Unfantastic Plastic: How Has Single-Use Plastic Reduction Affected Waste Management at the University of Virginia?

A Technical Report submitted to the Department of Engineering Systems and Environment

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

Pollution from plastic waste is a major problem affecting Earth's ecosystems and human health. Plastic's abundance and ability to bioaccumulate threatens humans and wildlife. In recent years, the United States has developed a notable reliance on single-use plastics (SUPs). To combat this, Governor Ralph Northam of Virginia ordered that all state agencies immediately discontinue purchase and distribution of SUPs and completely phase out the use of SUPs by 2025 per Virginia Executive Order 77 (Office of the Governor, 2021). As a public institution of higher education, the University of Virginia (UVA) had to adapt its waste management strategy to comply with this executive order. Executive Order 77 has since been rescinded and replaced by Virginia Executive Order 17 by current Governor Glenn Youngkin, but the University has chosen to continue to eliminate SUPs from the waste stream (Office of the Governor, 2022).

UVA is at a crossroads with composting. The recent ban on SUPs across the Commonwealth pushes the University to adapt the status quo waste management system to allow for more compostable materials in the waste stream. The UVA Sustainability 2020-2030 Plan is another driving factor in reducing the waste to 30% of the University's 2010 tonnage by 2030, while simultaneously striving to make University operations carbon neutral by 2030 and fossil fuel-free by 2050. In addition to reducing landfilled waste to 30% of the 2010 tonnage, the University strives to reduce water use and reactive emissions by 30%, and increase sustainable food purchases to 30% of the 2010 values. The third and final goal outlined in the Sustainability Plan is to partner with the community to accelerate collaborative initiatives to advance sustainable, equitable, and healthy places for all (UVA, 2020).

Leaders at UVA Facilities Management (FM) and the Office for Sustainability (OFS) emphasized the importance of the third sustainability goal and have characterized the success of waste management related goals as paramount to the success of the other sustainability goals. Students, staff, and faculty play a large role in UVA's current waste production, and can be part of the solution on the road to meeting UVA's Sustainability goals. Members of the UVA community care about sustainability. The role of waste reduction is paramount in sustainability as a whole. Combining the operations, knowledge and power of entities like OFS, FM, and Recycling with the passion and energy of students and faculty is the best way to reach UVA's sustainability goals. Waste management can be a stepping stone for interest and commitment to sustainability at the individual level.This can translate into the amount of resources allocated and prioritization of sustainable practices at large entities like public universities.

Each year, the University Office for Sustainability publishes an annual report tracking the progress of the sustainability goals. The University of Virginia Annual Sustainability Report for 2020-2021 indicates that the amount of landfilled waste has not been reduced to 30% (UVA Sustainability, 2021). While greenhouse gas emissions appear to be meeting goals, there is no particular trend with waste reduction shown by the Sustainability Report; it certainly does not indicate that UVA will be able to meet the goal of reducing waste to 30% of the 2010 tonnage (Figure 1).

Fig. 1 UVA Sustainability landfilled waste graphic

Assuming that UVA continues with a 2.8% yearly reduction in waste, UVA will still not meet its goal of reducing waste to 30%. This is indicated by a graph created by the student team which extrapolates the 2.8% reduction to 2030 (Figure 2).

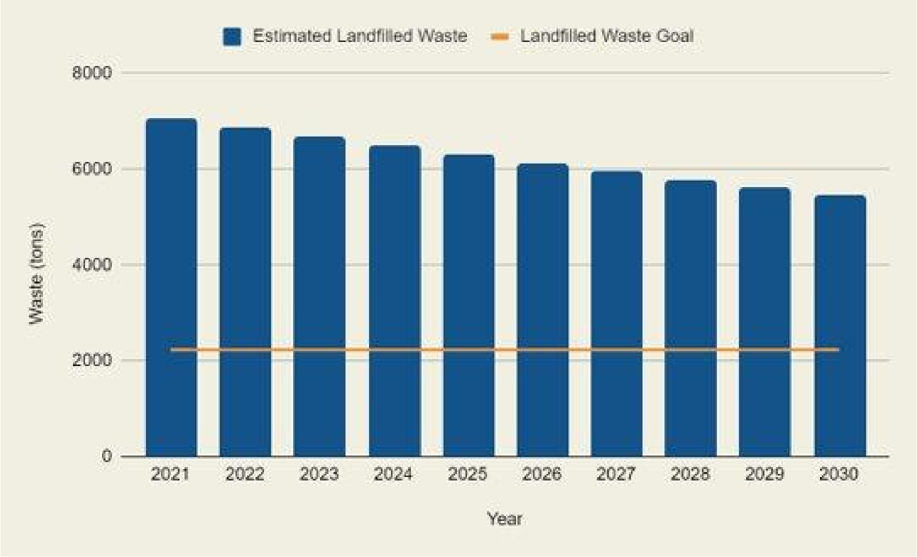

Fig. 2 Extrapolated landfilled waste assuming 2.8% annual reduction

The project team hypothesized that the implementation of the SUP ban would introduce a larger percentage of compostables to the waste stream. This hypothesis was supported by the 2022 waste audit shown in Figure 4. Figures 3 and 4 below come from the 2018 and 2022 waste audits conducted by the CE 3120 Solid Waste Management classes. These waste audits were performed on the dumpster located on the Olsson Hall loading dock. Data was calculated by Dr. Ivey-Burden (Burden, et al., 2022). As shown in the figures, there is a drastic difference in the waste stream composition between the two years. Notably, compostable waste increased from

47% to 60% of the waste stream, and non-divertible landfilled waste decreased from 36% to only 16% of the total waste. With this information, reducing landfilled waste to 30% of the 2010 tonnage seems possible with increased waste diversion.

