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Cost-Benefit Analysis of Food-Waste Composting Program at UMM

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Introduction and Research Question

In August of 2012, the University of Minnesota, Morris began composting its food waste and food-soiled paper from Dining Services. Prior to composting, the organic waste was picked up by Engebretson's disposal service to be incinerated at a facility in Alexandria. This change came about as a result of over two years of discussion and planning, beginning with the Minnesota GreenCorps service of student Will Dolezal. Specializing in waste prevention and recycling, he began the discussion of whether on-site composting might be a feasible alternative to incineration. Campus stakeholders agreed that composting was the missing link to the campus' sustainability efforts. As emphasized on the University of Minnesota's website, strong commitments have already been made to reduce the campus' carbon footprint such as the installation of wind turbines, solar panels, and a biomass gasification plant. UMM actively works to track its sustainability efforts through the Sustainability, Tracking, Assessment, and Rating System, or STARS program (Korn, 2010). Composting food waste was thought of as a way to enhance campus sustainability efforts. After Dolezal graduated, student Alicia Beattie[1] became the second Minnesota GreenCorps member dedicated to planning for composting on campus. During the planning period, students and faculty toured other facilities in Minnesota, conducted a literature review of composting best management practices, and established a waste-separation and weighing system for organic waste in Dining Services (Taylor 2013).

Composting has been hailed as an environmentally and economically friendly alternative to landfilling or incineration. According to the United States Environmental Protection Agency (EPA), composting yields many benefits including the reduced need for chemical fertilizers, water, and pesticides, higher crop yields, revitalization of poor soils, avoidance of methane and leachate generation in landfills, pollution prevention, and extension of landfill life (EPA 2013). However, there are also many costs involved in composting ranging from the need to purchase organics collection bins to the time needed each day to manage the actual composting site. The question, therefore, is whether it is worth continuing an on-site composting program at Morris. Given that the UMM composting project began in August 2012 and is on-going, my analysis will be in-medias res. The following cost-benefit analysis will include the steps outlined in

[1] I (Alicia Beattie) chose to conduct a cost-benefit analysis of the UMM composting project because of my extensive role in relationship building, planning, and assessment for the project. After serving for one year (2011-2012) as a Minnesota GreenCorps member in Waste Prevention and Recycling working, I continued to study composting systems and best management practices while interning at Carver County Environmental Services during the fall of 2012. During my internship, I worked with staff to conduct research on water quality at the University of Minnesota Arboretum demonstration composting facility as well as establish an organics collection program at an elementary school in Waconia. Upon my return to Morris in spring 2013, I was hired by Plant Services to serve as a student composting coordinator. I used my knowledge of composting science, collection methods, and composting costs and benefits to work on initiatives including composting education, collection and processing improvements, and convening stakeholders in a Compost Summit. This cost-benefit analysis will help determine whether the composting program at UMM should be continued and possibly justify future investments in the program.

Boardman, Greenberg, Vining, and Weimer's textbook *Cost Benefit Analysis Concepts and Practice:* specify the set of alternative projects, determine standing, identify the impact categories, estimate the impacts, monetize all impacts, calculate net present values, perform sensitivity analysis, and make a recommendation (Boardman et. al, 2011, 6-15).

