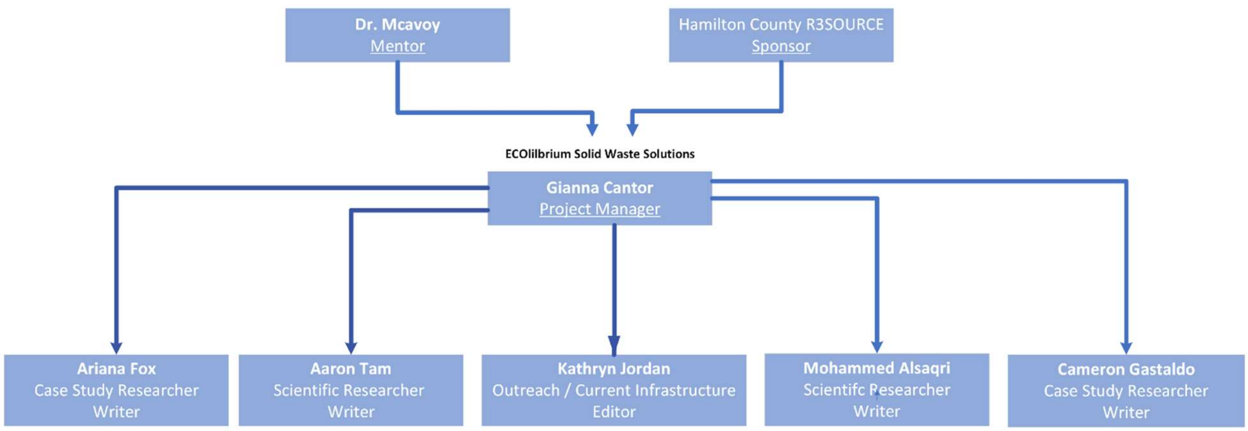
Name	Email	Phone Number	Company
David Matchinga	david@mavequip.com	440-635-7252	Maverick Environmental Equipment (Komptech Supplier)
Brandon Lowery	blowery@vermeerhl.com	865-801-4019	Vermeer Heartland
Corey Shaffstall	corey.shaffstall@ecoversesolutions.com	440-346-5937	ECOVERSE (Doppstadt Supplier)
Emilio Cervantes	ecervantes@reotemp.com	858-623-3235	Reotemp Instruments
Stacey Portell	sportell@rehrig.com	615-418-099	Rehrig Pacific Company (Trash Bin Supplier)

9.6 ECOlibrium Solid Waste Solutions Vision Statement, Organizational Chart, Biosketches, Resumes

9.6.1 Vision Statement

"At ECOlibrium Engineering, our vision is to lead the way in creating a world where waste becomes a resource, promoting a sustainable and harmonious balance in the environment through innovative engineering solutions."

9.6.2 Team Organizational Chart



9.6.3 Acknowledgements

ECOlibrium Solid Waste Solutions would like to acknowledge our sponsor, Hamilton County R3SOURCE, for giving us the opportunity to provide a research proposal that has real world potential.

We would also like to acknowledge Dr. Drew McAvoy for his support and knowledge. He has greatly helped the direction of our project and edited countless grammar mistakes.

Thank you to every professional we interviewed: Gary Dangle from Walnut Hills Redevelopment Foundation, Jess Anderson from A1 Organics, Jordan Norris from Jacobs, Jay Blazey Cedar Grove, Jamie Zawila from GT Consultants, Brian Fuchs from W.L. Gore, David Andre from GoZERO, and Craig Coker from Coker Consulting. Without them we would not have made the decisions we did.

9.6.4 Biosketches

Gianna Cantor

Gianna Cantor is a fifth-year environmental engineering major with minors in management and chemistry. Throughout five co-ops at GPD Group, Moss & Associates, and Black & Veatch she gained experience in consulting, design, and construction. She plans to work at Black & Veatch after graduation as an Environmental Field Manager.

Ariana Fox

Ariana Fox is a fifth-year environmental engineering major with a minor in German language studies. She gained experience in environmental compliance and monitoring via co-ops at Pixelle Specialty Solutions and Robert Bosch LLC. She completed her final two co-ops with Fraunhofer UMSICHT in Sulzbach-Rosenberg, Germany, researching sustainable fuel production from thermochemical conversion of biomass.