Fig. 3 & 4 CE3120 Waste Audits

The 2021-2022 “Un-fantastic Plastics” capstone project team consists of seven members committed to addressing the challenges of UVA Sustainability Goals on behalf of the University of Virginia Office of Sustainability and Facilities Management by April 2022. The team members involved in this project are Dr. Lisa Colosi Peterson and Dr. Lindsay Ivey-Burden and University students Madeleine Alwine, Madison Crouch, Taylor Donches, Shannon Hepp, and Geneva Lanzetta. Meeting schedules and goals for the duration of the project can be viewed in Appendix A. Relevant contacts for the project can be found in Appendix B. The team’s main objectives for the entire project are the following:

> Phase 1: Analyze the solid waste management (SWM) system used in 2018 by the University against the backdrop of relevant priorities.

> Phase 2: Analyze the SWM system used in 2021 and model possible systems configurations of interest to Facilities Management to determine their impact on relevant parameters.

Phase 1 was the priority for Fall 2021 and was finalized in February 2022. The target parameters for Phase 1 include total cost, GWP, and net energy usage across one landfill, two compost facilities, and five different streams of recyclables. A major limitation is the lack of facility-specific data across all waste streams. These values were estimated using scholarly investigation, which limits the certainty the project team can have in the model results. Energy and GWP from processing and operations at the landfill and composting facilities were not accounted for in the model. Phase 2 was addressed entirely in Spring 2022 and expected to continue with a new project team in the Fall 2022.

Methodology

Parameters

The team developed a methodology for creating the model and identified assumptions that reflect the following parameters: landfilled mass in tonnage, composted mass in tonnage, global warming potential (GWP) in metric tons of carbon dioxide equivalent (MTCO2E), energy in million British Thermal Units (mmBTU), and cost in U.S. dollars (USD). Each of these parameters are used with input data collected and provided by UVA Facilities Management (Appendix C, D, E) and sourced from scholarly investigation. Each of the key parameters are calculated for landfilling at Amelia Maplewood Landfill (Amelia) owned and operated by Waste Management in Jetersville, Virginia; composting at Blackbear Composting (Blackbear) in

Crimora, Virginia; composting at Panorama Paydirt (Panorama) in Earlysville, Virginia; and recycling for various recyclable streams that are sent to Sonoco in Raleigh, North Carolina and Gerdau Recycling. Recyclable waste streams include glass, metals (aluminum), cardboard, plastics (#1-7), and scrap metals (the only stream sent to Gerdau). Facility specific information for recycling operations and transportation were not accounted for. Rather, the 2016 EPA WARM model was used to estimate the impact of recycling. Please see the *Assumptions* section for more information.

The model was developed in Excel spreadsheets. **The model can be referenced in Digital Appendix F.** The model has three main output tabs: ‘Active Model’, ‘2021 Model Input & Results’, ‘2018 Model Input & Results’. The main inputs for the model are monetary cost and waste tonnage for each waste stream. Instructions for using the model are indicated in each of these tabs. The results from these tabs are graphed in the ‘Graphs & Figures’ tab. The ‘Transportation’ tab can also be modified with user-specific inputs to reflect more facility specific information and alternative strategies for waste management. The ‘Post-ban Alternative Scenarios’ tab is linked to ‘Scenarios 2-5’ tabs and graphs these scenarios against each other. The ‘Estimated Values’ tab indicates the coefficients assumed for any estimated variables and sources where those estimations can be referenced.

Assumptions

The target parameters were evaluated for calendar year (CY) 2018 to represent the status-quo and for CY 2021 to represent post-ban waste management. The model was originally created using Microsoft Excel software and Google Sheets collaborative network technology, but was transitioned to UVA Box for the final version to allow for greater Microsoft Excel compatibility and shareability.

The team used ranges of historical and projected data to evaluate the target parameters. Limitations in the development of the model include a lack of site specific emissions data for the landfill, composting, and recycling facilities. This led to the use of scholarly articles and EPA estimates for these numbers. Another limitation was the lack of a comprehensive waste audit for the University. Dr. Ivey-Burden's CE 3120 Solid Waste Management class conducted a waste audit in Spring 2018 and Spring 2022 from the dumpster at the Olsson Hall loading dock, each on a Friday (respectively, Figures 3 and 4). These waste audits were used to estimate UVA's waste composition. The findings from these audits may not reflect the waste stream breakdown of the entire University.

Assumptions were made for all four waste streams: landfilling at Amelia, composting at Blackbear, composting at Panorama, and the combination of all the recycling streams. Specific coefficients for different variables were estimated or sourced from scholarly investigation and can either be found in specific cell notes in the Excel model or are outlined in the 'Estimated Values (inc. Transp.)' tab of the model.

