In-vessel Compost Exploration, University of Denver

Hanna Gaertner

Environmental Science Honors Thesis/ Distinction Project

Advisor: Chad King, Ph.D.

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I. Abstract

Waste management proves increasingly nuanced as the human population grows and landfill space decreases. The average waste stream is largely comprised of discarded food components, which are typically wet and heavy. Composting, or the breakdown of organic materials into soil product, diverts food waste from landfills but takes a significant amount of time, produces unfavorable odors, and attracts pests. The cost of collection and bags coupled with the difficulty of avoiding contamination with landfill materials also contributes to the inconveniency of compost. One approach which seeks to overcome these nuances is in-vessel technology, which decomposes organic materials at an accelerated rate in a controlled environment. These systems are especially applicable to establishments with large waste profiles, such as universities; college campuses serve thousands of meals on a daily basis and therefore generate large quantities of food waste over short periods of time. This study investigated compost technologies to be utilized at the University of Denver. The research included a literature review, internal food waste data analysis, outreach to universities with in-vessel composters, and evaluation of potential vendors. The primary methods were email interviews with supplementary reading, in addition to statistical interpretation of waste data. The results suggest that the optimal solution for DU is to partner with BioCoTech Americas in a Compost as a Service (CaaS) program. Other feasible solutions include the ORCA food waste liquification machine and the Ecodrum rotary composter.

II. Introduction

The premise of this study was to examine the possibility of in-vessel composting at the University of Denver and to propose viable future steps. The first goal was to learn about composting and in-vessel technology. Another objective was to analyze the university's food waste generation and waste hauling costs to determine the processing needs as well as the potential to reduce expenses. The work also involved an investigation of colleges who currently have in-vessel composters to gain knowledge about the process of implementation, benefits, challenges, educational opportunities, and general advice for a university in the early stages of a project. Finally, this research aimed to compare different models and ROI reports to produce recommendations for which options the university should pursue in order to maximize economic and environmental sustainability on campus.

Worldwide, 40% of food is wasted (SOCAP 2020). According to a recent ReFED report, "the U.S. spends $218 billion a year – 1.3% of GDP – growing, processing, transporting, and disposing of food that is never eaten" (ibid.). In Colorado, the 2018 diversion rate for compost was only 5.4% and the overall diversion rate dropped in 2019, despite the fact that a third of the state's waste stream is compostable (Setzke, Bailey, and Katz 2019; ibid. 2020). Ultimately, food waste has a significant impact on climate change due to transportation emissions from hauling, greenhouse gas release from landfills, and an unnecessarily large agricultural footprint. An urgent need exists to reduce and redistribute food, but the waste that is unavoidable can and should be composted to help grow more food. Compost is often ruled impracticable for establishments with heavy waste streams, limited space, and a desire to maintain a pleasant aesthetic free of odors – university cafeterias, for instance. In-vessel technology has mitigated these challenges on a number of college campuses across the nation. Therefore, given the successful cases and urgency of the food waste problem, it is worthwhile to investigate vessel compost potential at the University of Denver.

If implemented, vessel composting has the potential to reduce waste management costs and increase campus sustainability at DU. At the same time, the process would generate valuable soil product and provide educational opportunities for students. Prior to investment, it is important to understand costs and benefits to the system. Moreover, the potential to generate cost savings for the university and meet sustainability goals should be evaluated. DU stated an intent to "achieve a 70% diversion rate, on the way to a waste-free campus by 2035" and a desire to engage the entire university community in sustainability practices (University of Denver Annual Sustainability Report FY 2019). In addition, the school boasts a commitment to contribute to the public good with sustainability as a core pillar. Thus, this research is significant in a broader context given the immense volume of waste produced at universities, particularly food waste from dining services. DU has the chance to join universities across the nation to set a standard for sustainable waste management and empower young adults to shape a superior future.

III. Background

i. Compost:

Composting is the process by which organic material is broken down by micro-organisms. The decomposition produces compost, which is a stable organic matter residue (Hermann et al. 2011). Composting can occur in natural environments as well as controlled settings both industrially and residentially (ibid.). The process begins when organic waste is combined in rows, piles, or vessels in which microorganisms are present. After decomposition, the compost undergoes a curing process in which it becomes mature. Mature compost is chemically stable and contains humus, which is applied to soil to improve its physical qualities (U.S. EPA 2020). The properties of compost are important for all stages of composting; micro-organisms require suitable nutrient, water, oxygen, and temperature conditions in order to effectively decompose organic material (Agnew and Leonard 2003). According to the EPA, the five factors to account for when composting are nutrient balance, particle size (large surface area and some porosity), moisture content, oxygen flow (turning required), and temperature (2020).

Composting promotes healthier environmental conditions. In landfills, organic waste produces methane, a harmful greenhouse gas, so the compost process significantly reduces methane emissions (U.S. EPA 2020). Not only does it effectively divert waste from landfills, but it also generates a usable soil product for food production and landscaping. Compost replaces toxic chemical fertilizers and boosts soil health to produce higher garden yields (ibid.). On a local level, implementation of compost practices creates circular economy jobs and generates community awareness of waste reduction (Vazquez, Perez, and Soto 2020). In a university setting, compost projects also provide meaningful educational opportunities for research and internships. Practical work better prepares students for the workforce and increases awareness of real-world issues and employment opportunities (Valentukevičienė, Rynkun, and Misevičiūtė 2019).

ii. C:N Ratio:

All organic matter contains an assortment of nutrients, primarily carbon and nitrogen. One important aspect to consider when dealing with compost is the composition of waste inputs in terms of carbon and nitrogen, or the C:N ratio. As the name suggests, the ratio is a measure of the proportion of carbon compared to the proportion of nitrogen. The optimal ratio is thought to be around 25-30:1 (Planet Natural Research Center 2020; Donahue, Chalmers, and Storey 1998). A balance of these two nutrients is essential to safe and efficient compost operations. The microorganisms responsible for decomposition require this balance since they use nitrogen for production of protein and carbon for energy (Planet Natural Research Center 2020). An excess of nitrogen creates unpleasant odors and toxic leachates, while carbon-heavy waste takes far longer to break down (Chaher et al. 2020; Planet Natural Research Center 2020).

Discarded food tends to be high in nitrogen (and moisture), so bulking agents can be added to absorb leachate, add carbon to the mix, and strengthen microbial activity to shorten the compost process (Chaher et al. 2020). Materials used as bulking agents include mulch, pallet chips, sawdust (Donahue, Chalmers, and Storey 1998), wood chips, wheat straw, rice husk, mature compost (Chaher et al. 2020), lawn trimmings, and paper products (Faucette and Risse 2001). Literature suggests that the optimal ratio of food waste to bulking material is around 1:2 (Donahue, Chalmers, and Storey 1998; Faucette and Risse 2001).

In the context of this analysis, it is assumed that the primary material to be composted is food waste generated from the dining halls on campus, which will contribute substantial amounts of nitrogen. It is also anticipated that to-go cups/containers and napkins will be present in the waste to add carbon content; although, based on current literature and other systems, it is expected that bulking agents will be required to add additional carbon.

iii. In-vessel Systems:

In-vessel composting is a waste reduction strategy that involves machines specifically designed to break down organic waste. According to Ecodrum, it is "a process in which compostable material is enclosed in a drum, silo, bin, tunnel, reactor, or other container for the purpose of producing compost, maintained under uniform conditions of temperature and moisture where air-borne emissions are controlled" with "forced aeration and/or mechanical agitation to control conditions and promote rapid composting" (2017, pp.7). Three different models were examined in this study: rotary drum, tunnel chambers, and liquification. In rotary drum machines, waste is inserted into a large, enclosed container in which organic material is rotated to accelerate the process of decomposition via oxygen circulation. For the chambers model, when waste is inserted into the collection compartment it immediately begins aerobically composting with the assistance of microbes. As it progresses through the chambers it continues to break down, then exits as soil product with only a fraction of the original volume (BioCoTech Americas, accessed July 2020). The liquification unit developed by ORCA also involves the breakdown of waste with the assistance of microbes, but it only processes food waste and produces drainable wastewater instead of soil.

Vessel composters have been implemented by businesses and schools to divert waste, alleviate compost collection costs, and produce usable soil. They have been found to be particularly beneficial in university settings, as the concentrated living arrangements and on-campus dining operations generate continuous large streams of waste. The primary benefits to the technology are the ability to control conditions (i.e. temperature, moisture, microbe population) to accelerate the process and maintain consistency, and that compost collection costs may be eliminated. In addition, the machines require less manpower to operate than traditional composting so fewer people are exposed to compost material, not to mention the emissions and leachate can be more easily controlled and treated (Ecodrum 2017; U.S. EPA 2000). Weather effects are also diminished, as are land requirements and restrictions on what waste may be composted (ibid.).

One example of a successful system is Georgia College, a campus that began vessel composting in 2016. An assessment after one year states that the system effectively diverts campus waste, reduces waste management fees, and produces soil product for campus gardens and landscape (Hearn 2017). Another is the University of British Columbia's vessel, which has the capacity to process five tons of waste daily and produce compost in two weeks; after six years of operation, it was found to still function effectively, safely, and sustainably (Reeve et al. 2010). In addition, a case study of Wellington Middle School's BioSpeed composter in Fort Collins, CO demonstrates the assortment of benefits to the technology; school staff report that the system provides 100% on-site organic waste diversion, is easy to operate, produces a nutrient rich product, integrates well into academic curriculum, and excites students (BioCoTech Americas 2019).

IV. Methods

This research project involved exploration of compost literature, analysis of DU's discarded food, interviews with in-vessel system owners, and dialogue with companies who sell the technology. Conversations occurred over the course of several weeks via email, with a handful of virtual meetings.

i. Preliminary Research

An extensive literature review was conducted to obtain information about food waste and associated issues, compost, factors to consider in the process, and available methods. Specifically, in-vessel systems were explored. Case studies from other universities were examined, as were the requirements of utilizing the technology. Benefits and challenges associated with in-vessel composting units were also investigated. The reading also sought to review evaluations of in-vessel composting effectiveness, particularly in terms of finances, sustainability, and student involvement.

ii. Waste Data Analysis

Food waste spreadsheets from Fall 2019 and Winter 2020 in Nelson and Centennial Halls dining centers were utilized to study the university's waste profile. The Lean Path system was used to measure food waste from various sources in the dining halls and assign average values to the food waste. In addition, overall waste statistics were examined to put food in the context of all compost on campus. The discarded food weight and cost totals, weekly averages, and waste/cost per day values were calculated for each term. The percentage of trim waste (as opposed to over-production, expiration, consumer plates) was calculated to gain an understanding of the proportion of wasted food that could be prevented. The cost per pound of food waste and waste per student meal swipe were also calculated. The results were used in the solutions exploration (iv) to determine machine sizes and costs as well as potential savings.

iii. University Outreach

Seven universities were surveyed to obtain information about implementation of in-vessel composting systems. Websites were perused along with any available reports, and sustainability departments were contacted. Ongoing informal interviews were conducted via email with representatives from three colleges that responded to the inquiry (Georgia College, Ohio University, and the University of Maine). Questions pertained to the process of purchase and initiation of the technology, successes and challenges of the project, campus education and involvement, maintenance, logistics, and planning considerations. Knowledge gleaned from those using in-vessel composting informed solutions exploration and exists as a valuable resource for DU stakeholders during future steps toward implementation.

iv. Solutions Exploration

Eight vendors of in-vessel composters were researched based on discoveries from literature, recommendations of current owners, and web search results. The companies were BioCoTech Americas, Nioex Systems Inc., FOR Solutions, Rotary Composters, XACT Systems, Green Mountain Technologies, Ecodrum, and Advanced Composting Technologies. In addition, one company with food waste liquification technology, ORCA, was investigated. Interviews via email and video conferencing were conducted with representatives from BioCoTech, FOR Solutions, Rotary Composters, Ecodrum, and ORCA. Inquiries focused on unit recommendations, how each system works, associated costs, operation, and maintenance. Waste data was provided to determine the models that would best suit the university's waste needs as well as to inform ROIs. The potential solutions were then assessed and compared to generate recommendations for the University of Denver.

V. Results

The results of the study generated valuable information with respect to DU's waste profile, implementation of in-vessel compost solutions, and a comparison of potential options for the University of Denver. The literature review established adequate background knowledge to inform dialogue with professionals, as did reviewing DU's food waste data. The university interviews provided practical and applicable insight into utilization of in-vessel composters on college campuses. Conversations with vendors assisted in the evaluation of solutions. The data collected informed primary and secondary proposals to be shared with university stakeholders.

i. Preliminary Research

A thorough literature review provided a foundation of issues related to compost and framed questions for university and vendor outreach. The reading shaped research queries, generated contact lists, and prompted interview questions. Most of the literature depicted favorable outlooks on the usage of in-vessel systems as a solution to waste challenges, citing the primary benefits as cost reduction, decreased environmental impact, ability to control temperature and moisture conditions, rich soil product, and student involvement. The challenges associated with the process include odors, pests, mechanical issues, and determination of the optimal compost recipe (i.e. bulking material ratio). In general, evaluations of composters suggest that despite substantial financial investment and the aforementioned nuisances, the technology is effective and worthwhile.

ii. Waste Data Analysis

In the fall of 2019, 25,509.27 lbs. of food were wasted from Nelson and Centennial Halls. The cost was $25,445.15, which amounted to almost exactly $1.00 per pound (calculated value of 0.997). The daily load ranged from 9 lbs. to 631.42 lbs. with an average of 303.68 lbs./day. Combined board counts for the two dining centers averaged 2,489/day, with a low of 1,200 swipes and a high of 3,716 swipes. For the 191,638 total meal swipes recorded, each one was calculated to account for 0.13 pounds and $0.13 of food waste; this calculation involved all recorded food waste, including trim, expiration, overproduction, and consumer plate waste. The total amount of trim waste was 9,960.83 lbs., 39% of the total food waste.