Aaron Tam

Aaron Tam is a fifth year-environmental engineering major. He is additionally pursuing a Geographical Information Systems (GIS) certificate. He has completed five co-op rotations with the Environmental Protection Agency in Cincinnati Ohio, researching per- and polyfluoroalkyl substances (PFAS) contamination in complex solid and liquid matrices.

Kathryn Jordan

Kathryn is a fifth-year environmental engineering major. She is also pursuing her Master of Business Administration through the Lindner College of Business. She completed co-op rotations with GE Appliances, Kroger, Matthews International, and Jacobs Engineering. She gained experience in environmental compliance, remediation, and stormwater permitting.

Mohammed Alsaqri

Mohammed is a fifth-year student majoring in environmental engineering. Throughout his five co-ops with MSD Cincinnati, Arcadis, and Cincinnati Incorporated, he has gained a background in environmental consulting, designing, and environmental health and safety.

Cameron Gastaldo

Cameron is a fifth-year environmental engineering student with a minor in environmental analysis and policy. He has had co-op experience at Altec Industries concerning environmental health. He has had four different co-ops at the USEPA researching PFAS and harmful algal blooms (HABS) in drinking water systems. Post-graduation Cameron will continue to work for the USEPA on HABs research.

9.6.5 Team Resumes

Gianna Cantor

cantorgr@mail.uc.edu | 216-633-0977

EDUCATION:

University of Cincinnati - *Cincinnati, OH* Class of 2024
Bachelor of Science in Environmental Engineering GPA: 3.8
Minor in Management & Chemistry

PROFESSIONAL EXPERIENCE:

Project Coordinator and EHS CO-OP - Black and Veatch
Vero Beach, Florida - Jan 2023-August 2023

- Created installation work packages for superintendents.
- Ordered and coordinated material deliveries
- Completed weekly SWPPP and SPCC Inspections.
- Sent weekly reports to clients.
- Managed construction safety program.

Project Engineer CO-OP - Moss and Associates
Vero Beach, Florida - Aug 2021-Dec 2021 & May 2022-Aug 2022

- Coordinated meetings with a project management team and superintendents on a $30 million solar project for Florida Power & Light
- Used stormwater pollution prevention plan certification to conduct weekly environmental inspections
- Built a task list for crews including land grading, stormwater management system implementations, etc.
- Tracked progress on 500-acre site and devised tracker maps using BlueBeam
- Initiated a heat illness prevention plan using OSHA 30 certification

Water Systems Consulting Engineer CO-OP - GPD Group
Cleveland, Ohio - Jan 2021-May 2021

- Learned/utilized Civil 3D, ArcMap, Excel VBA, and Photoshop to contribute to design plans in stream restoration, dam removal, storm/sanitary sewers, and green infrastructure projects
- Completed sewer inspections in field to assess if maintenance needs to be done

Undergraduate Researcher - UC National Alliance for Water Innovation Agro Project
University of Cincinnati - Aug 2020-Aug 2021

- Used Adobe Illustrator to develop drafts of figures for published critical reviews
- Conducted literature review on constructed wetlands and membrane technologies for boron and selenium removal of agricultural waste water
- Demonstrated findings through weekly 10-minute presentations to the project team

Retail Associate - Arborwear
Bainbridge, Ohio - Oct 2017-May 2021

- Met and exceeded monthly sales goals of > $10,000 by introducing and explaining the Arborwear brand to customers
- Developed a training manual for all new employees that is used five years later
- Designed and implemented displays with Photoshop and Microsoft Word to increase visual appeal

Research Intern - NASA Glenn Research Center
Cleveland, Ohio - May 2019-June 2019

- Researched solar cells for the Photovoltaic Department for the Mars Dust Project to assess how Mars dust decreases the efficiency of the cells by 10-40%
- Organized and archived solar cells dating back to the 1980s to create room for new prototypes in the lab. Coordinated with the lead research engineer to make him aware of all the types of cells

LEADERSHIP:

Theta Tau Professional Engineering Fraternity - Vice President, Treasurer

- **Vice President** (May 2022- present): Coordinate 7 committees for 100+ members, assign committee heads, track progress on chapter goals
- **Treasurer** (May 2021-May 2022): Managed budget of > $25,000, paid bills, collected dues from members, transferred all members to online billing, developed and introduced new spending/budget projection documents on Google Sheets