Landfill Assumptions

Landfilling waste is split into two transportation categories. The first category is the majority of the waste which is transported directly to Amelia. The second category is that which is transported first to IVY Materials Utilization Center (Ivy MUC) and then to Amelia. Transportation was based on the amount of trips per year trucks would have to take to dispose of all the landfillable waste based on the waste tonnages provided by UVA Facilities Management for CY 2018 and CY 2021. Emissions for carbon dioxide (CO2) are attributed to both the transportation and the decomposition of the waste in the landfill. The total amount of waste that Amelia received in 2020 was 963,718 tons (Horne & Donches, 2022). Information regarding Amelia Operations discussed by Horne and Donches can be found in Digital Appendix G. Using the respective tonnages for 2018 and 2021, the percentage of waste sent to Amelia from UVA that comprised the total amount of waste landfilled at Amelia was calculated. Emissions for nitrous oxide (N2O) and methane (CH4) were reported by the landfill and scaled down to account only for the percentage of Amelia's waste that comes from UVA. GWP was then calculated by including the emissions from transportation and decomposition. The Total Cost reported was based on billing data received from Facilities Management (Digital Appendix H). The average amount paid to Waste Management per ton over the year 2018 was $182.64. This value was used to estimate the landfilling cost for 2021 and all additional alternative scenarios. The Energy reported in the total energy used for the landfill comes solely from transportation. The Energy reported in the total energy produced from the landfill comes from an estimate based on the percentage of waste that comes from UVA and the 'amount of houses' powered by energy from Amelia's Ingeneco in-house generation per year. A thorough calculation of this energy estimate can be found in the 'Estimated Values (inc. Transp.)' tab. This model does not consider source reduction or the value of diverting volume from the landfill. Estimated values for these calculations are outlined in the 'Estimated Values (inc. Transp.)' tab of the model.

Compost Assumptions

Blackbear receives all composted food waste from UVA. Transportation emissions are based on trucking details outlined in the 'Transportation' tab of the model. Values for decomposition emissions are sourced from scholarly investigation and can be referenced in the 'Estimated Values (inc. Transp.)' tab of the model spreadsheet. Emissions in the 'Active Model' are attributed to transportation CO2 and decomposition CO2, N2O, and CH4. Emissions due to operations and processing at the facility itself were not accounted for in this model. The cost for roll-off carts, transportation, and tipping at Blackbear Composting was $178 per ton of compost according to Sonny Beale at UVA Facilities Management (Beale et al., 2021).   Energy usage is attributed solely to transportation.

Panorama currently receives no compostable waste from UVA but is of interest as an alternative composting facility due to its closer location to the University. Transportation emissions are based on trucking details outlined in the 'Transportation' tab of the model. Values for decomposition emissions are sourced from scholarly investigation and can be referenced in the 'Estimated Values (inc. Transp.)' tab of the model spreadsheet. Emissions in the 'Active Model' are attributed to transportation CO2 and decomposition CO2, N2O, and CH4. Emissions due to operations and processing at the facility itself were not accounted for in this model. The cost for tipping is valued at $145 per ton of compost according to Sonny Beale at UVA Facilities Management (Beale et al., 2021). Were UVA to acquire trucks or a service to transport compost to Panorama, the closer distance to the facility may contribute less to total GWP and Energy usage but the capital costs would increase. The cost can be modified in the cost input cell in the model to test this alternative in the 'Active Model' tab. Energy usage is attributed solely to transportation.

Limitations on the composting calculations include the decomposition emissions being sourced only from scholarly investigation. The N2O value, in particular, is quite variable and contributes significantly to total GWP. Further investigation into this value by measuring gas values with a gas flux chamber on site would help to refine this model. The model does not consider the waste reduction value of diverting the volume of the waste from the landfill, the potential biological fuel use of organic matter, the carbon sequestration benefits of finished compost, or source reduction by keeping organic matter in circulation.

Recycling Assumptions

Recycled glass, cardboard, all plastics, and aluminum metals are sent to Sonoco recycling facility. Recycled scrap metal is sent primarily to Gerdau. Glass is first sent to Rivanna Solid Waste Authority and then to Sonoco. These facilities were not specifically used in calculating any values in the model but could be used in future iterations for better estimations. Rather, the 2016 version of the EPA WARM model was used to determine coefficients for recycling processing and transportation for each of the aforementioned recyclable streams. Details for how these coefficients were applied to the model are outlined in the 'Estimated Values (inc. Transp.)' tab of the model spreadsheet. These coefficients for GWP and Energy were then multiplied by the tonnages of the recyclable streams to calculate the GWP produced from recycling processes, the GWP saved by recycling instead of manufacturing from virgin materials, the energy used to recycle the materials, and the energy saved from recycling instead of manufacturing from virgin materials. The WARM model develops the coefficients for their model based on the entire life-cycle of the materials. The Unfantastic Plastics team model aims to characterize only the end-of-life waste management of materials; however, it was determined to be valuable to include the total life-cycle of recycling considering the value of keeping the material in circulation, rather than treating the recyclable materials as single-use. This may contribute to why the graphs noted in the *Results* section of this report show recycling to contribute significantly more to target parameters than landfilling or composting. This model does not include source reduction.

Deliverables

Major project deliverables include: a status quo analysis; a post-ban analysis; analysis of hypothetical post-ban scenarios; comparison of the target parameters of the status-quo, post-ban, and alternative scenarios; and an identification of potential alternatives for sustainable materials management (SMM). An additional alternative scenario zooms in on the composting facilities using 2018 tonnages of yard waste and food waste to determine the impact of the two options on target parameters. These results are summarized in this report. Specifically, UVA Facilities Management is interested in the impact of different composting facilities on UVA Sustainability goals.