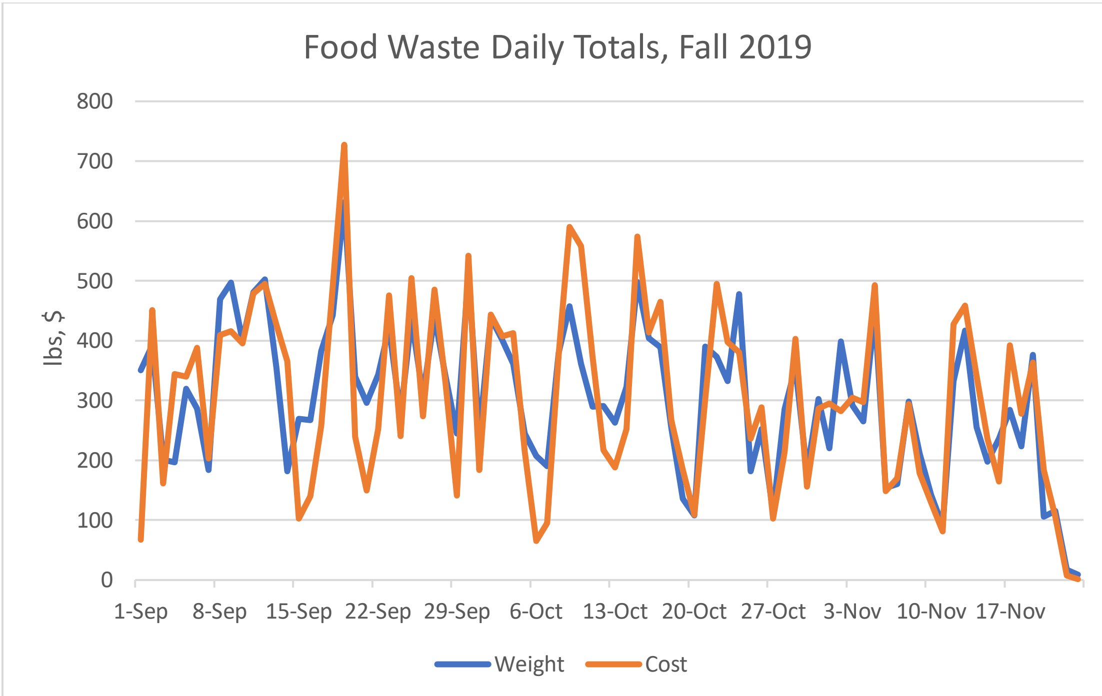

Figure 1: Graph depicting total food waste per day in terms of weight and of cost for Fall Quarter 2019. Lean Path data from Nelson and Centennial Halls dining centers was utilized and reported by Sodexo Dining Services.

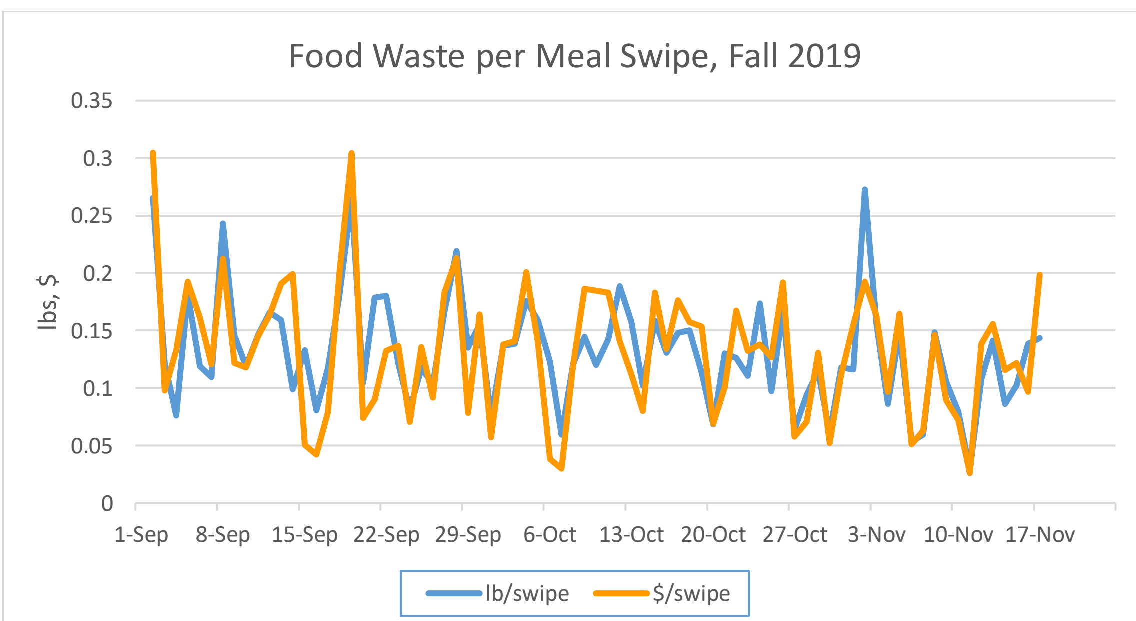

Figure 2: Calculated daily values for the pound and dollar amounts of food waste attributed to a single meal swipe for Fall 2019.

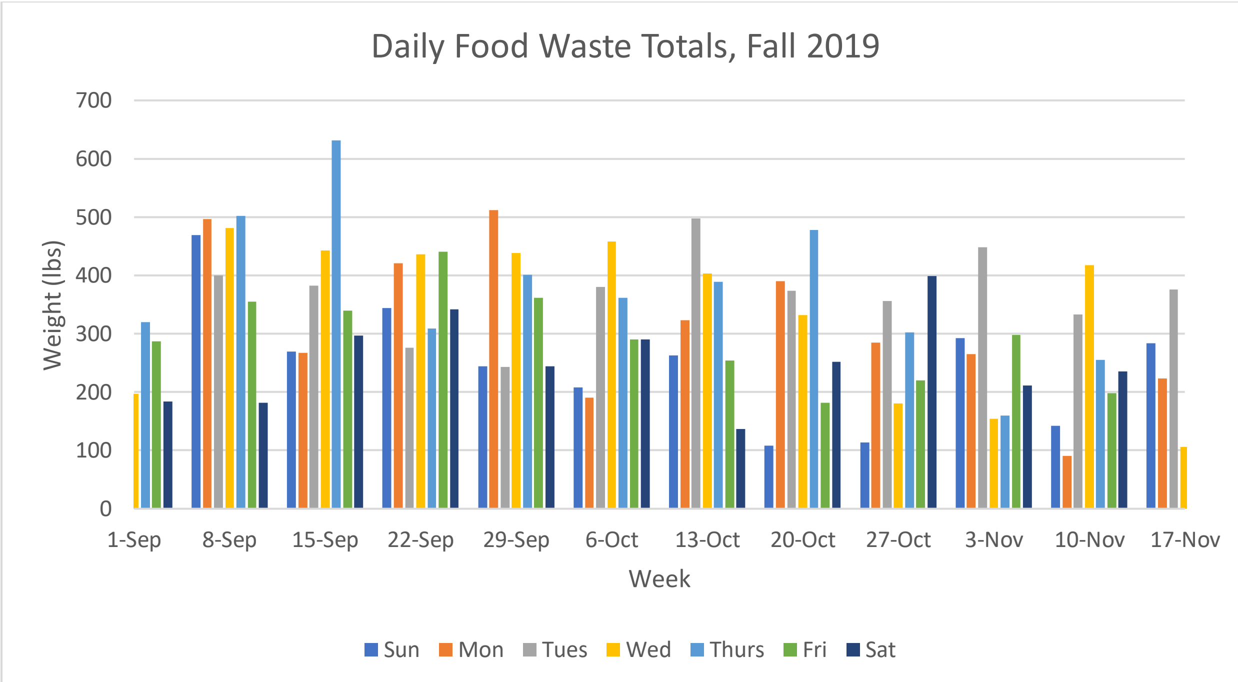

Figure 3: Food waste totals brokenn down by day of the week for Fall Quarter 2019.

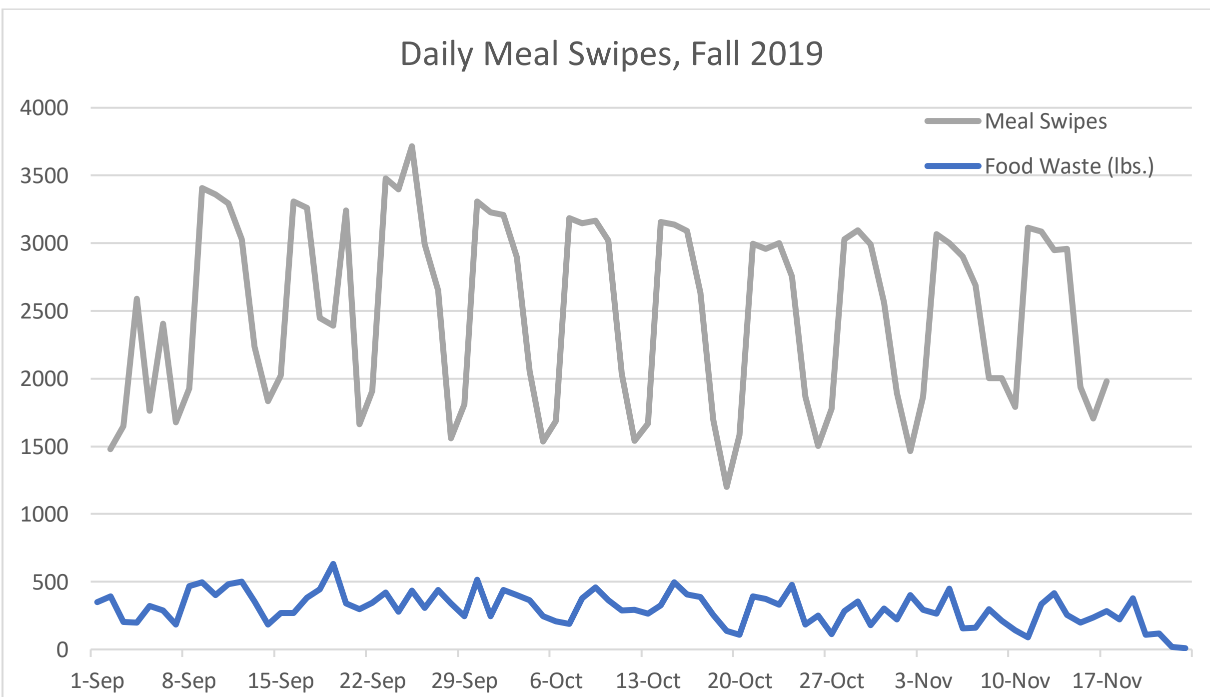

Figure 4: Graph of Fall 2019 board counts, with total food waste (both pre- and post-consumer) included for reference.

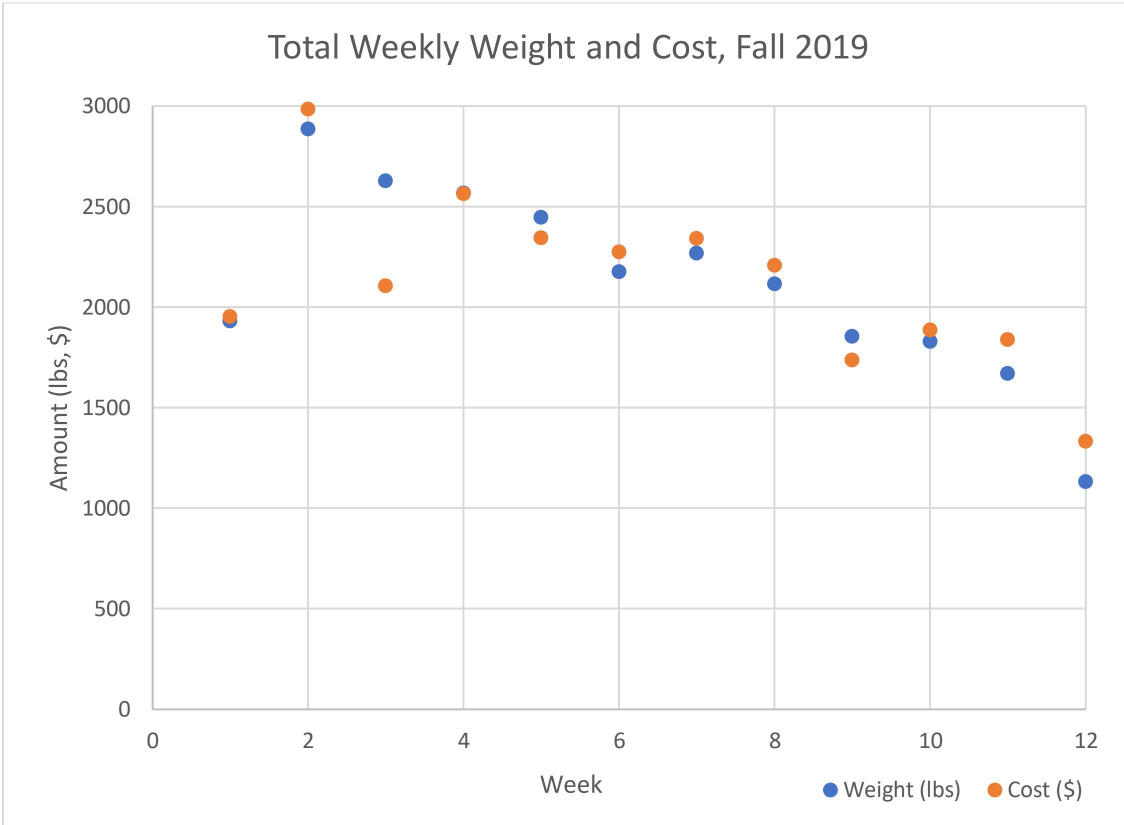

Figure 5: Food waste by week for Fall 2019. Week 2 falls on the start to the academic quarter.