Cost-Benefit Analysis

Alternative Projects

The first step of the cost-benefit analysis is to identify the set of alternatives. In 2012, the University of Miami conducted a full ex-ante cost-benefit analysis of composting and anaerobic digestion options for dealing with food waste. They examined three methods of composting (windrow composting, aerated static pile composting, and in-vessel composting, two methods of on-campus anaerobic digestion (stand alone or include collection from City of Oxford), contracting out of organic waste hauling and composting, and the status quo of paying to dispose organic waste materials (Smith, 2012, 1). For my analysis, however, I will only use the most feasible alternatives of doing nothing or continuing the composting program using the windrow method. The University of Miami is much larger in scale than the University of Minnesota, Morris and had not yet invested resources in a particular alternative. Morris, on the other hand, has already invested in infrastructure for windrow composting such as a concrete tipping and mixing area and has invested money in training workers in windrow composting science. It was decided early in Dolzal's GreenCorps service that the best composting method would be to use the windrow composting method, in which the operator mixes food waste with carbon-rich materials such as leaves and twigs and shapes the material into long piles that are turned periodically. Based on my own conversations with Dolezal, this method was chosen based on the relatively low capital needed to start the program and the infeasibility of other alternatives such as donating the food waste to a hog farm. Given that the project is in its fledgling phase and capital has already been invested in the program, the two realistic alternatives for UMM are to do nothing and continue to compost food waste or to quit and switch back to having the organics picked up as garbage and hauled away to the incinerator in Alexandria.

Standing

In terms of whose benefits and costs count, I have yet to find any existing literature that explicitly explores the issue of standing for a university compost project. The University of Miami's study only considered the economic costs and benefits for the University itself. In fact, their abstract specified that the paper would consist of a cost-effectiveness analysis, implying that that an alternative to landfilling would be chosen regardless of whether the costs exceeded the benefits. One of the goals of the report was to help get closer to reaching the University's Sustainability Commitment and Goals of 2010 which "aims to divert the majority of Miami University's solid waste from the landfill by 2017" (Smith, 2012, 1). Their assessment does not specifically explore the costs and benefits of all who might be impacted. The standing of many other people should be included in an analysis of a campus-composting project. These people might include University students, who may care about whether the University is meeting its goal of providing a "renewable, sustainable education" and might benefit from learning about composting and other related topics such as the psychology of sustainable behavior. It could also include professors who might benefit from using the project for research, particularly in the science and environmental studies departments. Given the environmental focus of the project, it also makes sense to consider the impact of the project on people external to the campus. This could include current and future generations who benefit from the University’s commitment to reducing its environmental impact. This serves as a justification for calculating the carbon footprint of the composting program. Because the University of Minnesota, Morris emphasizes the need to reduce its carbon footprint, including carbon emissions in calculations of net present values for the alternatives will be essential. Morris is already rated as a leader in sustainability. In *The Princeton Review’s Guide to 322 Green Colleges*, Morris was praised for its “deep roots in agriculture and land stewardship” as well as local generation of renewable energy including the biomass gasification plant, commercial-scale wind turbines, and solar-thermal system (Ray, 2013). The composting project would only add to Morris’ reputation and progress.

Identify the impact categories, catalogue them, and select measurement indicators

Impact categories (costs and benefits) must be identified for both the food waste collection alternative, conducted by Engebretson’s disposal service, and the current composting project at the University of Minnesota, Morris. Table 1 below shows the different impacts and their measurement indicators.

Table 1: Impact Categories

Engebretson’s Disposal of Food Waste		Windrow Composting Method	
Costs	**Benefits**	**Costs**	**Benefits**
Collection fee*: $280/ ton* or $6,114.08 in food waste collection fees	Takes little time for UMM staff to use this method	Organics collection containers: *$700* for Dining Services, $275 for Residence Halls pilot = $975	Reduced need for chemical fertilizers: create natural soil amendment
Incineration externalities: Incineration inefficiencies, reduced BTUs during incineration, longer hauling distance (56 miles)	Little equipment or infrastructure needed for collection	Compost facility operator certification training at Iowa State University (cost $1,185 for three people)	Reduction in waste hauling fees: $6,114.08 saved in waste hauling fees each year (24.3 tons of food waste diverted from combustion)
		Tipping and Mixing Area ($10,500)	Research and educational opportunity
		Temperature probe and probe guard: $231.10	Non-use value: Reputation of Morris as “renewable, sustainable education"
		Gas used to operate S250 bobcat: 5 gallons a week at $4 per gallon (total = $20 / week x 30 weeks in school year = $600 / year or 150 gallons of gas = 1.3 metric tons of carbon dioxide equivalent (captured by WARM model)	WARM mode: Reduce metric tons of carbon dioxide equivalent by 2 tons / year from baseline = 231 gallons of gas
		Labor required: *(five hours per week)*	