Results

Status Quo Pre-Ban

Waste streams were separated and compared against the backdrop of UVA's current sustainability goals. The Status-Quo Model (labeled '2018 Inputs & Results' in the Excel spreadsheet) estimated a total annual cost of \$1,594,000, total net energy usage of -40,990 mmBTU, and a total GWP of 1,710 MTCO2E. The negative net energy usage indicates that more energy was produced by LFGTE production and saved from recycling than was consumed across the entire SWM system in 2018. These values will be compared to the Phase 2 results to determine how UVA Waste Management is progressing toward the 2020-2030 Sustainability Goals.

Figure 5 below shows the post-sorting breakdown of UVA's waste for the year 2018. The vast majority of UVA's waste is landfilled, which explains why landfilling has a much larger impact in total, when composting seems to have a greater impact per ton.

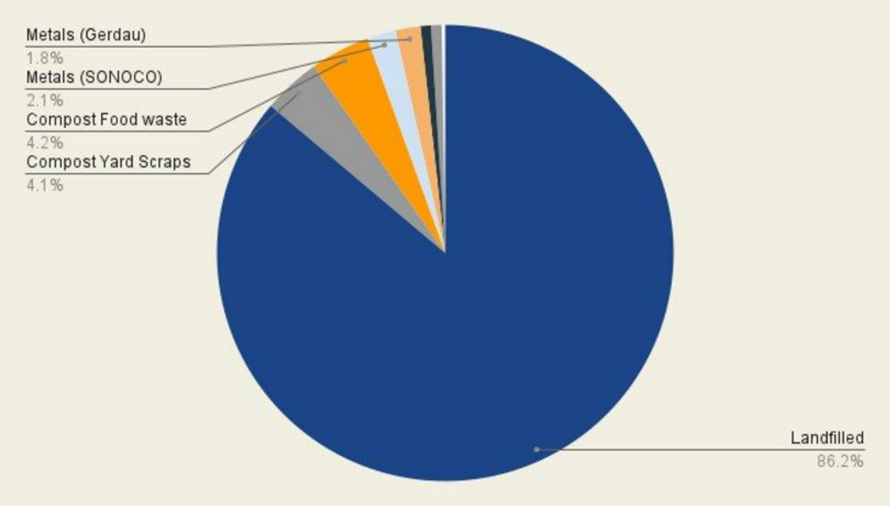

Fig. 5 UVA Waste Breakdown post-Sorting 2018

Post-SUP Ban

The 2021 Post-Ban Model (labeled '2021 Inputs & Results' in the Excel spreadsheet) estimated a total annual cost of $1,423,000, total net energy usage of -39,190 mmBTU, and a total GWP of 1,580 MTCO2E. The cost and GWP values have decreased since 2018 due to a slight decline in the waste tonnages for the landfill and compost waste streams. The decrease in landfilled waste also caused the net energy usage to increase (become less negative), as less energy is being produced from landfill gas. Figure 6 below shows the post-sorting waste breakdown for 2021. The waste stream composition has not changed significantly since 2018, with still the vast majority of waste being landfilled.

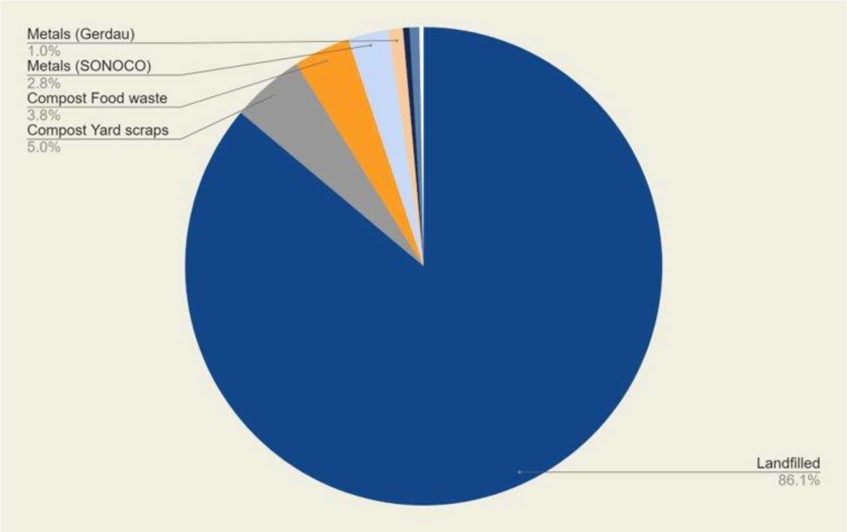

Fig. 6 UVA Waste Breakdown Post-Sorting 2021

Pre- and post-ban Comparison

Figure 7 shows that landfills have the advantage of producing energy, whereas composting does not. It also shows that the energy required to recycle (shown as Recycling (direct)) UVA's recyclables is less than the energy required to manufacture the same materials from virgin materials. The recycling savings are significant and are shown by 'Recycle (SAVINGS)' in the graphs below. It is important to note that the estimates for recycling account for the entire life-cycle of the recycled material because it continues to be processed, transported, discarded, and remade. Future investigation may desire to scale down the recycling values to an annual basis, if possible and of interest to relevant parties. The composting data also did not consider the production of finished compost sold by Blackbear that can offset GWP and energy usage for traditional fertilizer and soil (EPA, 2016). The model also shows that although landfilling contributes more GWP in total, compost contributes slightly more GWP when the waste streams are normalized per ton of respective waste (Figure 8). However, it is important to consider the relative proportions of waste that are landfilled versus composted.