Ariana Fox

7192 Pickway Drive, Cincinnati, OH, 45233 | (513)543-7846 | fox2aj@mail.uc.edu

Education

ENVIRONMENTAL ENGINEERING | University of Cincinnati Expected May 2024

- Minors: German Studies and Materials Science Engineering 3.2/4.0 GPA
- CEAS General Scholarship, Saradelle Sadler University Scholarship, Cincinnatus Century Scholarship

Oak Hills High School Graduated May 2019

- 7/611 Class Rank 4.0/4.0 GPA
- National Merit Commended Student

Skills & Abilities

CODING & SOFTWARE

- MATLAB, Excel, VBA, AutoCAD, Python, LabVIEW, PI/Processbook
- Microsoft Office, Ohio EPA e-Business Center, Air Services, LoggerNet, ArcGIS, Adobe Illustrator

GERMAN LANGUAGE

Work Experience

ENVIRONMENTAL RESEARCH CO-OP | Fraunhofer UMSICHT | February 2023 – August 2023

- Constructed and operated pilot-scale hydrodeoxygenation plant for production of waste-derived fuel
- Evaluated the combustion behavior, pyrolysis behavior, and efficiency of waste-derived feedstock
- Collected and analyzed feedstock, oil, and diesel samples for chemical and physical properties
- Wrote and assembled scientific reports and presentations for internal and external stakeholders

ENVIRONMENTAL CO-OP | Robert Bosch LLC | May 2022 – August 2022

- Prepared Title V, MACT, SARA 312 Chemical Inventory, NPDES eDMR, and other EPA emissions and discharge compliance reports
- Collaborated on completing monthly and weekly inspections of fuel samples, scrubber and ESP parametric data, LDAR inspections, and other emissions control data

ENVIRONMENTAL CO-OP | Pixelle Specialty Solutions | January 2021 – May 2021

- Managed multiple Continuous Emissions Monitoring Systems and H_2S Monitors
- Surveyed composite samplers for quality-driven preventative maintenance procedure creation

CASHIER ASSOCIATE | Aldi USA | June 2020 - Present

- Managing stocking, cashiering, and customer service responsibilities in a fast-paced environment

HOSTESS & EVENT STAFF MEMBER | Aston Oaks Golf Club | Sept. 2018 - Present

- Organizing and customizing schedules to accommodate needs of guests and event requirements

AARON TAM

Researcher specializing in per- and polyfluoroalkyl substances at the EPA

513 227-9752 @ 19aarontam@gmail.com https://www.linkedin.com/in/aaron-tam-8141911a7/ Cincinnati

EDUCATION

Pursuing B.S. in Environmental Engineering

University of Cincinnati
08/2019 - Present Cincinnati, Ohio GPA 3.434 / 4

CERTIFICATION

Pursuing Certificate in Geographical Information Systems (GIS)
University of Cincinnati

EXPERIENCE

ORISE Researcher for study of per- and polyfluorinated-alkyl substances (PFAS)

Environmental Protection Agency 02/2021 - Present
26 W. Martin Luther King Dr. Cincinnati, Ohio

- Performed on a routine basis, laboratory extractions of PFAS from complex solid and liquid matrices using several EPA internal methods
- Analyzed and reported the data from these matrices using liquid chromatography mass spectrometry (LC-MS/MS) analysis
- Assembled and reported data packages to clients regarding PFAS concentrations and impact
- Involved in method development of PFAS extraction methods derivative of standardized EPA method 1633
- Streamlined standard operating procedures (SOPs) and methods through detailed revision
- Implemented quality control and quality assurance (QAQC) standards into methods and laboratory activities
- Managed and transported hazardous waste according to EPA safety, health, and environmental management system (SHEMS) regulation
- Field sampling of wastewater for PFAS at a wastewater treatment facility
- Assembled sampling bottle kits to be sent out to sites across the country frequently
- Supported the onboarding of new researchers by training them in general lab practices and standardized methods
- Full-time (40 hours/week during co-op semesters) and part-time (12 - 16 hours/week during school semesters) on alternating semesters

Waiter and customer service representative

Wok Inn Express 06/2018 - 08/2018 4609 Vine St, Cincinnati, OH 45217

- Client facing
- Food preparation and organization
- Customer phone service

PRESENTATIONS

+ Presentation of PFAS concentrations from study of grass in Alaska

Aaron Tam, Elijah Layton, Jim Voit, Jean Van Buren. *Analysis of PFAS in Plant Matter.* OSAPE/CESER PFAS Research Workshop. April 25, 2023; Cincinnati, OH. Poster presentation.