For the Engebretson's alternative, one of the largest costs is the collection fee assessed for waste hauling. Although the rate can change slightly from month to month based on the spreading of the base rate across tonnage, \$280 per ton is the average fee assessed (Harris, 2013). Other costs include the carbon footprint of hauling waste and combustion and reduced BTUs during incineration. Prior to composting food waste, all of UMM's organics were trucked to Alexandria for incineration (Engebretson, 2013). Incineration of food waste leads to the generation of carbon dioxide and nitrous oxide, a greenhouse gas 310 times better at trapping heat than carbon dioxide (Eureka Recycling, 2008, 2). Additionally, food waste leads to a reduction in efficiency of incinerators. For a waste-to-energy (WTE) incinerator to be efficient, it has to have average heat content between 5,000 and 5,500 BTUs per pound. Food scraps are far beneath this value, at 2,600 BTUs per pound, thereby decreasing the amount of energy created by the incinerator (Clean Water Action, 2007, 1). Due to the wet nature of food waste, incineration is highly inefficient.

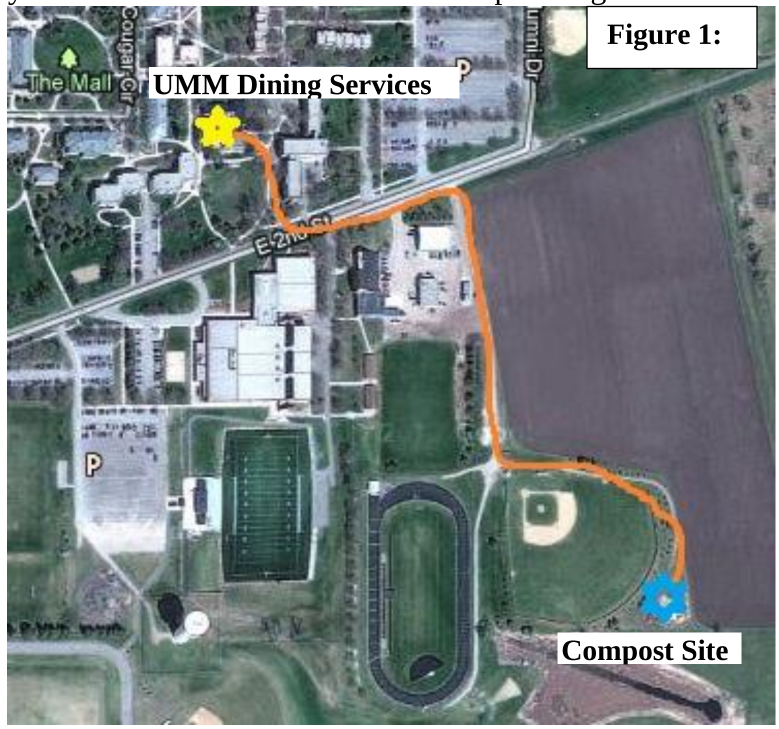


Figure 1:

One big difference between the alternatives is the hauling distance from the source of food waste generation to the destination. The edited Google image (see figure 1) shows the very short distance (.4 miles) that it takes to get from Dining Services to the Morris compost site. In contrast, the Pope / Douglas WTE Solid Waste Management plant in Alexandria is 44.7 miles away. In order to get a better sense of the costs and benefits of WTE versus composting, I used the Environmental Protection Agency's Waste Reduction Model (WARM) tool. This tool allows users to compare greenhouse gas impacts of different waste management options based on travel distance as well as the waste management technique itself. I input 24.3 tons of food scraps in a baseline (combustion) and alternative (composting) scenario in order to determine greenhouse gas (GHG) emission reductions from the baseline waste management scenario. While composting still generates GHGs which contribute to climate change, there is a clear reduction in GHGs when switching to composting. The output summary (see figure 2) shows the total GHG emissions from the baseline Municipal Solid Waste (MSW) generation and management at (-3) metric tons of carbon dioxide equivalent ($MTCO_2E$) and total GHG emissions from alternative MSW generation and management at (-5) $MTCO_2E$. As shown in the calculation of change (Alternative – Base $MTCO_2E$), this represents a reduction of two $MTCO_2E$ per year. The report noted that this change is equivalent to saving 231 gallons of gasoline over a year (EPA 2013).