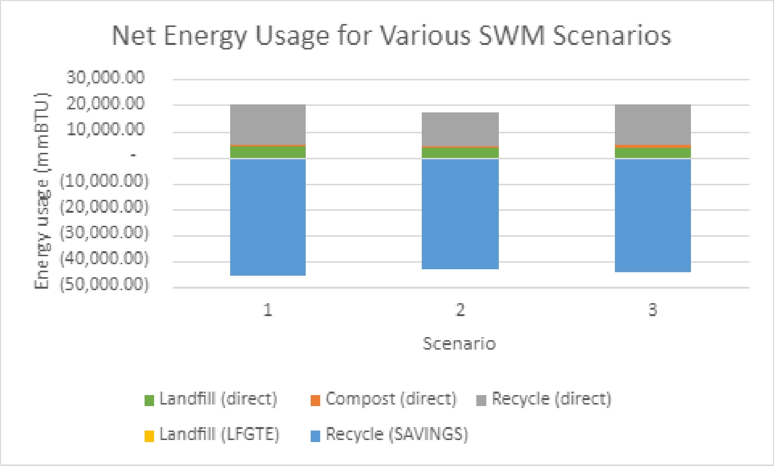

Fig. 7 Net Energy Usage for Various SWM Scenarios

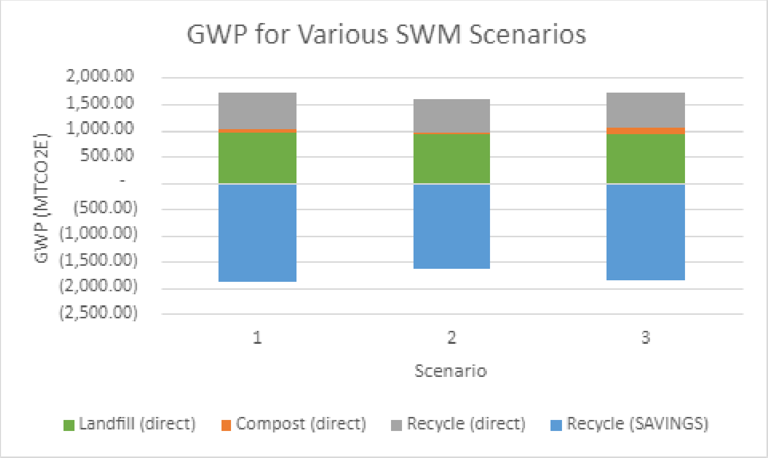

Fig. 8 GWP for Various SWM Scenarios

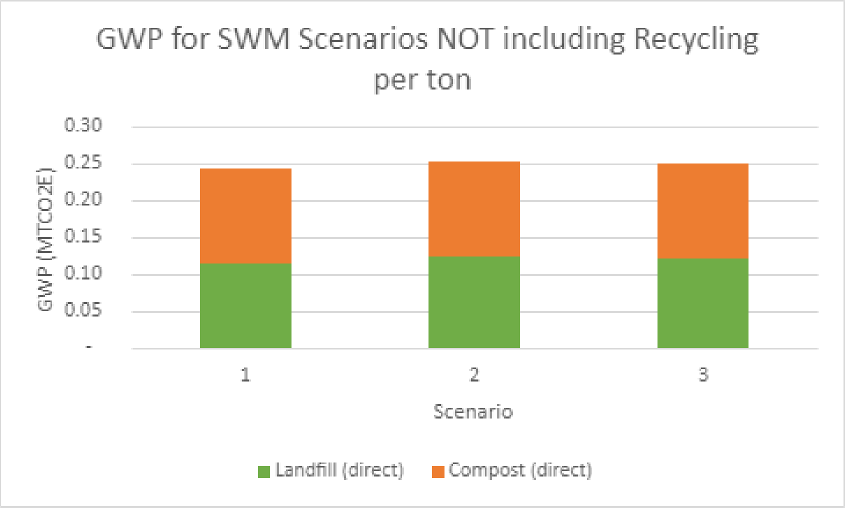

Fig. 9 GWP Breakdown of Landfilling and Composting

Transportation is a prominent factor in waste management. Transportation GWP contributes 68% of the overall landfill GWP, whereas the composting GWP consists mainly of decomposition emissions, with transportation accounting for only 15% of overall GWP. Please note that operations emissions of the landfill and transfer station were not included in the model. Recycling transportation emissions were factored into the recycling data obtained from the EPA WARM model. It was found that for all recycling waste streams the total GWP, including transportation and processing, contributed less GWP than the transportation and processing of the corresponding virgin materials.