For Winter 2020, the total food waste amounted to 19,013.39 lbs. at a cost of $19,803.16. The cost per pound was $1.04. Daily waste generation ranged from 0 to 521.78 lbs., with an average of 225.60 lbs. per day. The number of meal swipes averaged 2,281. Of the days with recorded board counts, the highest was 3,436 and the lowest was 896. There were 164,262 meal swipes recorded in Winter Quarter; the food waste cost per swipe was $0.12 and the food waste weight per swipe was 0.11 lbs. Calculations accounted for all categories of food waste: expiration, overproduction, trim, and consumer plate waste. Trim waste accounted for 6,441.26 lbs., which was 33.88% of the total.

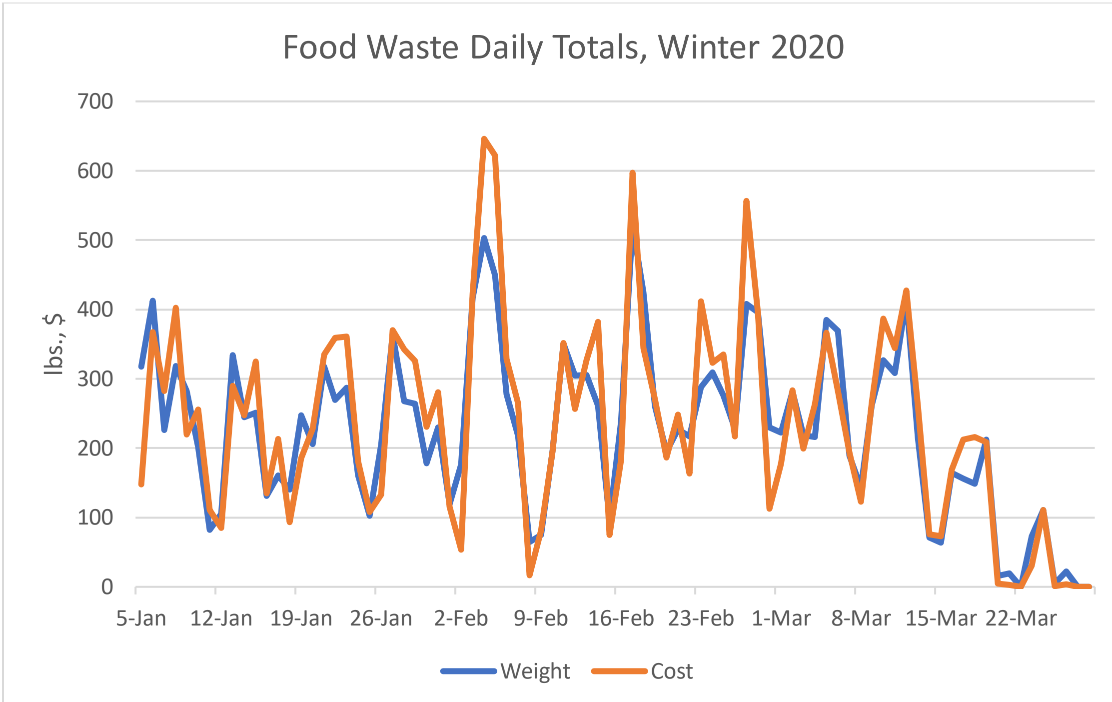

Figure 6: Winter Quarter total daily food waste graph, 2020. Data obtained from Lean Path system data provided by Sodexo Dining Services.

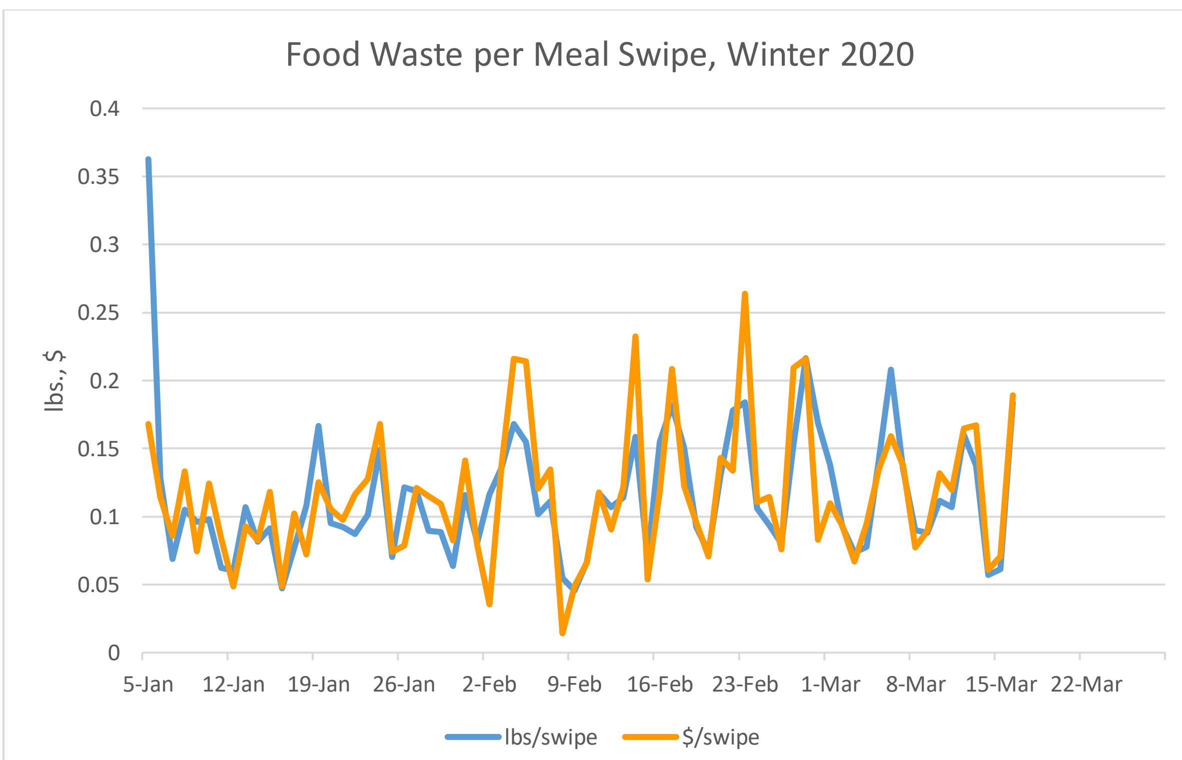

Figure 7: Daily cost and weight of food waste (all categories) per meal swipe, Winter 2020.

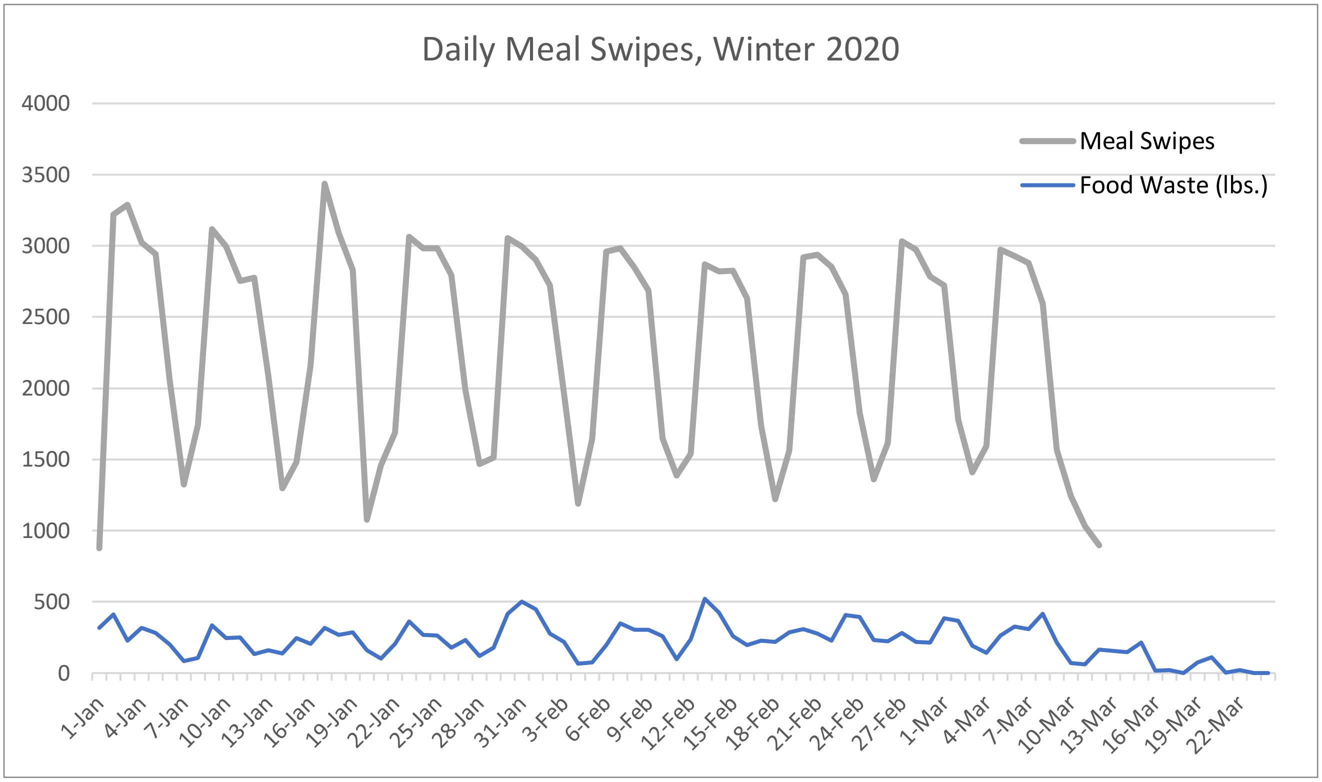

Figure 8: Daily board counts for Nelson and Centennial Halls dining centers, shown with total food waste (pre- and post-consumer) generated per day.

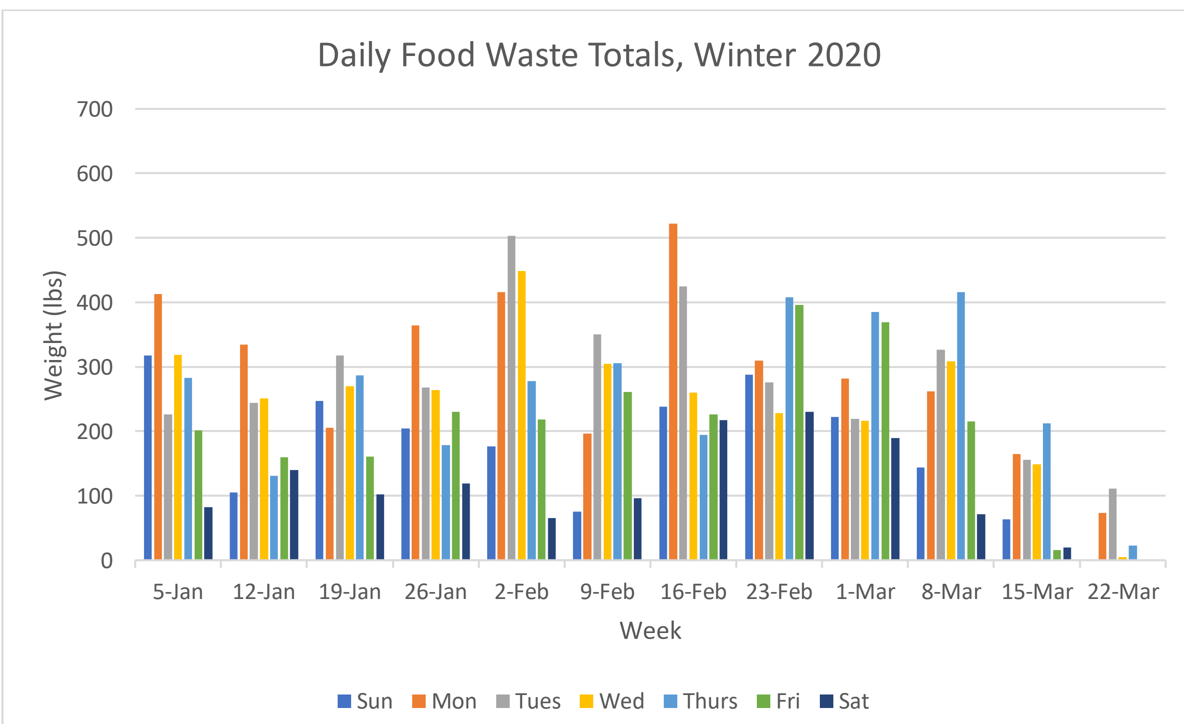

Figure 9: Food waste totals broken down by day of the week for Winter Quarter 2020.