Figure 2: **GHG Emissions Analysis — Summary Report**

(Version 12, 2/12)

Analysis of GHG Emissions from Waste Management

GHG Emissions from Baseline Waste Management Scenario (MTCO2E):	-3
GHG Emissions from Alternative Waste Management Scenario (MTCO2E):	-5
Total Change in GHG Emissions: (MTCO2E):	**-2**

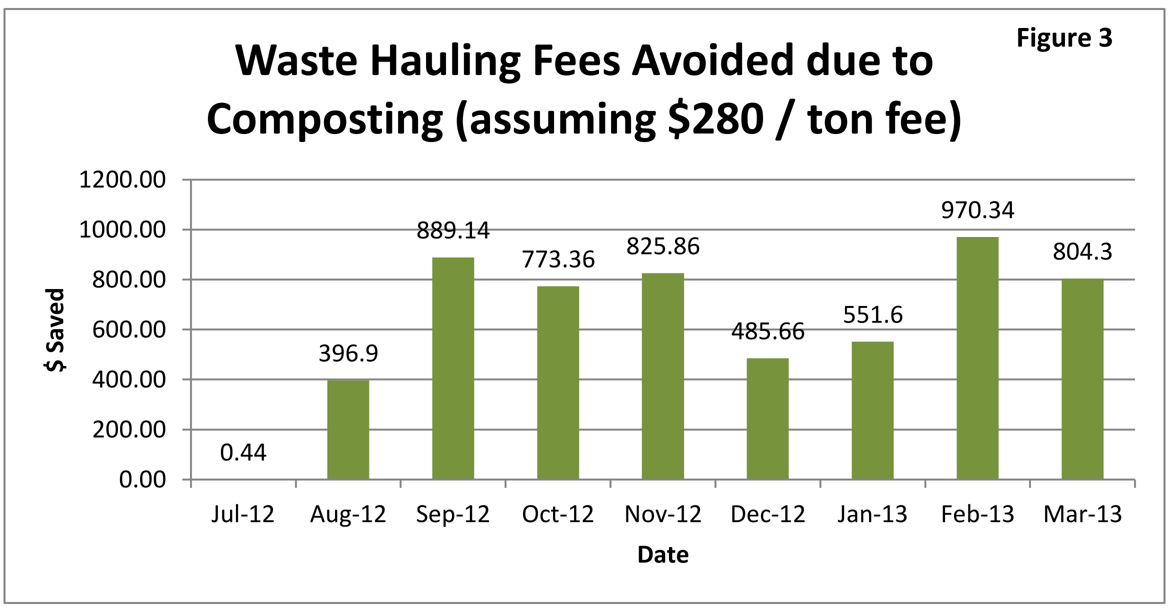
	Baseline Scenario					**Alternative Scenario**						
Material	**Tons Recycled**	**Tons Landfilled**	**Tons Combusted**	**Tons Composted**	**Total MTCO2E**	**Tons Source Reduced**	**Tons Recycled**	**Tons Landfilled**	**Tons Combusted**	**Tons Composted**	**Total MTCO2E**	**Change (Alt - Base) MTCO2E**
Food Scraps	N/A	0	24	0	-3	0	N/A	0	0	24	-5	**-2**