Scenarios

The project team modeled the following post-SUP ban scenarios:

1. Plastic mass does not change, i.e. 2018 status quo
2. Plastic mass decreases by 50% and is replaced by composted compostables
3. Plastic mass decreases by 50% and is not replaced (e.g. refillable water bottles)

4. Plastic mass decreases by 50% and is replaced by aluminum alternatives
5. Plastic mass decreases by 50% and is replaced by landfilled compostables

The amount of plastic in the waste stream was estimated by adding the landfilled and recycled plastics together. The mass of landfilled plastic was extrapolated by multiplying the total landfilled waste by 10%, the percentage of plastic in the landfill from the 2018 waste audit, and was calculated to be 836 tons. This was then added to the amount of plastic recycled by UVA, 71.6 tons, to estimate the total plastic in UVA's waste stream, 907.6 tons. It is estimated that single use plastics make up about 50% of the total plastic waste, so we chose to analyze scenarios with a 50% reduction in plastic mass following the ban. These numbers can be changed later to reflect more accurate values if needed. The calculated mass of plastic was then divided in half to result in 35.88 tons of recycled plastic and 418 tons of landfilled plastic. This number was then removed from the two waste streams and added to the waste stream specified in the scenario. For example, Scenario 2 would remove 35.88 tons of plastic from 'Recycled Plastics' and 418 tons from 'Landfill' and add 453.88 tons to 'Compost: Blackbear.' Please note that this estimation does not account for the difference in weight of the polylactic acid (PLA), aluminum, and other numbered plastic packaging, nor does this estimation account for the difference in emissions from PLA, aluminum, and other numbered plastics.

GWP

The four scenarios were analyzed to determine the change in total GWP, total cost, and net energy usage. The baseline Scenario 1 reads a GWP of 1,709 MTCO2E. As shown in Figure 10, the total GWP was highest for Scenario 4, replacing plastic with aluminum at 2,566

MTCO2E. This is due to aluminum requiring the most energy and emissions to be recycled but does not account for the fact that aluminum can be recycled numerous times over its life-cycle. Scenario 2 which involved plastic replacement with composted compostables has the second largest GWP at 1,737 MTCO2E. Landfilling compostables and no replacement of plastic indicate GWP at, respectively, 1,683 and 1,679 MTCO2E.Compared to the Status-Quo Scenario 1, replacement with aluminum and composted compostables have larger values for GWP. This is attributed both to aluminum recycling and composting contributing more GWP per ton of waste. Please refer back to the *Assumptions* section of this report for assumptions regarding composting emissions.

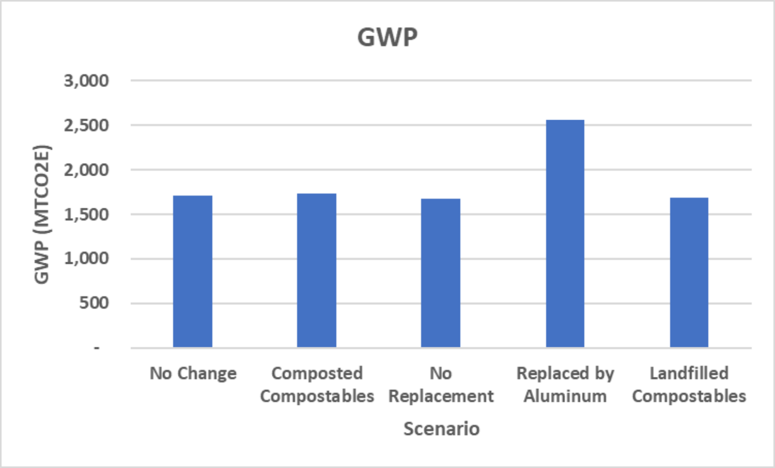

Fig. 10 Total GWP for Scenarios 1-5

Cost

Replacing plastic with aluminum or landfilled compostables is more expensive than no replacement (as no replacement eliminates a significant tonnage from the waste stream to be treated or disposed of). No replacement and composted compostables are more affordable options (Fig. 11).

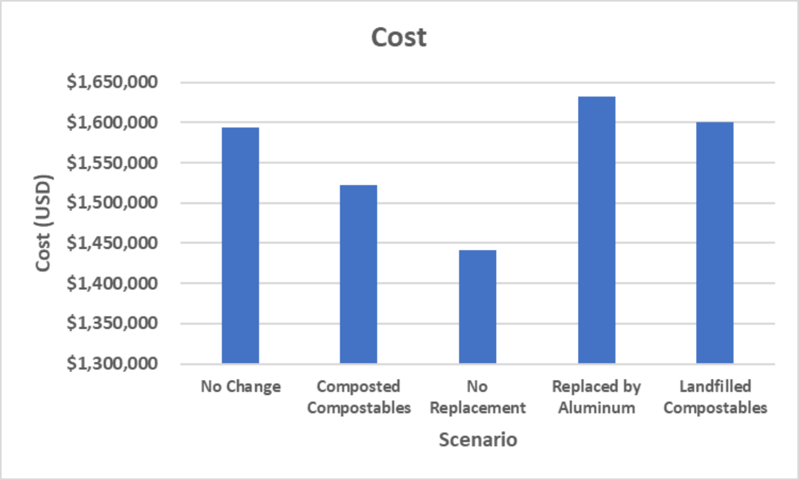

Fig. 11 Total Cost for Scenarios 1-5

Energy

Lastly, when comparing total energy usage, energy attributed to transportation for the landfill and energy attributed to processing and transportation for recycling were considered. Replacing plastic with aluminum results in significant energy savings of 107,817 mmBTU (Figure 12). While the recycling process does use energy, to find this net energy usage we subtracted the energy required to recycle aluminum minus the energy required to produce virgin aluminum. It takes much more energy to produce virgin aluminum than recycled aluminum, so there is a net negative energy usage. The other three analyzed scenarios have slightly lower energy savings than the status quo system, but not very significant differences since recycling in each of these scenarios comprises such a large amount of energy savings. Each of the scenarios have certain pros and cons, and could be chosen depending on which metric is most important to UVA.