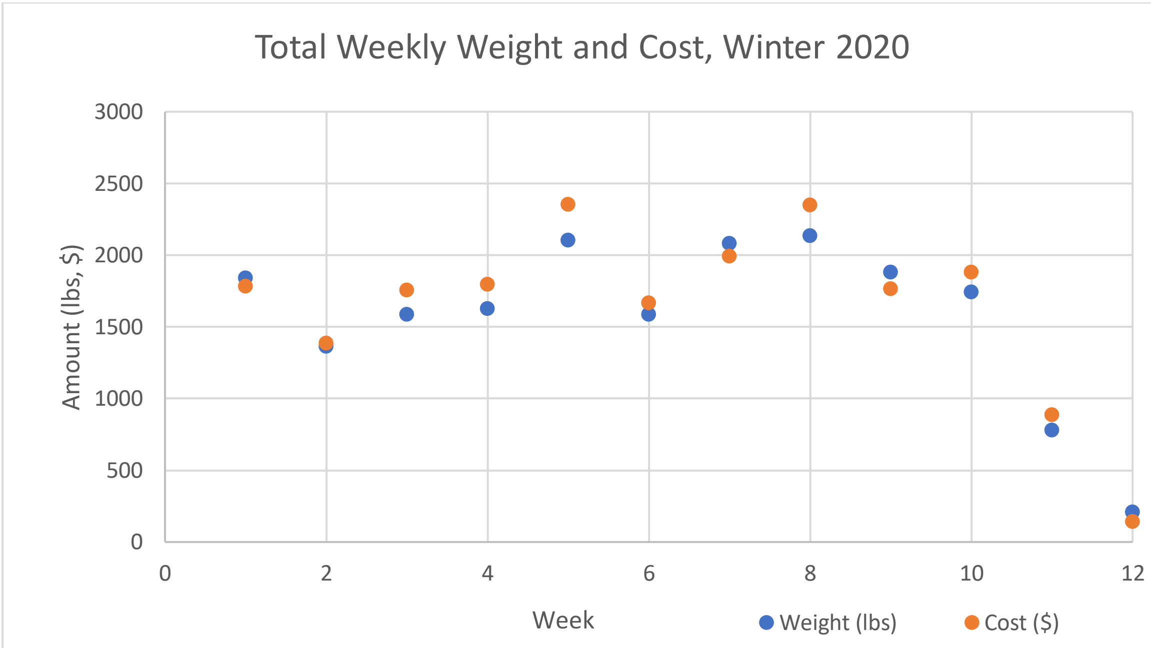

Figure 10: Weekly food waste totals for Winter 2020. Week 1 is the beginning of the academic term.

In the 2019 fiscal year, the cost per ton for recycling and compost hauling was $153.73. For FY 2020 the price was $287.61 per ton. For 2020, the total amount of compost was 291,882 lbs. (145.94 tons) at an annual cost of $30,583.62; thus, the cost per ton for only compost was $209.56. The total food waste for Nelson and Centennial Halls was 44,522.66. September to March was assumed to be roughly 50% of yearly waste – 145,941 total pounds – which means food waste from the two dining centers accounted for approximately 30.5% of campus waste.

iii. University Outreach

Each university had a unique story behind in-vessel implementation, with several commonalities. Georgia College's project began as a class research venture at the home of a professor and gradually expanded to a facility for all food waste on campus. Funding is provided from the student "green fee" which generates about $60,000 per year and also provides payment for student interns. At the University of Maine, the goal was to reduce cost and bring compost back to campus. The monetary investment totaled $475,000 and the university was paying $75,000 yearly for compost collection. The payback period was 7.5 years due to unforeseen additional costs, as the large scale of the project meant the unit was under designed and therefore required several upgrades and adjustments. Ohio University currently houses the largest in-vessel compost facility in the nation that can accommodate 100% of the campus's pre- and post-consumer dining waste. The initial total cost was $800,000, funded by an assortment of grants as well as the Facilities Management operational budget; an American Recovery and Reinvestment Act grant enabled the expansion of the project in 2012.

The successes for universities included improved sustainability, money saved, collaboration with a vast assortment of stakeholders, and establishment of the optimal compost ratios and conditions. In addition, the in-vessel systems provide opportunities for students to learn and take initiative. The University of Maine is now "able to close the loop on most organic material generated on campus. This has been an important concept for students to learn and see that it can be accomplished" (Mark Hutchinson, personal communication, 2020). Horse bedding from the campus equine center is used as bulking material, so everything that goes into the machine is generated on campus, and the product is used for UMaine's landscaping. Hutchinson also explained that he teaches classes on-site about compost, microbiology, soil health, and sustainability. Georgia College has a similar perspective about in-vessel success. According to their Chief Sustainability Officer, "the greatest success to me was getting this project off the ground and running. However, from an education standpoint, the greatest success would be the number of students that are interested in interning with the compost. Internships have become really competitive, especially in the last couple of years" (Lori Hamilton, personal communication, 2020).

Aside from generating funds and support for the project, which is difficult by nature, one of the primary challenges cited was maintaining cleanliness, particularly in terms of spilled food. Any uncovered material creates odors and attracts pests, which is not only displeasing but can be harmful to human health. However, Mark Hutchinson remarked that with a little care, site hygiene does not have to be a major problem. Another aspect that takes some patience and diligence is discernment of the optimal compost recipe with respect to the C:N ratio in balance with other conditions (i.e. temperature, moisture). Similarly, the viability of the compost must be tested before application and parameters adjusted as needed; this process is almost entirely trial and error which can prove arduous.

Interviews also discussed the role of students with in-vessel projects. Students were involved in the process of implementation on all three campuses and continue to be a part of the project. At Georgia College, the operation is entirely run by undergraduates as part of an internship program, which has become increasingly competitive. Other student responsibilities include tabling, awareness events, informational signs, and "bin goalies" to sort food court waste. Students also assist sustainability offices with research contribution and feedback on proposed systems.

The interviewed compost representatives offered valuable advice for universities in the early stages of in-vessel application. Georgia College has a training manual that they send electronically to all interns in addition to the hard copy kept on site. They are willing to share this manual as well as other training resources with the University of Denver. Other advice from colleges is to ensure plans include details, such as what additional materials (shovels, wheelbarrows, etc.) are required, where compost will be cured, and exactly how the product will be used. That being said, they also recommended being prepared to continually learn and adjust along the way, since maintenance is often self-taught. Sam Crowl of Ohio University also recommended to apply for permits to sell any excess compost and to contact local farms; otherwise, consider a waste-to-energy system.

iv. Solutions Exploration

Five potential solutions emerged upon examination of possibilities with company representatives who were willing to provide information about their products. Inquiries focused on operation, maintenance, size, price, ROIs, and input requirements. The highlights from these communications are depicted in **Table 1**.

Table 1: In-vessel compost solutions comparison

	BioCoTech	FOR Solutions	Rotoposter	Ecodrum	ORCA
What	Chambers w/ agitation unit	Rotary drum	Rotary drum	Rotary drum	Waste liquification
Price	$35,000 (+$5,000 ship)	$200,000	$51,290	$36,450	$21,229 (+$188/month)[1] Lease: 597/month
Size (LWH)	6.7' x 3' x 5.2' M1 Unit	26' x 6' x 11' Model 500	16' x 6.7' x 6.8' Model 540	No data Model 720	4.2' x 2.9' x 4.1' OG25
Processing Capacity	300 lbs/day	350 lbs/day (7 days/week)	430 lbs/day	600 lbs/day	25 lbs/hr [300 lbs in 12 hr]
Operation	Plug in, load, retrieve; computer panel	Plug in, load, retrieve	Plug in, load, retrieve	Plug/load/ retrieve; computer-controlled	Plug in and load
Maintenance	Bi-annual gear greasing, daily/ weekly checks for errors/ problems, basic cleaning	Few moving parts = minimal maintenance	No data	Built-in program tells when oil needs to be changed/ bushings need to be oiled	Service included every 2 months
Energy/ Power	200-240V, 50-60 Hz, 30A; 3.3 kW/h Max consumption	240V or 480V; 6000-8500 kWhrs; 304,657 BTU reduction[2]	2HP motor, runs 2hrs/day	220V, 20A; 1 hp motor	120V, 15A; 0.43 kWh usage
Water	n/a	n/a	No data	n/a	30 gallons/day
Timeframe	24 hrs (mature compost)	5 days (mature compost)	1-3 weeks +30 days to cure	2 weeks +30 days to cure[3]	Continual, runs until empty
Other Notes	need collection receptacle; no bulking; can buy hydraulic lift; university partnership offer[4]	need heating, scale, receptacle		need shelter; can make solar powered; willing to help work out details	only for food; no soil product; need grease trap, clear sewer line

Sizes and prices are based on recommendations from company representatives.

[1] For service; shipping cost is $1,100; 60-month lease, can also rent 36 months at $830
[2] From current practice, according to company-generated Return on Environment (ROE)
[3] Can take sample and test with A&L Laboratories to review C:N, fecal coliforms and compost material makeup
[4] Compost as a service, details in **Discussion**

VI. Discussion

Examination of food waste generated in DU's dining centers provides a baseline for decisions about in-vessel composting units. An understanding of how much food waste the university produces and when waste is highest informs not only the size of the unit but also the operation of the vessel. It should be noted that the analysis in this investigation is largely an estimation, given that Nagel Hall was not included and the dining facilities are shifting to use of the newly constructed Community Commons; all food service will be in one location which will make future waste analyses much more expedient. The comparison between the dollar amount and weight of food waste (approximately $1/lb) clearly illustrates the cost of discarded food to the university. The conversion can be used alongside Weigh the Waste initiatives to promote waste reduction. In addition to being environmentally and fiscally responsible, reduction in food waste would create added capacity in a vessel to process other compostable materials on campus.

Another outcome of the food waste analysis is board count insight. It is useful to look at how many meals are served, and the graphs depict a cyclical pattern of meal swipes with peaks mid-week and lows on weekends. Also, the number of swipes exhibit a strong correlation to food waste, as higher board counts correspond to more waste. Moreover, the waste/swipe graphs are almost identically shaped to the waste and cost graphs for both Fall 2019 and Winter 2020. This suggests that food waste increases disproportionately to the number of meals served; in other words, the waste attributed to a single meal swipe becomes larger with higher daily loads. More investigation is necessary, but one explanation is that consumer plate waste accounts for the extra waste per swipe.

The valuable insight from university representatives and their willingness to speak honestly about their experience with in-vessel composting suggests that while the practice is not without challenge, it is worthwhile to explore. Financially, the University of Maine had 7.5 yr payback period for $475,000 expense when paying $75,000 annually for compost collection. DU's annual compost collection cost in FY20 was $30,583.62 – just under half that of UMaine's - and the proposed solutions for DU are a fraction of the investment required for Maine's system. Thus, it appears likely that the payback period would be much shorter, regardless of the slight variations between each school's circumstances. In fact, according to an ROI from BioCoTech Americas, the break-even point is approximately 4 years, with an estimated $73,000 in savings after 10 years. In terms of success of the project, Ohio University was willing and able to expand their system after three years of operation which demonstrates the opportunity for growth. As for education, Georgia College's completely student-run project shows the potential for meaningful educational experiences. The internship program has become increasingly competitive and well-established as the system ages.

The most advantageous option is to partner with BioCoTech Americas. The 10 and 15-year ROI estimates of 221% and 381% respectively demonstrate the potential for significant reduction in waste expenditure. In addition to diminishing waste hauling costs, the technology has the capacity to generate approximately 13,500 pounds of rich compost annually, about 340 (40 lb.) bags worth $1,700. This will help establish a circular organic waste stream which is advantageous in terms of both practicality and sustainability. Moreover, it will reduce the need to purchase compost product for campus landscaping. In comparison to competitors, the M1 unit has a lower upfront cost than other companies and has a much smaller physical footprint. Also, the compost produced by the machine does not need to cure for several weeks before use, according to their website, which sets it apart from most machines, including the Rotoposter and the Ecodrum. Also, BCTA says that bulking material is not required for their technology, which would eliminate one of the primary nuances to in-vessel composting. The machine is expected to function well for at least 15 years and requires minimal maintenance, so the investment is worthwhile.

In complement to the predicted benefits of the BioSpeed unit, the BCTA Director of Operations has proposed a Compost as a Service (CaaS) arrangement in which a company partner will cover the entire cost of the M1 unit and installation. The university will pay an agreed upon amount per ton of waste for a set term. The price will be negotiated according to current hauling costs at DU (so as to ensure expenditure reduction), expected waste volume, labor costs (if applicable), and BioCoTech's target internal rate of return. Additional components of the contract include a confirmed minimum time period, customer performance incentives to increase diversion efforts, expected waste quantities for the time period, and liquidated damages. As DU alumni, the founders of BioCoTech Americas are excited about the potential to install this technology at their alma mater; they have expressed their willingness to collaborate significantly with the university in the process of implementation.