There are no clear benefits for this alternative not already captured in analysis of the windrow composting method. Costs in the windrow composting method include a large number of fixed costs. The organics collection containers for Dining Services cost about $700 (Nemmers 2013). Bins used for a pilot collection program in the residence halls totaled $275. This included fifteen blue twist off and on lids at $11 each, ten five gallon blue recycle pails at $7.25 each, and five three gallon blue recycle pails at $7.50 each (Ladner, 2013). This comes out to be a total of $975 spent on organics collection bins. Another cost was compost operator certification at Iowa State University in July of 2013. I and two Plant Services employees attended, costing $1,185 total. A major cost was a cement tipping and mixing area used for the actual composting site, which cost $10, 500 (Ostby, 2013). Finally, a temperature probe was purchased for monitoring the compost piles. The temperature probe that I recommended based on suggestions from the Arboretum compost facility in Chanhassen, Minnesota, cost $231.10 based on my records. These are all fixed costs. On-going costs include the gas needed to run the Bobcat front-end loader and labor required (about five hours per week). It should be noted that Troy Ostby, the Recycling Director who manages the composting project on a day-to-day basis, has not been putting in more hours due to the composting project. Rather, he “squeezes” it in. The five hours Ostby spends hauling the food waste and managing the site could be equated to $33 an hour x 5 hours = $165 / week. However, Troy Ostby has reported that he has never stayed beyond his forty hours a week to fit in the new project. The gasoline use of the Bobcat equates to five gallons a week x $4.00 per gallon, equating to $20 per week, or $600 per year (Ostby 2013). However, this does not include the carbon footprint of the gasoline use needed to run the equipment. The U.S. Environmental Protection Agency’s Greenhouse Gas Equivalencies Calculator allows for the calculation of metric tons of carbon dioxide equivalent. For 150 gallons a year, this equates to 1.3 metric tons of carbon dioxide equivalent (EPA, 2013). While it is helpful to see the exact carbon footprint for the composting option, however, these costs are already factored into the WARM model which considers the carbon footprint for the alternatives. For the purposes of standing, the $600 per year in gas money should be included though.

Due to our waste recording system in Dining Services, the University has excellent data concerning quantities of food waste diverted to composting and associated waste hauling fees avoided (see table 2). Because it took a while for organics collection to begin, quantities of collection were low for July and August. However, a reasonable estimate can be made for waste hauling fees avoided due to composting by examining the average from September through March. The average pounds of organic waste diverted per month is 5,408 pounds or 2.704 tons. During a February 2013 discussion with Lisa Harris, of UMM Plant Services, I was told that waste hauling fees approximate about $280 / ton. Figure 3 shows the waste hauling fees avoided each month. Assuming nine months of school in session, this equates to 24.3 tons of food waste x $280 = $6,114.08 saved in waste hauling fees each year.

Table 2: **UMM Food Waste Diversion Data**

Date	Waste Diverted to composting (tons)	Waste Diverted to composting (Pounds)	Waste Hauling Fees Avoided (due to composting) $	Average Composting pounds / day
Jul-12	0.001575	315	0.441	
Aug-12	1.4175	2,835	396.9	
Sep-12	3.1755	6,351	889.14	6,351/ 30 = **211.7**
Oct-12	2.762	5,524	773.36	5,524/31 = **178.19**
Nov-12	2.9495	5,899	825.86	5,899/30 = **196.63**
Dec-12	1.7345	3,469	485.66	3,469/13 = **266.85**
Jan-13	1.97	3,940	551.6	3,940 /18 =**218.88**
Feb-13	3.4655	6,931	970.34	6,931/28 = **247.53**
Mar-13	2.8725	5,745	804.3	5,745 / 31 = **185.3**
TOTAL	**20.35**	**41,009**	**$5,697.6**	**Average = 215 lbs. / day**



Potential Impacts over the Life of the Project

While the fixed costs of the composting appear steep, the potential impacts over the life of the project needs to be calculated to determine whether the project is valuable. The University of Miami chose a terminal value of ten years for their study based on the recommendations of several faculty members and their Sustainability Coordinator. They justified this terminal value based on the lifespan of equipment. I will adopt this terminal value as well since much of the equipment used at the University of Minnesota, Morris will likely have a lifespan of about this time (Smith, 2013, 41). Furthermore, it is unknown how long the project will last given that it is a pilot project. Using a conservative estimate is important given the possibility of project termination.