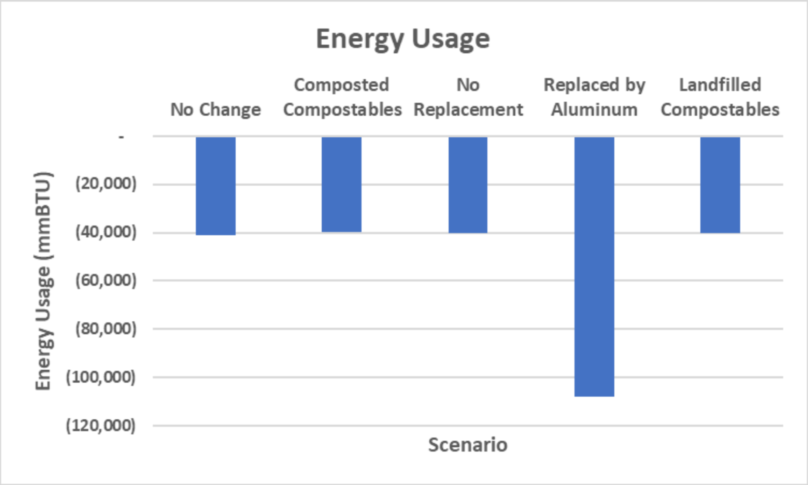

Fig. 12 Change in Energy Usage for Scenarios 1-5

Composting Scenarios

The project team modeled the following alternative scenarios for composting operations:

1. All compost is sent to Blackbear Composting (including food waste and yard waste)
2. Food waste is sent to Blackbear Composting; Yard waste is sent to Panorama Paydirt
3. All compost is sent to Panorama Paydirt (including food waste and yard waste)

As of Spring 2022, yard waste is still being managed in-house at UVA. Yard waste was not accounted for in composting totals for the 2018 Status-Quo model and the 2021 Post-ban model. There is some interest to UVA Facilities Management about optimizing compostable waste dependent upon the facility. The two facilities of interest are Blackbear Composting and Panorama Paydirt. In 2018 and 2021, UVA sent composted food waste to Blackbear Composting. Due to the more representative waste tonnages from the pre-pandemic calendar year of 2018, the waste tonnage values for 2018 were used to compute these alternatives. The target parameters of GWP (MTCO2E), Cost (USD), and Energy (mmBTU) were analyzed to compare the three scenarios. The results are described below.

GWP

The closer location of Panorama Paydirt to UVA, compared to the farther location of Blackbear Composting, indicates that sending all waste to Panorama Paydirt (Scenario 3) would contribute the least to GWP (Figure 13). Emissions coefficients used to calculate the GWP attributed to decomposition emissions are the same for both composting facilities based on values sourced from scholarly investigation. The difference in GWP comes solely from transportation emissions. It was assumed that transportation truck and weight carrying capacity would be the same for both Panorama Paydirt and Blackbear Composting so the distance appears to contribute the most to a difference in GWP for the three Scenarios.

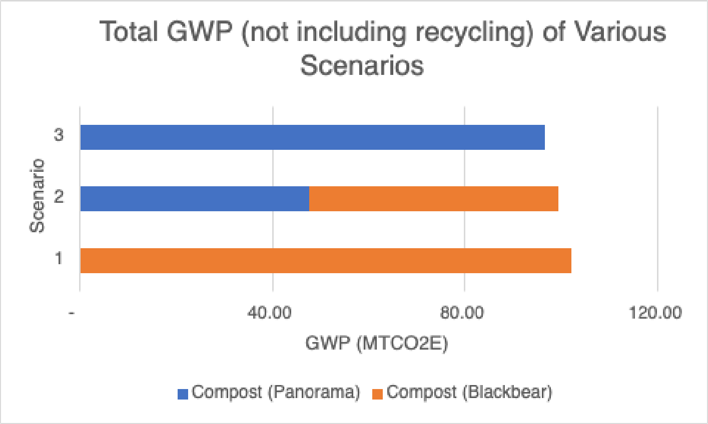

Fig. 13 Total GWP (w/o Recycling) of Various Scenarios

Cost

Based on values from Sonny Beale at UVA Facilities Management, the cost for roll-off carts, transportation, and tipping at Blackbear Composting was $178 per ton of compost. Panorama Paydirt tipping fees are valued at $145 per ton of compost. Costs of purchasing vehicles or a service to transport compost to Panorama Paydirt were not considered in this analysis. Based solely on these numbers, the costs were compared for the three scenarios. The lesser fee to dispose of compost at Panorama Paydirt shows Scenario 3 as being the most cost effective (Figure 14).