The ORCA unit provides another option for the university to improve waste management on campus. The OG25 is the least expensive option of those explored in this study and is the cleanest method of managing food waste. Its size is quite manageable (4.2' x 2.9' x 4.1') and it requires less operation input than the larger vessel systems. Its kitchen location proves convenient for loading (since the dining facility produces the food) and it is much cleaner than the other vessels. ORCA units have scales with which to weigh all inputs, and the data is stored to create diversion reports. The ORCA does not produce soil product for campus grounds, since the discharge is primarily water. However, a study is underway at the University of Southern Florida that aims to test the effluence of an ORCA machine to determine whether it can be turned into fertilizer. This type of project could potentially be conducted by students at DU as well, which would be a move towards the closed loop of the other vessel options. The ORCA requires water unlike the other units, but it is possible to connect the machine to a gray water system which could help reduce consumption.

A third alternative is the Ecodrum rotary composter. The price is comparable to full purchase of the BioCoTech M1, but with a greater capacity. Dimensions were not given but the unit is indeed larger than the M1, and clearly the ORCA as well. Thus, the Model 720 would likely be the best option if the primary objective is to incorporate all of campus compost initially. The national sales manager communicated his willingness to work out details for the project such as shelter for the machine, recipe with respect to carbon and nitrogen content, and the possibility to utilize solar power. The Ecodrum model does require curing, unlike the previously discussed options, and waste spends more time in the machine. Fortunately, Ecodrum offers to send compost samples to a lab for testing viability. Finally, the Model 720 has a low energy cost for its size in comparison to other models.

Based on the findings of this study, DU would benefit from the implementation of an in-vessel composting system. The concept has been successful in reduction of waste hauling costs and improvement of campus sustainability at universities across the nation. Decentralization of waste management works to eradicate hefty financial demands, excessive fuel usage, and extensive land use through the creation of a circular waste path. In addition, the technology provides a number of valuable opportunities for student involvement and campus-wide education.

VII. Conclusion

In-vessel composting offers a feasible means to process organic waste at the University of Denver. The technology would help divert landfill waste, reduce hauling costs, facilitate a more sustainable campus, and provide meaningful educational opportunities. The best option moving forward is to partner with BioCoTech Americas in a compost as a service arrangement. Secondarily, the ORCA unit offers a convenient food waste focused approach. Lastly, the Ecodrum rotary composter was determined to be the third best option. This study analyzed waste data, current university systems, and possible vessel options. The research provides insight into DU's waste profile, factors to account for in the process of implementation, and recommended solutions to pursue for in-vessel composting.

Investment in vessel composting technology proves a promising option to address waste challenges. For DU, it would be a promising step towards achievement of the university's many sustainability goals. In addition, DU would have an opportunity to be a part of the solution to America's food waste problem. As the human population grows, it becomes increasingly difficult but imperative to manage waste effectively. Vessel composting is one approach that is a means to process large amounts of organic waste with attention to the health of humans and the environment.

VIII. Recommendations

Future studies should include analysis of additional quarters of food waste data to generate a more accurate waste profile, especially with the Community Commons opens as of Winter 2021. The waste stream will likely shift given that all dining will be in one place; the setup is certainly more convenient for use of in-vessel technology since collection will be straightforward and loading dock space is limited. In addition, a more complete financial assessment should be completed that includes numbers on purchase of compost products, more detailed waste hauling cost information, and prices of extra requirement prices for a given solution once details are solidified. It is worthy of note that compost companies are more willing to provide specific cost information as clients become more serious about buying their machines. Finally, the results of stakeholder surveys should be considered. Brief questionnaires will be given to research presentation attendees. Also, the graduate study lead by Dinko Hanaan Dinko seeks to learn about DU opinions with respect to sustainability and will include inquiries about compost and the potential to implement in-vessel systems. Results from his surveys and interviews will certainly assist as the university moves forward with compost solutions.

It is recommended that a plan be established with respect to extra equipment and accommodations (i.e. cement pad, electrical work, basic tools such as shovels and PPE, storage bins, collection receptacles, who will operate and what compensation, energy usage). This will likely occur while potential options are discussed in pursuit of a decision. If a decision is made to implement one of the proposed solutions, an operational training system should be developed, hopefully with involvement of students and likely as a facet of the Center for Sustainability. Fortunately, Georgia College has supplied thorough training material that university personnel are free to use as a reference. In addition, testing of compost qualities and C:N ratio trial and error should occur upon implementation of a vessel system; this could potentially be one of many student research ventures. As intricacies become ironed out, it may prove beneficial to look into renting out the machine or selling the service when the waste stream is thin (such as during winter or summer breaks). This could help generate revenue and ensure that the technology does not sit idle.

The results of this study are intended to be used by university stakeholders in the pursuit of environmentally and fiscally optimal compost solutions for food waste in particular. It is hoped that the information will point the university in the direction of implementing an in-vessel compost system and alleviate the challenges of the process. Additionally, this study may exist as a resource for other universities or municipalities interested in compost solutions.

IX. Acknowledgements

I would like to extend many thanks to Chad King, my advisor for the investigation. His guidance and expertise were greatly appreciated and without his assistance the project likely would have lacked direction. I am also immensely grateful for the willingness of both university representatives and composter vendors to speak with me and respond to a steady flow of questions. I truly appreciate their time and their interest in this work.

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XI. Appendices

Appendix A: List of Successful Contacts

Note: Dates reflect point of initial contact, all communications were ongoing from then

9-16 Lori Hamilton, Georgia College Chief Sustainability Officer

lori.hamilton@gcsu.edu

9-18 Daniel Dixon, University of Maine Director of Sustainability

daniel.dixon@maine.edu

9-21 Sam Crowl, Ohio University Associate Director of Sustainability

crowls1@ohio.edu

10-20 Mark Hutchinson, UMaine Extension Professor, Maine Compost School

mhutch@maine.edu

10-23 Kurt Good, Rotary Composters Founding Partner

kurt@rotarycomposters.com

10-28 Byron Irwin, Ecodrum National Sales Manager

byron@ecodrumcomposter.com

10-30 Barbara Garcia, ORCA Southeast Acct. Executive, Sustainability Specialist

bgarcia@feedtheorca.com

11-2 Tanner Farrow, BioCoTech Americas Director of Operations

tanner@biocotechamericas.com

11-2 Nick Smith-Sebasto, FOR Solutions Founder and Executive Chairman

dr.nick@forsolutionsllc.com

Appendix B: University Interview Questions

These questions were used as a general guideline for outreach to schools currently utilizing in-vessel composting. Wording was modified to suit each context and some queries were answered from university websites.

1. Story of how the system was implemented – what research went into it, who was involved, where did the funds come from, how was the decision made about which vessel to purchase?
2. Where is the compost for the vessel coming from? Landscaping/cafeterias/ household/other?
3. What has been the greatest success of the project? (i.e. finances, sustainability, student involvement, etc.)
4. What maintenance is required to ensure safe and efficient operation of the system?
5. How is the campus population educated about compost collection? What is the role of students in waste management?
6. What are the primary challenges of running a vessel compost system?
7. What else should a university considering an in-vessel system know or consider?

Appendix C: ROI Forms

393 Corona St. # 524
Denver, CO, 80218
United States of America

+1 (208) 721 -0991
www.biocotechamericas.com

BIOCOTECH Americas

Reducing **waste.** Replenishing **resources.**

To: Hanna Gaertner, University of Denver (DU)

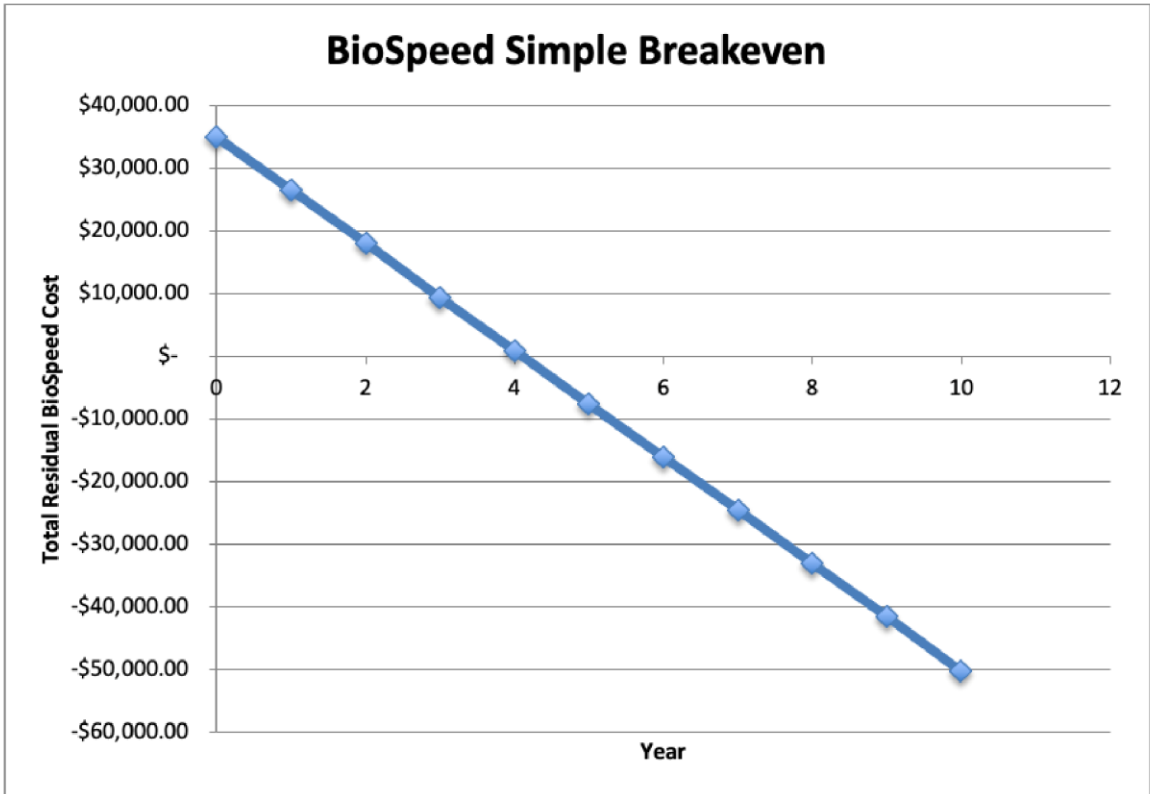
From: Tanner Farrow, BioCoTech Americas (BCTA)

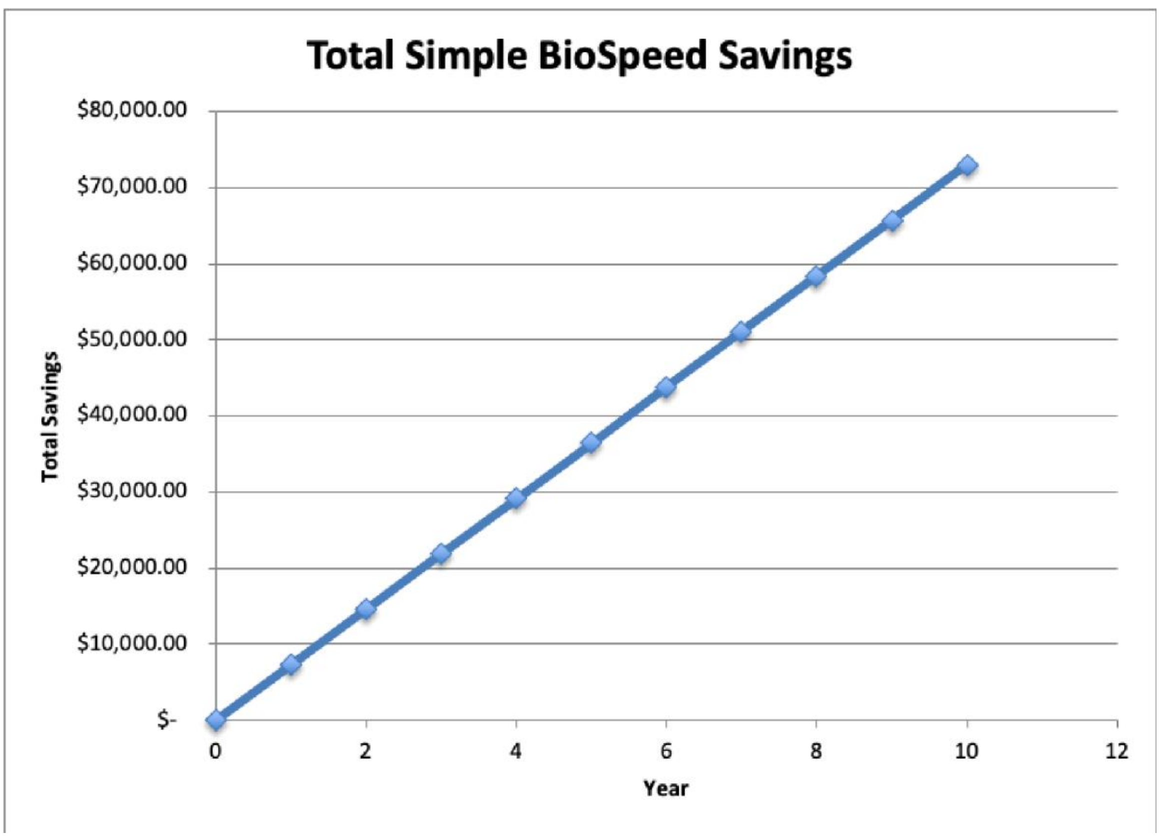
RE: Campus Composting Project

Thank you for your interest in the BioSpeed products. In congruence with DU's sustainable efforts, the integration of BioSpeed products will optimize the campus's organic waste diversion efforts, eliminate the environmental and financial costs of waste collection services, and provide a nutrient-rich soil that can be utilized across campus.