OBJECTIVE

Current researcher with nearly 3 years of experience studying PFAS interactions in the environment at the EPA AWBERC location in Cincinnati, Ohio. **I will be graduating in May 2024 with a bachelor's degree in Environmental Engineering from the University of Cincinnati.** I aspire to continue my career at the EPA in fields of scientific research for the preservation and protection of the environment.

SKILLS

- **LC-MS/MS**
- **QA/QC practices for PFAS analysis**
- **Analytical lab practices**
- **Analytical data verification**
- **Detailed record keeping**
- **Manual solid phase extraction of PFAS**
- **Automated solid phase extraction of PFAS**
- **Data processing and reporting**
- **Science Communication**
- **Lab Inventory Management Systems (LIMS)**
- **Field sampling**

PROJECTS

Bipartisan Infrastructure Law (BIL) targeted PFAS analysis of drinking water

03/2023 - Present Cincinnati, Ohio

I worked on ORD's Bipartisan Infrastructure Law (BIL) PFAS project regarding PFAS in drinking water across the country. This was done in a PFAS analytical research team in the Land Remediation Technology Division (LRTD) of ORD CESER.

- I prepared and sent sampling materials to drinking water sites, and extracted and analyzed the samples for PFAS using CESER standard operating procedures. This includes samples from drinking water treatment plants in Ohio, Wisconsin, and Kentucky

AWARDS

- Dean's List Recipient - University of Cincinnati

VOLUNTEERING

Turner Serves

University of Cincinnati
2019 - Present
The Darwin T. Turner Scholars Program at the University of Cincinnati arranges an annual event in which all of its scholars clean up its campus and areas surrounding the campus.

LEADERSHIP

Darwin T. Turner Ambassador of Community Service 2022 - Present
I organized and led volunteer opportunities, such as "Turner Serves" for over 400 students. I provided resources and advice for students to serve their communities.

Darwin T. Turner Mentor 2020 - 2022
I had taken a total of 5 incoming freshmen at the University of Cincinnati under my guidance. I helped integrate these students into a new environment, providing advice about studying, the Turner program, and the university.

PROJECTS

Study of PFAS contamination in Boise Idaho biosolids application

03/2021 - Present Cincinnati, Ohio
PFAS compounds were analyzed in Boise Idaho to determine if biosolids applied across agricultural land was contaminated. The grass from this same land was then taken and analyzed for PFAS.

- I was involved in sample extraction, LC-MS/MS analysis, data analysis, and data reporting.

Study of Great Lakes and streams

2021 - Present Cincinnati, Ohio
The status and conditions of the Great Lakes and streams project were studied over periods of several months. This involved tracking the changes in pH, conductivity, temperature, turbidity, and Oxidation-Reduction Potential (ORP) over time.

- This involved the maintenance and deployment of over 50 sensors along the Cuyahoga River. Sampling of the river took place during this field work as well.

Study of PFAS compounds in Alaskan grass adjacent to naval base

08/2022 - 12/2022 Cincinnati, Ohio
A lake near a naval base in Alaska had been contaminated with PFAS. The grass growing from that lake was then sampled and analyzed for PFAS to determine if plant uptake of PFAS from bodies of water was prevalent.

- I was involved in sample extraction, LC-MS/MS analysis, data analysis, and data reporting.