For the Engebretson disposal method, the cost of the program would be $280 / ton for food waste collection. This fee accrues across all ten years of the project. For other impacts, such as the reduction in combustion efficiency and BTUs generated due to the addition of food waste, no clear literature value exists that would be helpful for predicting the impact of the University of Minnesota's food waste. This value would likely be negligible due to the relatively small quantities generated. All other impacts are captured in the composting alternative, since the WARM model's output is based on comparison between the baseline and the new alternative. For the windrow-composting alternative, most of the costs would appear in year zero, prior to the first year of composting. This would end up being $975 for bins, $1,185 for compost school, $10,500 for the tipping and mixing area, and $231.10 for the temperature probe. For years one through ten, yearly costs would include 150 gallons of gasoline used per week to operate the S250 bobcat (including hauling the organics and turning them) and the five hours of week of labor required. All of the benefits for the program occur in years one through ten. The first benefit is reduction in the use of chemical fertilizers. However, it is unclear at this time how much the finished compost will be able to displace purchased fertilizers. This value is contingent on many unknown factors such as the quality of the finished compost and future campus landscaping projects. So far, several employees at the University of Minnesota, Morris have discussed the potential for the end product to be used for landscaping at the Green Prairie Living and Learning community (green dorm) and the alumni garden. However, it may be premature to calculate the benefits of reduced fertilizer use given that the first batch of composting has not yet finished curing. Benefits that are more concrete include a reduction in waste hauling fees ($6,114.08 / year) and a reduction of two metric tons of carbon dioxide equivalent. In addition, two important values for the project include students who feel happy to be at a university that lives out its model of providing a "renewable, sustainable education" and the educational and research opportunities afforded by the project. On January 31, 2013, for example, I presented information about the composting project including the science and process of getting it started to Professor Ed Brand's Environmental Problems and Policy class. However, these benefits are difficult to estimate without use of a contingent valuation survey or some other mechanism to calculate monetary values.