Financial Analysis

Based on data provided by DU, the campus diverts generates ~3.21 tons of food waste per month at cost of $209.00 per ton. In order to effectively manage the food waste stream, DU will require the integration of an M1 machine. At the current food waste volume, the M1 will be operating at 89% of daily capacity, offering an additional 11% capacity for increased diversion efforts. On an up-front basis, at a cost of $35,000, the estimated break-even point is at roughly 4 years, with savings of $73,000 at ten years Because the BioSpeed units are made from stainless steel and premium Nord Motor components, the expected lifespan of the units is long, thus a 10 and 15-year ROI are used. The 10-year ROI is 221% with a 15-year ROI of 381%. (*these estimates assume a $.07kWh, a tax rate of 35%, and a 10-year straight line depreciation).


BioSpeed Simple Breakeven
$40,000.00
$30,000.00
$20,000.00
$10,000.00
$-
-$10,000.00
-$20,000.00
-$30,000.00
-$40,000.00
-$50,000.00
-$60,000.00
0
2
4
6
8
10
12
Total Residual BioSpeed Cost
Year


Total Simple BioSpeed Savings
$80,000.00
$70,000.00
$60,000.00
$50,000.00
$40,000.00
$30,000.00
$20,000.00
$10,000.00
$-
0
2
4
6
8
10
12
Total Savings
Year

Additional Savings

In addition to incurring substantial hauling costs, DU is also spending about $2,000 per ton on food that is ultimately wasted. At BCTA, we believe that food waste shouldn't be considered waste, but rather a valuable resource. Based on DU's current food waste stream, the M1 has the potential to generate about 13,500 lbs. of rich, healthy compost.

This would generate roughly 340, 40-pound bags of compost, valued at $1,700.

Remarks

BioSpeed in-vessel, composting technology is the leading solution for all of your organic waste needs. It is our mission to decentralize traditional waste management in an effort to eradicate the indefinite economic burden, excessive fuel usage, and land intensive requirements of collection companies, while completing a circular approach. At BCTA we are confident in the BioSpeed technology and guarantee the quality as well as functionality of our products.

We are sincerely excited about the prospect of working with DU.

Best,
Tanner Farrow, Director of Operations

BIOCOTECH Americas

Date:

QUOTE [Nov. 2, 2020]

393 Corona St. #524 Denver, CO 80218 +1 (208) 721-0991 biocotechamericas.com	**Quote Number:**	DU_001_M1
	Invoice Date:	November 2, 2020
	Bill To:	
	Address:	2199 S University Blvd, Denver, CO 80208

1. Description of Goods

Description	Units	Cost Per Unit	Amount
BioSpeed M1	1	$ 35,000.00	$ 35,000.00
Installation, Training, Commissioning	1	inc.	$ -
Shipping	1	$ 5,000.00	$ 5,000.00
		-	

Quote Valid for 10 weeks	Invoice Subtotal	$ 40,000.00
	Applicable Sales Tax	-
We look forward to doing business with you!	Deposit	-
	Other	-

TOTAL BALANCE DUE $40,000.00

ORCA™

Rate Per Ton: $209.56

LEASE MODEL

Tons/ Month	Waste Cost	ORCA Model	Lease Cost	Utility Cost	Monthly Cost	Monthly Savings	Annual Savings	5-year Savings
4.5	$943	OG25	$597	$43	$640	$303	$3,636	$18,181

PURCHASE MODEL - FULL SERVICE PLAN

Tons/ Month	Waste Cost	ORCA Model	Purchase Price	Service Cost	Utility Cost	Monthly Cost	Monthly Savings	Payback Period	5-year Savings	8-year Savings
4.5	$943	OG25	$21,229	$188	$43	$231	$712	29.8	$21,492	$47,125

FOR SOLUTIONS
FOOD • ORGANICS • RECYCLING

ROI + ROE

RETURN ON INVESTMENT & RETURN ON ENVIRONMENT ANALYSES AND REPORT

prepared for University of Denver, November 3, 2020

RETURN ON INVESTMENT (ROI) ANALYSIS

Date:	11/03/20

Model Recommendation	500

Generator Information			
Generator:	University of Denver		
URL:	https://www.du.edu/		
Location:	Denver	CO	80208

Contact Information	
Name:	Hanna Gaertner
Title:	Student
Phone:	651-900-1813
E-Mail:	hanna.gaertner@du.edu

Purchase Price:	$200,000
10-Year Purchase ROI:	114%
20-Year Purchase ROI:	377%
10-Year Purchase Cash Flow:	$194,420
20-Year Purchase Cash Flow:	$710,547
7-Year Lease Payment:	$2,826.78
10-Year Lease ROI:	81%
20-Year Lease ROI:	307%
10-year Lease Cash Flow:	$156,558
20-year Lease Cash Flow:	$659,664

Discarded Uneaten Food	
Weight:	300
Units:	lbs.
Period:	1. day
Load Days/Wk:	7
Avg. Daily Load:	300
Annual (tons):	55

Disposal Fees		
Fee	Cost	Frequency
Hauling		
Fee	Cost	Frequency
Tipping		
Fee	Cost	Frequency
Combined	$36,000	3. Yearly

Total Annual Disposal Costs
$36,000

Site Prep Costs	
Shelter:	
Concrete Pad:	
Electricity:	
Plumbing:	

Annual Operating Costs	
Electricity (system only):	$682
Water (shelter only):	
Maintenance (system only):	
Bulking Agent/Carbon Source:	

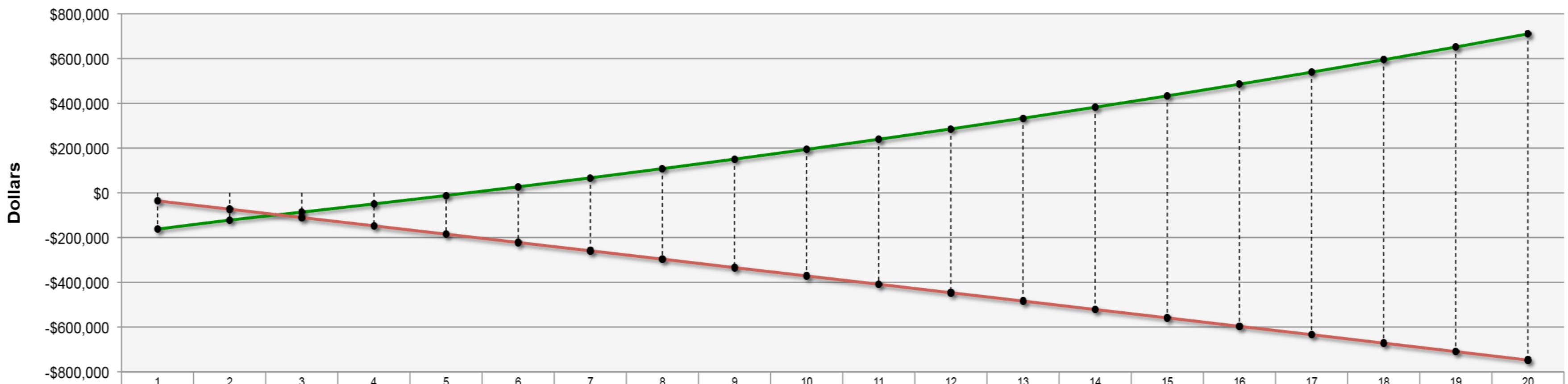
Annual Labor Costs	
$/hr:	
hrs/wk:	
TOTAL:	

Annual Savings	
Fertilizer:	
Mulch:	
Top Soil:	
Compost:	$2,730

Annual Revenue - Fees	
Hauling:	
Tipping:	

Annual Revenue - Compost Sales			
Wholesale		Retail	
Cubic Yard:		Cubic Yard:	
Packaged:		Packaged:	

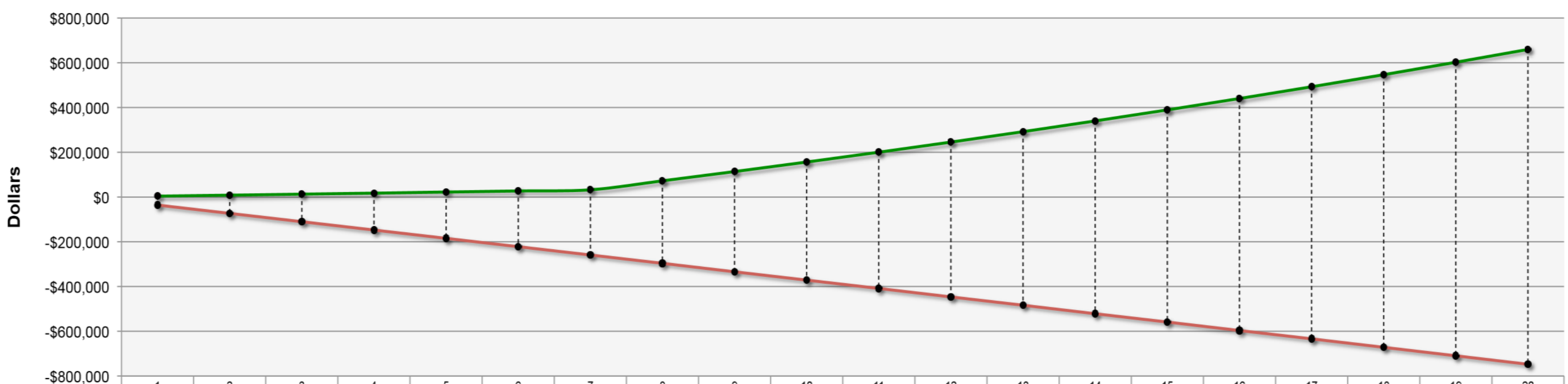
Purchase Cummulative Cash Flow Versus Current Practice: 20-Year Projections



Years	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Purchase	-$161,952	-$121,621	-$86,080	-$49,473	-$11,768	$27,068	$67,070	$108,271	$150,709	$194,420	$239,442	$285,814	$333,578	$382,775	$433,448	$485,641	$539,399	$594,771	$651,803	$710,547
Current Practice	-$36,000	-$73,080	-$110,192	-$147,338	-$184,518	-$221,734	-$258,986	-$296,275	-$333,604	-$370,972	-$408,381	-$445,832	-$483,327	-$520,867	-$558,453	-$596,087	-$633,769	-$671,503	-$709,288	-$747,126

Years

7-Year Lease Cummulative Cash Flow Versus Current Practice: 20-Year Projections



Years	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Lease	$4,127	$8,501	$13,006	$17,647	$22,427	$27,350	$32,421	$72,583	$113,950	$156,558	$200,444	$245,647	$292,206	$340,161	$389,555	$440,432	$492,834	$546,808	$602,402	$659,664
Current Practice	-$36,000	-$73,080	-$110,192	-$147,338	-$184,518	-$221,734	-$258,986	-$296,275	-$333,604	-$370,972	-$408,381	-$445,832	-$483,327	-$520,867	-$558,453	-$596,087	-$633,769	-$671,503	-$709,288	-$747,126

Years

RETURN ON ENVIRONMENT (ROE) ANALYSIS

Discarded Uneaten Food (tons/yr)	55	Potential Compost Production (tons/yr)	55
Disposal Destination	3. off-site composting	Distance to Disposal Site (miles)	13

Net Annual Emissions, Tons CO_2 Equivalent (TCO_2E)	-2

Effect of Composting on Carbon Storage and Greenhouse Gas Emissions

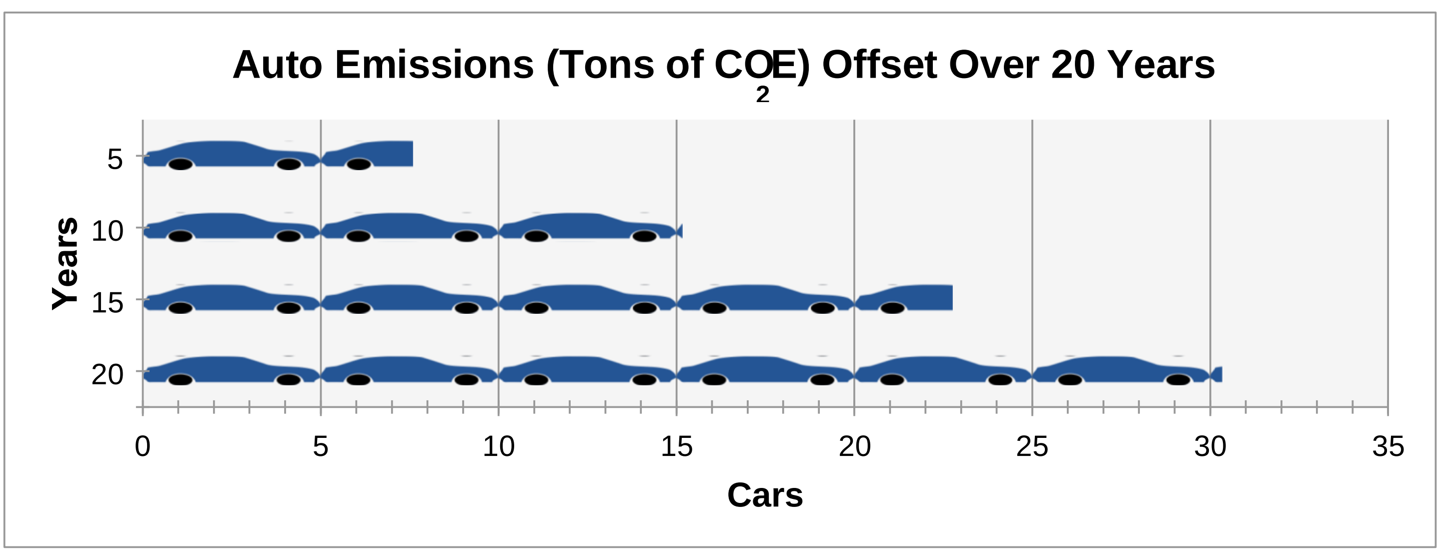
Net Annual Carbon Storage from Compost Use (TCO_2E)	8	
Net Annual Carbon Emissions Reduction (TCO_2E)	-9	Negative values = emissions reduction or carbon storage.
Annual Difference from Current Practice (TCO_2E)	-8	Negative values = emissions reduction or carbon storage.
Emissions from Number of Passenger Cars Offset	2	
Number of Trees That Would Sequester This Much CO_2 Annually	303	