KATHRYN JORDAN

(859) 878-8981 |Kathryn.e.jordan@outlook.com

EDUCATION

University of Cincinnati College of Engineering and Applied Science
Master of Business Administration — Expected May 2024
Bachelor of Science in Environmental Engineering – 3.23 GPA — Expected May 2024

WORK EXPERIENCE

Jacobs – Sharonville, OH — 1/2023-Present
Environmental Engineering Co-op
- Contributed to the development of Stormwater Pollution Prevention Plans for overhead transmission line rebuild projects
- Evaluated environmental and road permits for transmission line rebuild and offshore wind projects
- Conducted soil sampling for polychlorinated bisphenols and lead for potential contamination and assisted in report writing
- Consistently peer reviewed data for contaminated sites and performed groundwater monitoring

Matthews International – Cincinnati, OH — 1/2022-12/2022
Corporate Environmental, Health, and Safety Co-op
- Wrote and updated corporate environmental, health, and safety programs to be used at over 200 sites globally
- Performed monthly inspections of hazardous waste and underground storage tanks at a casket manufacturing plant
- Organized a shared document repository on SharePoint for all sites to share environmental documents and permits

The Kroger Co. – Cincinnati, Ohio — 8/2022-12/2022
Environmental Compliance Co-op
- Conducted audits of Kroger store's hazardous waste racks, pharmaceutical waste, FOG containers (fats, oils, grease) and storm drains to ensure they comply with EPA and DOT regulations
- Examined and approved asbestos containing material reports for renovation projects spanning Kroger brand stores in the US
- Analyzed phase one environmental site assessment reports and communicated findings in memos

GE Appliances, a Haier Company – Louisville, KY — 1/2021-5/2021
Environmental Health and Safety co-op
- Facilitated a 3rd party wall to wall audit for the refrigeration plant working to track over 250 regulatory audit findings to closure
- Assisted in monthly stormwater inspections throughout five plants and the onsite water treatment facility
- Implemented tablet integration across five different plants, streamlining the process of writing work orders, filing Attention Tracking System items, looking up Safety Data Sheets, and completing compliance training for production floor staff
- Performed quarterly waste assessments and the tracking of hazardous and non-hazardous wa

INVOLVEMENTS AND LEADERSHIP

College of Engineering and Applied Science Ambassador — *2020-Present*
- Member of a service organization that helps recruit incoming students through group and individual tours and maintains relations with students, faculty, and admissions counselors of CEAS

University of Cincinnati Cheerleading Team — *2019-2022*
- Student athlete cheering for football, men and women's basketball, volleyball, and compete at UCA nationals

Engineers Without Borders — *2019-Present*
- EHS Officer – Ensure the safety of students working on international and domestic service projects.

Ecolibrium
Solid Waste Solutions

Mohammed Al saqri

3336 Jefferson Ave, Cincinnati, OH | alsaqrma@mail.uc.edu | 513-417-3588
www.linkedin.com/in/mohammed-alsaqri-8636031a6

EDUCATION

College of Engineering & Applied Science | University of Cincinnati - US *Class of May 2024*
Bachelor of Science in Environmental Engineering *GPA: 3.72*

WORK EXPERIENCE

Environment, Health & Safety CO-OP | Cincinnati Incorporated *05/23-08/23*
-Compared and and evaluated various brands of Personal Protective Equipment (PPE) options to ensure optimal safety and efficiency in diverse work environments
-Performed FMEA (Failure Mode & Effect Analysis) on select 2022 high-level JHA's, enhancing workplace safety
-Enhanced awareness among team members regarding the concept and importance of psychological safety
-Collaborated with colleagues and instructors in the annual fire extinguisher training program

Water Resources Engineer | IBI Group - Arcadis *01/23-03/23*
-Generated precise construction documents, calculations, and reports to serve diverse public and private clients
-Collaborated closely with a project manager to streamline the production of construction documents for site development, water resources, and civil projects
-Showcased specialized skills in crafting construction documents for esteemed public sector clients, including cities, counties, and water districts
-Led design for subdivision master plans, grading plans, and utility plans, driving innovation in new developments

Biodiesel Research | University of Cincinnati *08/22-12/22*
-Utilized waste cooking oil to produce biodiesel through three distinct processes
-Conducted titrations using different chemicals and oil to establish and confirm free fatty acid percentages
-Reduced free fatty acid percentages by implementing a precise chemical mixture under the heat plate

Health & Safety Environment CO-OP | Metropolitan Sewer District of Greater Cincinnati *05/22-08/22*
-Executed chemical inventory for all chemicals and reviewed the Safety Data Sheet (SDS)
-Ensured teamwork on monthly safety assessments for buildings, machines, firefighting systems, and electric rooms
-Participated in sound testing projects for buildings, machines, vehicles, and equipment using sound monitors
-Examined job field issues, ranging from major injuries to minor incidents, and completed the necessary paperwork related to these occurrences.