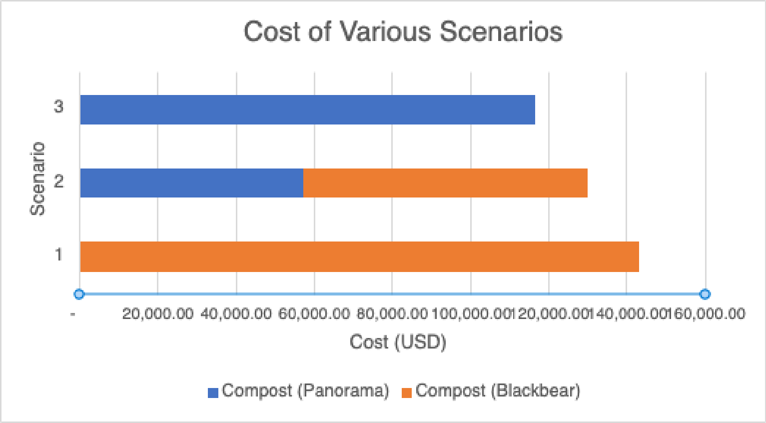

Fig. 14 Cost of Various Scenarios

Energy

Values used to compute the total net energy usage of the scenarios can be solely attributed to transportation. While energy usage across the three scenarios are relatively similar, the lesser distance to transport compostable waste to Panorama Paydirt shows that Scenario 3 would use the least amount of energy (Figure 15).

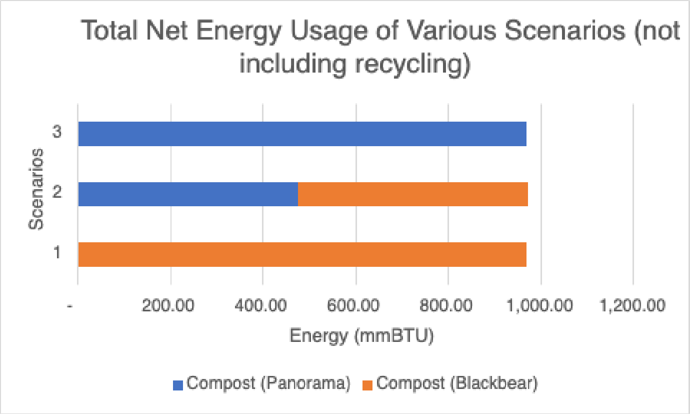

Fig. 15 Total Net Energy Usage of Various Scenarios (without Recycling)

These findings were presented to the relevant contacts listed in Appendix B on April 26, 2022. A copy of the presentation can be found in Digital Appendix I.

Discussion

Through our investigation of this topic, the project team has identified several areas for further study that are of interest to FM and the University. Representatives from FM and OFS expressed interest in determining a break-even point for collecting heavy (ex: food waste) versus lightweight (ex: paper towels) compostables. Paper towels are compostable, which presents a significant opportunity to divert from landfills. However, they are inefficient to transport due to their low density compared to food waste. Through a preliminary investigation of this topic we determined that it takes approximately 3.4 more trucks to transport paper towels when compared to the same mass of food waste (Digital Appendix J). Future groups can continue the preliminary exploration to include the effect on cost, emissions, and energy use, as well as the impact of compaction. Similarly, we began to explore a cost-benefit analysis of Blackbear versus Panorama for composting based on the model's parameters. Further study would include comparing costs of transportation with capital costs of equipment and waste stream separation.

Another topic of interest to facilities is to analyze the value of hand sorting recycling and implementing new possible waste management strategies. In order to answer this, future groups would have to consider the labor costs and efficiency of hand sorting and other waste management strategies, weighed against their success in improving waste reduction and recycling performance. Finally, if single-use items continue to be replaced by compostable materials, the university could consider implementing an on-site composting facility to save on transportation costs and emissions. In order to investigate this scenario, future groups must weigh the capital costs against the transportation savings, as well as consider if the waste stream composition would necessitate this investment.

Conclusions

The main conclusion at this point is that context matters. Transportation and decomposition related emissions both have a significant impact on the sustainability goals as they relate to Energy and GWP. Due to the impact of decomposition related GHG effects, compost is not necessarily better for the environment and reaching the 2020-2030 Sustainability Plan goals. However, the waste goal is to reduce landfill waste to 30% of 2010 levels, and that goal must be kept in mind along with the emissions goals. The results of our model indicate that there may be a tradeoff between the university's waste goal and their carbon neutrality goal. It is also important to note that the calculations presented in this report are estimates and that many of our parameters vary, which could change the reported emissions of landfill vs compost.

While some of the data used in the model are estimates and need refinement, high level conclusions can be drawn from the pre- and post-ban situations. Based on the model, the post-ban waste stream produces less GWP, but uses more net energy than the Status-Quo, or pre-ban scenario. The post-ban waste stream contains less single-use plastic and more compostable materials, though these compostable materials are mainly ending up in the landfill and not the compost. The uncertainty of facility-specific emissions data makes it difficult to draw definite conclusions about the best way for the university to proceed as a result of the SUP ban. However, the results of the model suggest that replacement by compostables may not be the best solution for UVA to achieve its sustainability goals. The results suggest that the "no replacement" scenario cuts down on cost, GWP, and energy usage, making this option something worth considering. The biggest takeaway from our work on this topic is that further investigation is needed before making major structural changes to the system. Having more complete and accurate data about the waste stream and facility-specific emissions would assist in further research. It would also be helpful to know the data on GWP and energy offsets from the finished compost produced by Blackbear, which is used to replace traditional fertilizer. This data could come from conducting more waste audits as well as measuring greenhouse gas fluxes from the waste processing facilities used by the university.

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