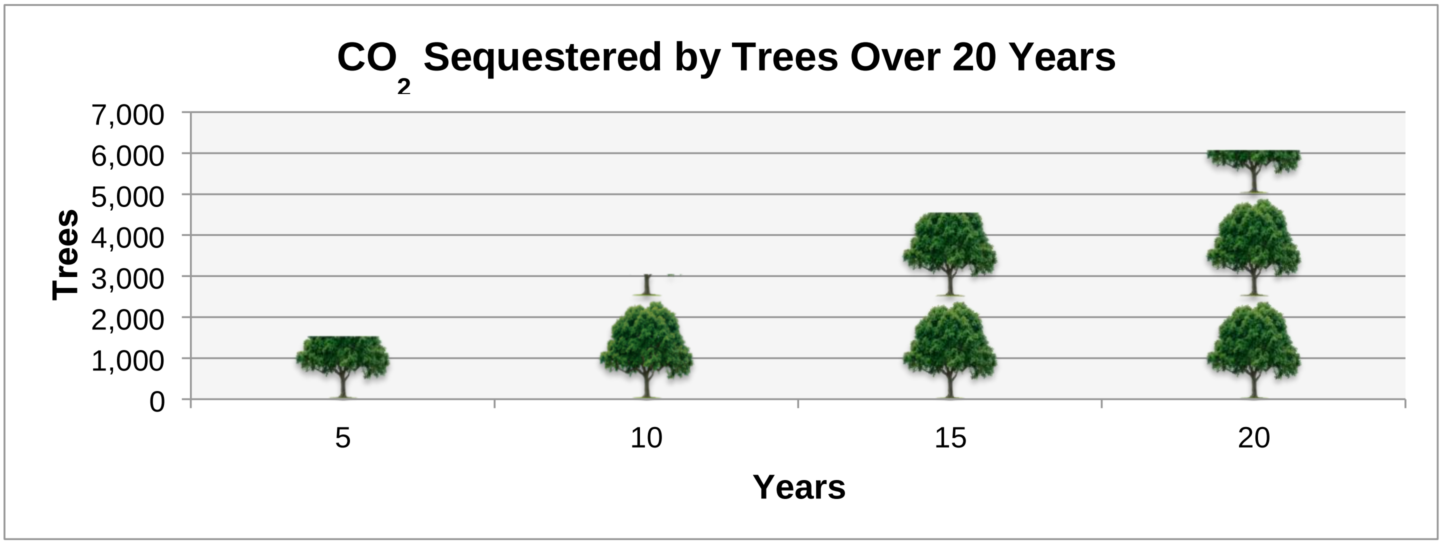
Effect of on-Site Composting on Energy Use (in BTUs)

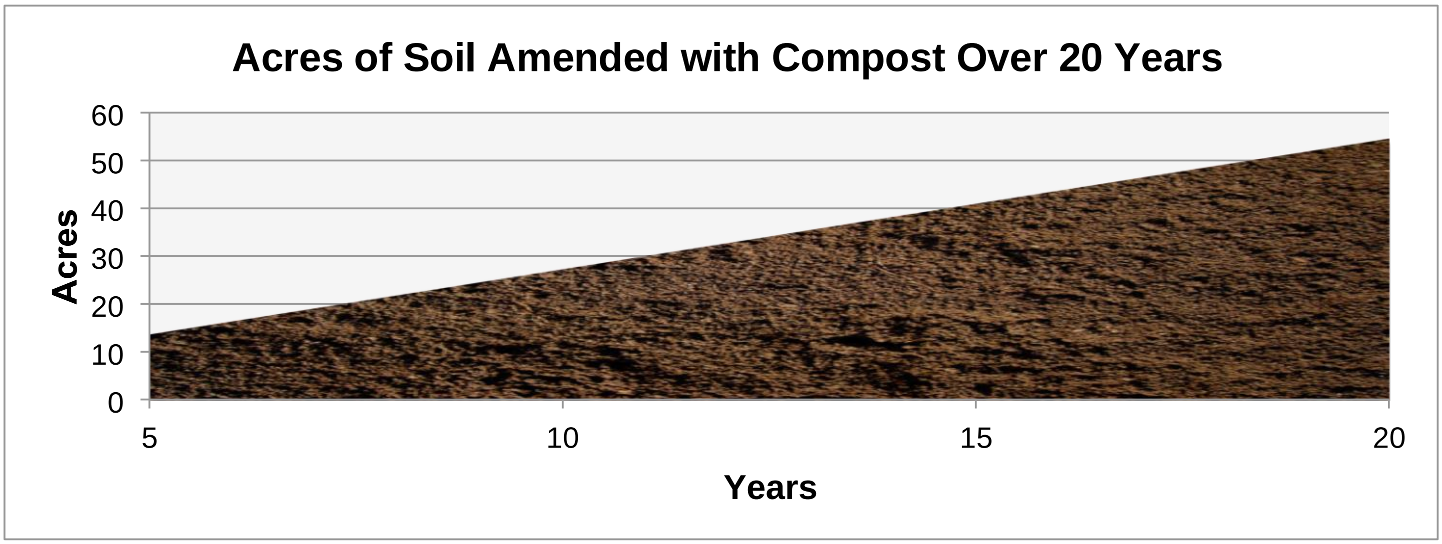
Annual Energy Use by Current Practice	28,796,040		
Annual Energy Use by FOR Solutions System	28,491,383	Avg. Annual Household Energy Use	38,488,958
Annual Reduction from Current Practice	304,657	Household Energy Use Offset	0

Effect of Compost on Soil Revitalization

Acres of Land That Could be Treated Annually with Compost Generated	3




CO2 Sequestered by Trees Over 20 Years
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Trees
5
10
15
20
Years


Acres of Soil Amended with Compost Over 20 Years
60
50
40
30
20
10
0
Acres
5
10
15
20
Years

Appendix D: Vessel Diagrams

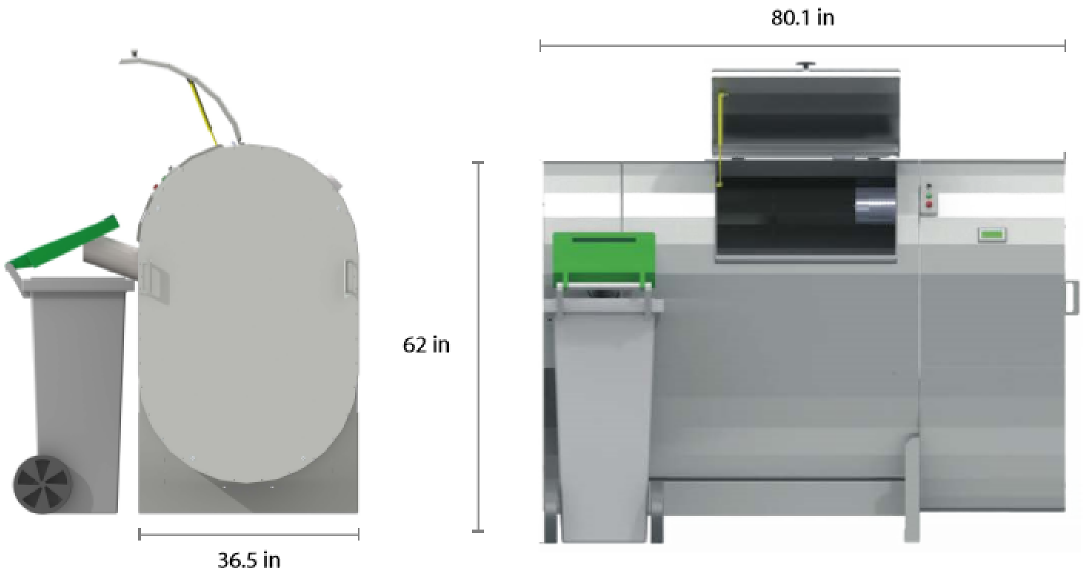
BioCoTech
Biologic Waste Management & Consulting

BioSpeed M1 Composting

HOW IT WORKS

BioSpeed composting process is based on a method that facilitates microbes operateing under optimal conditions. All microbes used in BioSpeed system is further developed mesophilic and thermophilic microbes, including the cellulose degrading. This means that they are working at a temperature of up to 80 degrees C. These parameters enables continuous degradation of organic material to powder very quickly. This provides large capacity in compact machines.Pre defined process controls ensures optimal degradation of organic waste.

BIOSPEED | M1



Our *small capacity* machine, the BioSpeed M1 is capable of processing 150 + liters/day of waste.

Equipped with:

Automated computer system, two composting chambers, one compost collection chamber and 20-Ft prefabricated containerized options.

INSTALLATION
Indoor/Outdoor protected from weather

DIMENSIONS
L 80.1 in, H 62 in, D 36.5 in

AUTOMATIC COMPUTER
Temperature control
Air extraction
PLC display and control
Sequence controlled dispensing of finished compost
Adjunstable dispensing time interval

DAILY CAPACITY
150 Lts, .2 Yds3

ELECTRICAL CONSUMPTION
Main Motor: 0.75 kW
Heat Tracing: 2 kW
Fan: 0.18 kW
Output Motor: .25 kW
Max consumption: 3.3 kW/h

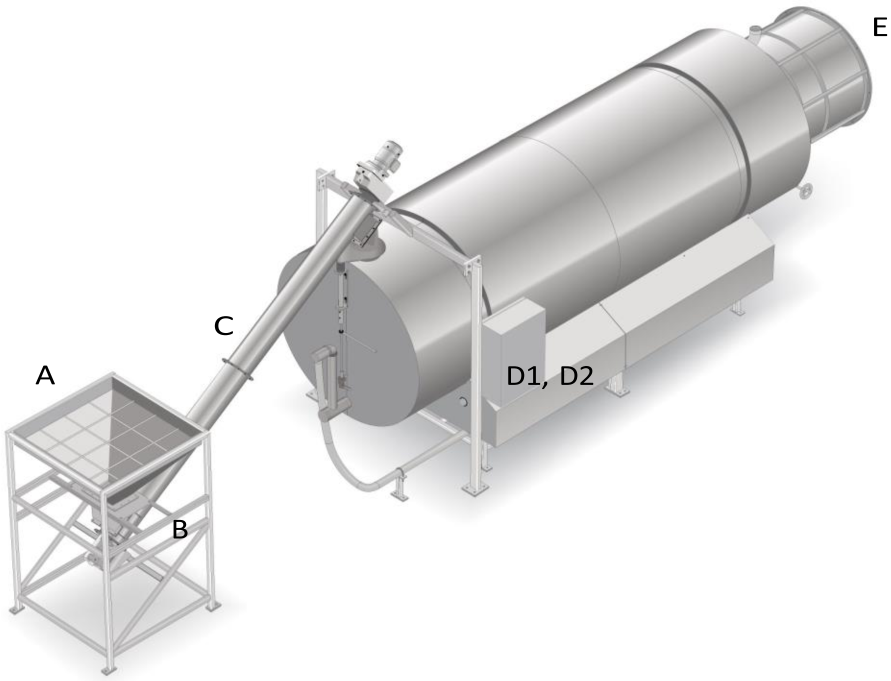
POWER SUPPLY
200-240 vac, 50-60 Hz, 30 Amp

NET WEIGHT
1287 Lbs

ADITIONAL FEATURES
Lift for containers, customizations upon request
Cloud connectivity and control

SAFETY SYSTEM
*All our models come with a standarized safety system composed of:
Individual motor alarm feedback, time and component display, safety switch for high Temp. & heating elements hatch safety switch during operation, manual emergency stop, automatic standby mode, automatic repowering after loss of power, alarm and event recorder on display, fault indicator lamp.