WORKSHOPS

Annual Pilot Research Project Symposium On Occupational Safety & Health | University of Cincinnati *10/23*

-Generated innovative occupational and environmental health research, pushing the boundaries of knowledge
-Engaged in in-depth discussions about latest developments in occupational and environmental health research

SKILLS

Technical: Matlab, Python, ArcGIS, AutoCAD, Civil 3D, and Microsoft Office
Soft: Communication, Multitasking, Problem-solving, and analyzing data skills

CERTIFICATES, AWARDS & ACTIVITIES

Certificates:
-Certificate of completion OSHA 30-Hours: General industry safety training class *11/23*
-Certificate of Appreciation, attending annual health and safety pilot research *10/23*
-Certificate of completion OSHA 10-Hours: General industry safety training class *06/22*
-Dean's list Certificate from the University of Cincinnati *12/22 & 05/21*

Ecolibrium
Solid Waste Solutions

Cameron Gastaldo

cxgastaldo@gmail.com • (614)-404-3315 • Cincinnati, OH, 45219

Dedicated fifth-year Environmental Engineering student committed to advancing sustainable solutions for a resilient and eco-friendly future. Seeking full-time employment May 2024.

EDUCATION

University of Cincinnati, Cincinnati, OH Expected May 2024

Bachelor of Science in Environmental Engineering GPA:3.88/4.00

- Minor in Environmental Analysis and Policy
  - Relevant coursework: Air Pollution, Basics of Environmental Law, Climatology, Engineering Hydrology, Fluid Mechanics, GIS, Life Cycle Analysis, Physical Principles of Water Treatment
- Cincinnatus Century Scholar 2019- Current
- Dean's List Recipient 2019-Current
- Robert W Kershner Scholarship Recipient 2019

SKILLS

- Proficient in: R, MATLAB, LabVIEW. ArcGIS, Python, Google Colab, Microsoft Office & Excel

WORK EXPERIENCE

United States Environmental Protection Agency May 2023-Present

Pathways Intern - Physical Science

- Conducted weekly field sampling of the East Fork Watershed for harmful algal blooms
- Performed lab and data analysis on samples on four different instruments to forecast blooms
- Participated in workshops centered on leadership and professionalism within the workplace

Oak Ridge Institute for Science and Education August 2021-May 2023

On-Site Research Co-op for the United States Environmental Protection Agency

- Improved grinding process to grinding time for activated carbon used in lab tests by up to 50%
- Compiled and analyzed data of kinetics and isotherm tests to influence future test parameters
- Conducted peer reviews for four co-authored publications, enhancing proficiency in the review process.

LEADERSHIP EXPERIENCE

- College of Engineering and Applied Science Ambassador 2020-Present
  - Represented the College of Engineering and Applied Science by taking prospective students on tour of the engineering college and answering questions
- Theta Tau Professional Engineering Fraternity Vice Regent May 2023- December 2023
  - Fostered conversations with chapter on tough subjects such as DEI in the fraternity, committee performance and member engagement
- UCDM Executive Board Member August 2020-November 2022
  - Created and maintained relationships between the organization and outside event sponsors during a global pandemic

9.7 Request for Proposal

UC Environmental Engineering Senior Capstone Project RFP

Solid Waste Organics Diversion and Processing Study
Sponsor: Hamilton County ReSource

Background

Hamilton County, Ohio is located in the far southwest corner of Ohio, with Indiana bordering on the West and Kentucky bordering on the South (Figure 1). The current estimated population is 836,759 with 48 political subdivisions including the largest, the City of Cincinnati. The Greater Cincinnati Region has a population of roughly of 2,256,884 according to the 2020 U.S. Census. Hamilton County achieved a diversion rate of 55.78% in 2020. More background on Hamilton County's diversion can be found in the draft 2024-2038 Hamilton County Solid Waste Plan Update (Plan).

Figure 1. Location of Hamilton County in the state of Ohio.

Hamilton County ReSource (ReSource), the solid waste district for Hamilton County, has identified organics, in particular food waste, as a target material with potential for an increase in diversion. According to analysis in our Plan, 32% of the residential waste stream going to landfill is comprised of organic material (15% food scraps and 17% yard trimmings) and 23% of the commercial waste stream going to landfill consists of organic materials (15% food scraps and 8% compostable fiber). ReSource estimates that approximately 254,934 tons of organics (96,896 from residential and 158,038 from commercial sources) are landfilled from Hamilton County sources every year.