FOR Solutions Patented Aerobic In-Vessel Rotary Drum Composting Process



A: Weighed discarded uneaten food and weighed bulking agent/carbon source (BA/CS) placed into shredder hopper

B: Discarded uneaten food and BA/CS (feedstock) volume reduced by shredder

C: Enclosed screw auger conveys feedstock from the shredder discharge to the input port of the digestion vessel

D: In a 5-day through-process, feedstock is transformed into nutrient-dense compost

D1: Process control panel assures that vessel rotates on a prescribed timing

D2: Process control panel assures that vessel receives enforced aeration on a prescribed timing and of a prescribed volume

E: Compost is discharged from the vessel through a screener attached immediately adjacent to the digestion vessel discharge port

ORCA MODEL OG15

MODEL OG15 SPECIFICATIONS

REQUIRED SUPPLIES ORCA Biochips, microorganisms & wipers	**DIMENSIONS** L 31.89" x D 26.77" x H 45.52"
WEIGHT OF ORCA 350 lbs	**HOURLY PROCESSING CAPACITY** Average of 15 lbs per hour
ELECTRICAL USAGE 0.43 kwh	**WATER CONSUMPTION** 30 gallons per day* *Calculated based on an incoming flow rate of 2 gallons per minute*
INSTALLATION REQUIREMENTS Electrical - Dedicated 120V / 1 Phase (15 amp) Electrical Cord Length - 36 - 48 inches Water - Cold 1/2 inch water connection Drain - 2 inch sanitary drain complete with grease interceptor Additional Space - A minimum of 24 inches of free space must be available on both sides of the machine	

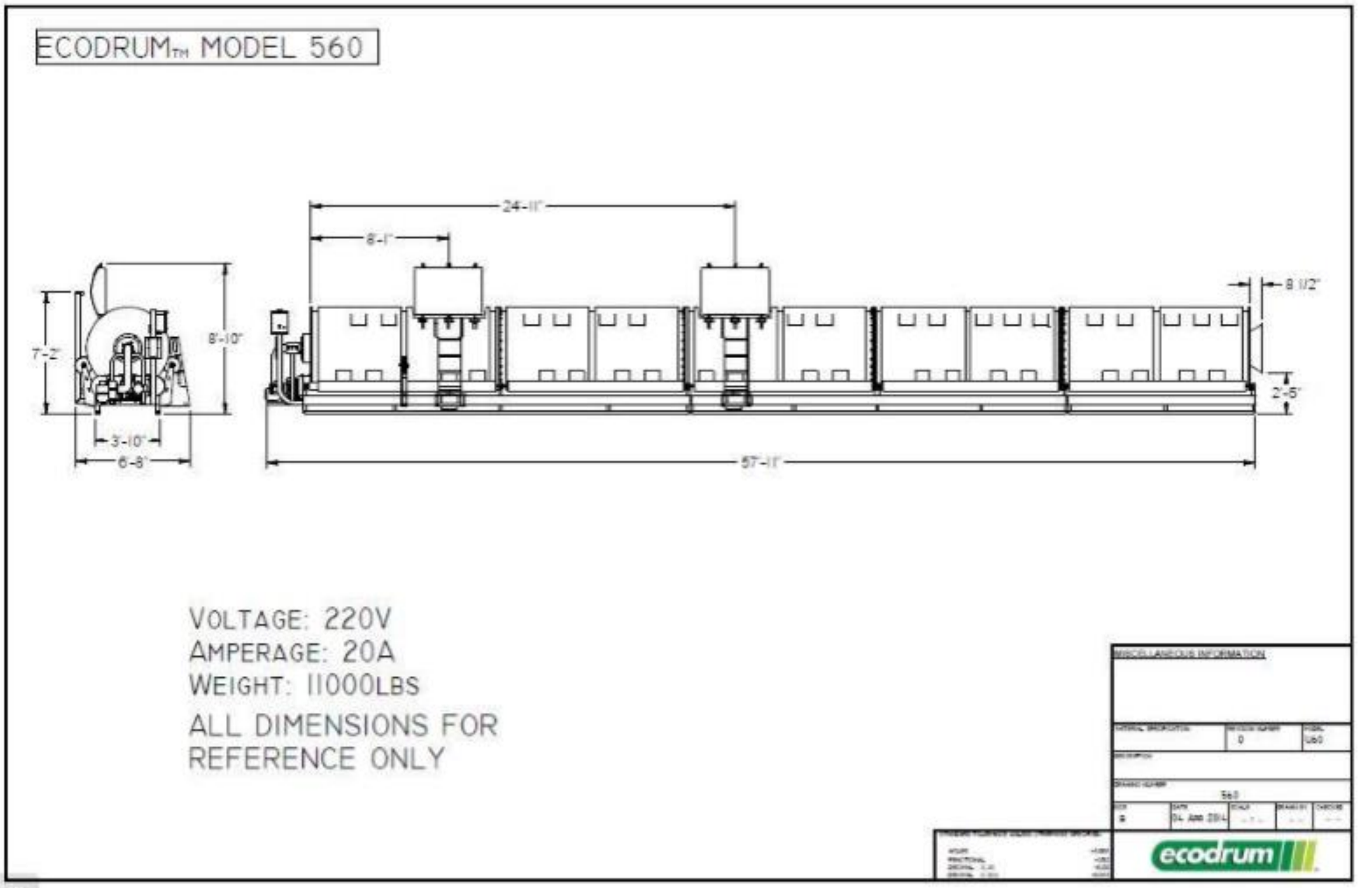
FEATURES

- Aerobically processes an average of 15 lbs of food waste per hour
- On-board scales for diversion tracking, with an extractable data file through Ethernet or USB
- Online customer portal for diversion goal tracking and reporting
- Food grade stainless steel construction
- Safety control turns off machine when door is opened
- Food waste can be added continually within the units designated capacity limits.
- Engineered for quiet operation, with a touch screen HMI
- Utilizes ORCA Biochips to hold high levels of microorganisms that digest organic waste
- Effluent from machine tested safe to enter wastewater system

CE

Note: The OG15 is one size smaller than what DU would require (the OG25). The OG25 sheet was not provided. The specifications and shape are similar, which is why the smaller unit diagram was included. The actual dimensions are 4.2’ x 2.9’ x 4.1’ (LxWxH).

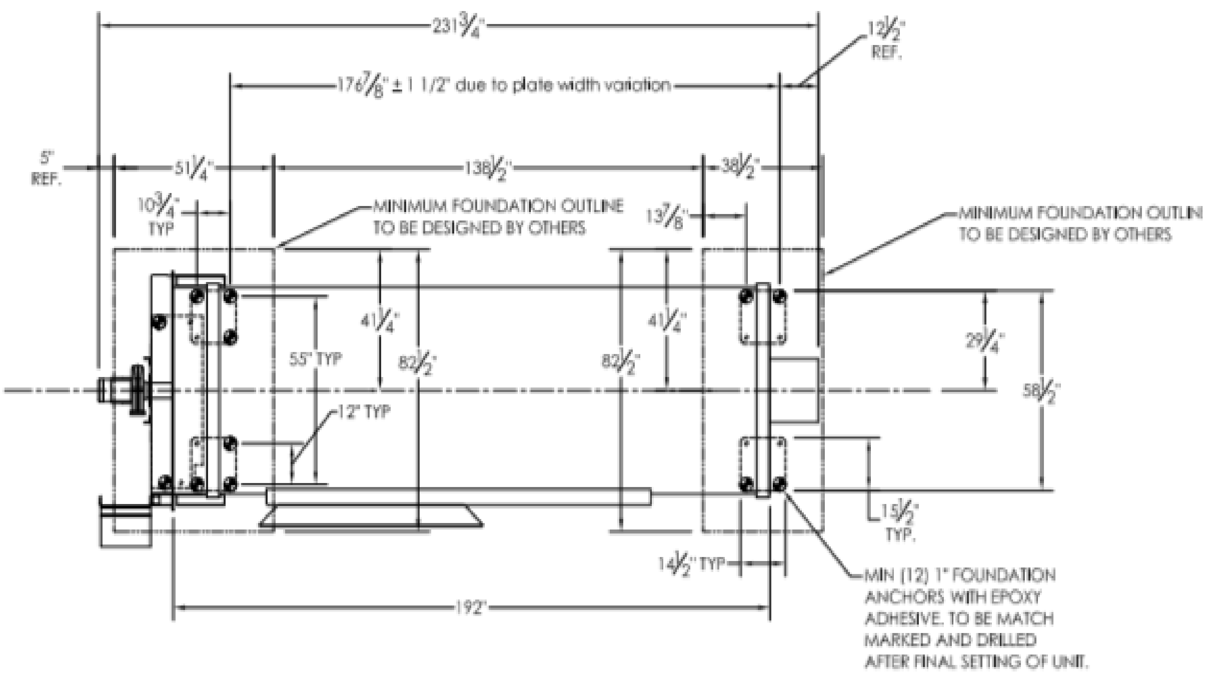
ORCA WASTEWATER LIFECYCLE
ORCA
Effluent
WATER 75%
Water is released as the food waste is broken down. It is conserved and then returned to the watershed.
CARBS, FATS & PROTEINS 20%
Carbs, fats and protein represent the energy contained in food waste that is converted via anaerobic digestion into a renewable fuel called Bio-Methane.
MINERALS 5%
Minerals are non-degradeable but conserved and returned to soils.
Wastewater Treatment Plant
Anaerobic Digester
WATERSHED
BIOGAS
LAND APPLICATION

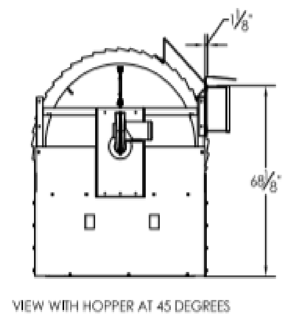


NOTE: The proposed Model 720 is even larger than the Model 560 in this diagram but is of similar shape and requires the same power inputs.

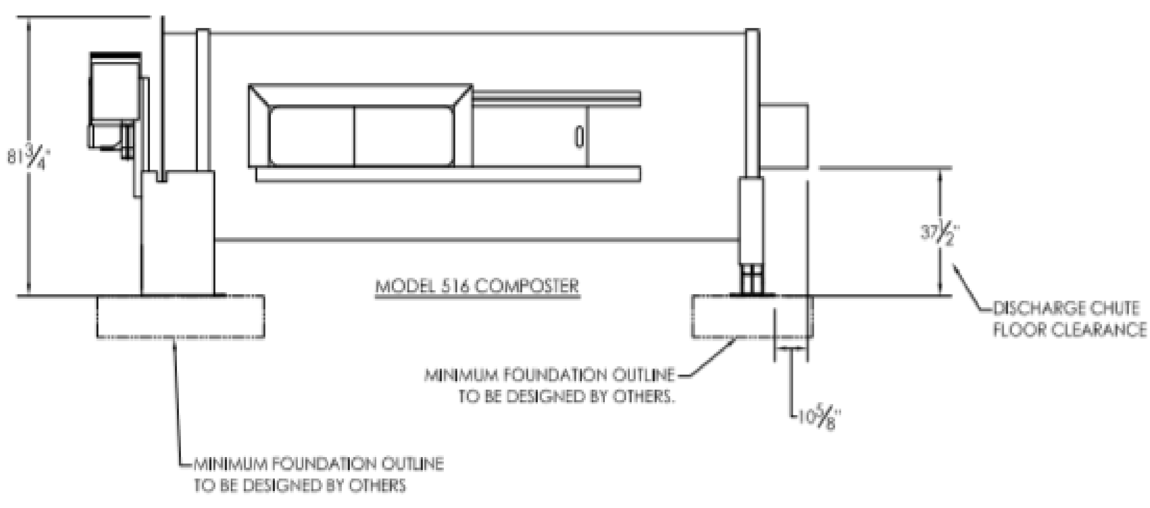
NOTES:
1. 5,830 LB/SQFT FOUNDATION LOAD PER MOUNTING PAD.
2. TOTAL OPERATING WEIGHT OF THE MODEL 516 COMPOSTER IS 27,300 LBS. EMPTY WEIGHT = 6,184 LBS.
3. ALL MANDATORY ANCHOR LOCATIONS ARE INDICATED BY THIS SYMBOL - ⊕
4. ELECTRICAL UTILITY SUPPLY - 1Ph 230V, 12A MAX DRAW. DEDICATED CIRCUIT BREAKER TO BE INSTALLED AND SIZED PER LOCAL CODE.
5. THIS DRAWING SHOWS THE 16 FT LONG MODEL. LONGER OPTIONS ARE AVAILABLE IN 8FT INCREMENTS.
6. OPERATING CAPACITY @ 80% FULL = 8.43 CU YARD

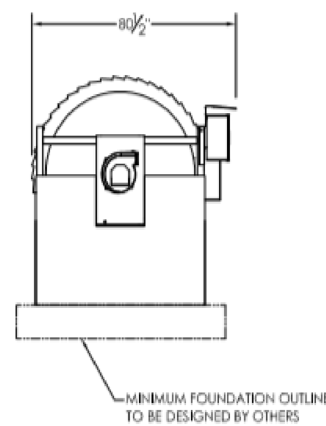
ROTARY COMPOSTERS LLC
DENVER PA





VIEW WITH HOPPER AT 45 DEGREES





MACHINE TOLERANCES
BREAK ALL SHARP EDGES

X.	±1/32
X.X	±.020
X.XX	±.010
X.XXX	±.005

FRACTIONAL DIM ± 1/32
ANGLES ± 30 MIN

FABRICATION TOLERANCES

0° TO 30°	±1/16"
30° TO 120°	±1/8"
> 120°	±3/16"

BREAK ALL SHARP EDGES

MODEL-540 COMPOSTER (SIDE LOAD)
540 ARCHITECTURAL BLOCKS
& TECHNICAL SPECIFICATIONS

Weight:

SCALE	DATE	APPD.
NONE	10-6-12	
DRAWN DG	CHKD. DG	APPD.

DWG NO. 540-ARCH-SL

Appendix E: Stakeholder Feedback Questionnaire and Summary

1. What facet of the university do you represent?
2. On a scale of 1-10, with 10 being the highest, how would you rate your level of interest in implementing an in-vessel composting system at DU?
3. What do you see as the advantages of in-vessel solutions?
4. What are the primary disadvantages?
5. In terms of compost management, what should the university's next steps be?

Results: pending