Because Southwest Ohio lacks strong infrastructure for processing food scraps, ReSource seeks a capstone consultant team to lay the groundwork of establishing better organics processing infrastructure in the region with a focus on food scraps.

Project Description

ReSource's goal is to divert both residential and commercial generated food scraps, yard trimmings, and compostable fiber from the landfill (Figure 2). Hamilton County has set a goal of reducing food waste by 50% by 2030. This study will identify infrastructure and evaluate technologies to move our region closer to that goal.

Figure 2. Food waste as part of municipal solid waste going to landfills.

This study will evaluate best practices and potential scenarios for a successful public private partnership that would divert most of the organics, including food scraps, from the landfill without competing with current private and public diversion infrastructure. Hamilton County seeks a multi-faceted approach that will reduce solid waste organic material going to landfill, not create a nuisance for surrounding neighbors, and provide an environmentally beneficial end product.

Service Required

ReSource is seeking a recommendation for the best processes and infrastructure to effectively manage Hamilton County and the surrounding region's organic solid waste. This project should include an evaluation of existing facilities and infrastructure, and the operation of these facilities (e.g., publicly owned, privately operated, etc.). Factors important when considering best methods include:

- Greenhouse gas impact of method.
- Bi-product created and end-of-life management (preferred 95%+ material collected diverted from landfill/incineration).
- Startup cost involved for equipment, property, studies, etc.
- On-going operation cost.
- Potential revenue streams for operation.
- Best practices to minimize nuisance impact to neighbors.

- Impact on marginalized, low-income, and Environmental Justice neighborhoods.
- Ease of public private partnerships.
- Potential for job creation.
- Proven successful implementation.
- Multi-use potential (ability to co-locate with other operations/facilities).
- Seasonal variations in performance.
- Proximity to end market.
- Impact on water system, air quality, and other environmental impacts.

The capstone consultant team will research a slate of options with benefits and consequences and then conduct an alternative analysis of these options to determine the best option for Hamilton County. The amount of land required should also be evaluated as well as how the facility(s) would be operated.

The project team should meet (virtual acceptable) with Hamilton County ReSource periodically throughout the project. In addition, the project team will provide a detailed written report and provide an oral presentation at the end of each semester. The final report needs to include any advanced technical training for the operators or other considerations that would be helpful in moving the project to the next stage of implementation.

Deliverables

The capstone team shall submit a project proposal and give an oral presentation to the Sponsor at the end of the 2023 Fall Semester. The report and presentation should include a recommendation on the best solution(s) for processing organic materials for Hamilton County. At the end of the 2024 Spring Semester, the project team shall submit a final report and give a presentation on key findings of the project.

2023 Fall Semester

Specific task to be performed should include, but are not limited to, the following:

1. Evaluate existing solid waste organics processing methods. This would include investigating current successful operations throughout the United States as well as investigating current organics processing infrastructure active in Hamilton County and the surrounding region.
2. Examine options via an alternative analysis for determining the best processes and infrastructure or combination of opportunities to effectively manage Hamilton County and the surrounding region's organics. This analysis should include impacts on water systems, air quality, and other environmental systems like greenhouse gas emissions.
3. Estimate the preliminary cost of the options evaluated including the capital and operational costs, and potential revenues from the end product.
4. Prepare a proposal report on key findings and the recommended best solution(s) for the processing of diverted solid waste organics from a landfill.
5. Provide a presentation to the Sponsor that covers the key findings and recommended best process and infrastructure options for managing the solid waste organic material.

2024 Spring Semester

Specific tasks should include, but are not limited to, the following:

1. Prepare a design of the final configuration of the organics processing facility.

2. Develop an economic analysis of the final system.
3. Develop best practices to minimize nuisance impact to neighbors.
4. Assess the potential impacts on water systems, air quality, and other environmental systems like greenhouse gas emissions.
5. Prepare a final report that includes the design specifications, expected costs via an economic analysis, and potential impacts on the environment and neighbors.
6. Provide an oral presentation on key findings at the end of the semester.

Contacts

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