Monetizing Impacts

In the previous section, many of the costs and benefits were expressed in dollar values that can be used for calculating impacts over the life of the project. However, several of the impacts need to be monetized. For the five hours a week spent operating the program, the costs were previously explained as undetectable, given that the current operator has not been working more hours in the day to accommodate the program. In the future, though, a student worker might take over the day-to-day responsibilities if trained sufficiently in composting facility operation. A work-study student, making $7.50 an hour would be a cost to the program of five hours a week x fifteen weeks x $7.50 per hour, or $562.50 per year. Furthermore, estimates needs to be made for the social cost of carbon. The social cost of carbon (SCC) refers to the negative externalities associated with gradually increasing carbon emissions. These externalities include changes in the overall production level for agriculture, human health impacts, property damages due to more severe weather, spread of disease including dengue fever and malaria, and loss of ecosystem services. Values differ among different studies depending on the climate model used, discount rate chosen, and extent of costs factored into the model. This SCC needs to be applied to the metric tons of carbon equivalent calculated using the Environmental Protection Agency's tools in order to honor the standing of individuals external to the University and future generations with standing. In February 2010, the Obama administration created an interagency working group to determine an official SCC. The group consisted of six executive branch offices and six regulatory agencies. This interagency group formed as a result of a U.S. Court of Appeals for the Ninth Circuit ruling from 2007, in which the Court ruled that the National Transportation Traffic Safety Administration (NHTSA) had to monetize the benefits of carbon dioxide emission reductions and include the value when calculating fuel economy standards. The working group reported a central value of $21 per metric ton for carbon but suggested that the values of $5, $35, and $65 should be used in sensitivity analysis given uncertainty in future emission levels and climate response. Discount rates used in the calculation included 2.5 percent, 3 percent, and percent and were based on observed market interest rates. While the SCC established by the working group is now regularly used by U.S. agencies to conduct regulatory impact analyses, the SCC has been heavily criticized by climate scientists, economists, and environmentalists as severely understating damages from future climatic changes. Laurie Johnson, chief economist in the climate and clean air program for the Natural Resources Defense Council, and Chris Hope, of the Judge Business School at the University of the University of Cambridge, for example, argue in their study, "The social cost of carbon in U.S. regulatory impact analyses: an introduction and critique" that much lower discount rates should be used to adequately consider intergenerational impacts of climate change. Their 2012 study was published in the Journal of Environmental Studies and Sciences. They note that the EPA and Office of Management and Budget use intergenerational discount rates of .5 to 3 percent and that the United Kingdom uses a SCC of 1.4 percent for example, representing a much lower bound than what was used by the working group. Using alternative discount rates of 1, 1.5, and 2 percent, they estimate a SCC of 2.6 to 12.7 times larger than the $21 per ton of carbon dioxide estimate established by the working group. This equates to values between $55 and $266. They argue that these values better reflect the economic havoc likely to be wreaked by climate change and other externalities such as public health damages (Johnson and Hope, 2012, 207 – 210). This article has received prominent attention, with a New York Times article highlighting the new study and the contention over how to value future generations (Foster, 2012). Other studies also point to a higher SCC. In 2006, Nicholas Stern, Head of the Government Economic Service and Adviser to the British Government on the economics of climate change and development, published the Stern Review on the Economics of Climate Change. He calculated a SCC of $85 per ton of carbon dioxide. His study was one the first major official economic reports on the pressing problem of climate change and represents one of the higher estimates for the SCC. He used very low parameters, including a 0.1 percent for the annual pure rate of time preference, 1.3 percent for the annual growth rate, and an elasticity of marginal utility consumption equal to 1, leading to a real interest rate of 1.4 percent. His central value was calculated at $85 per ton of carbon dioxide. He justified his SCC by noting that the current generation has an ethical obligation to consider future generations and that the risks and uncertainties of climate change are great. The United Kingdom currently uses a similar value, calculated at $41 per ton of carbon dioxide to $124, with a central value of $83 (Ackerman and Stanton, 2010, 1-17). Given the wide range of SCCs calculated, I will use sensitivity analysis when performing calculations for the changes in GHG emissions from baseline to alternative. I will use the U.S. Government's central value of $21 for a lower bound, the Stern Review's $85 as middle bound, and Johnson and Hope's $161 central value as an upper bound. These values will be applied to the 2 metric tons of carbon dioxide equivalent avoided when switching from the baseline of combustion and large travel distances to composting. This equates to a lower bound of $42, a middle value of $170, and an upper bound of $322. All other values have already been monetized due to my choice of original measurement indicators. Table 3 below shows an updated version of monetized costs and benefits. Note that most of the costs and benefits are captured in the windrow composting method alternative. Impacts that cannot be monetized at this time are excluded from this table but are available in Figure 1 for review. These may serve to reinforce or discredit the final recommendation.

Table 3: Monetized Impact Categories

Engebretson's Disposal of Food Waste		Windrow Composting Method	
Costs	**Benefits**	**Costs**	**Benefits**
Collection fee: $6,114.08 in food waste collection fees / year		Organics collection containers: $975	Carbon footprint reduction: $21 per metric ton of carbon dioxide – lower bound, $85 middle range, $161 – upper bound each year
		Compost facility operator certification training at Iowa State University (cost $1,185 for three people)	$6,114.08 saved in waste hauling fees each year
		Tipping and Mixing Area ($10,500)	
		Temperature probe and probe guard: $231.10	
		Gas used to operate S250 bobcat: $600 / year	
		Labor costs: $562.50 / year	

Net Present Value Calculations

At the heart of any cost-benefit analysis rests the discount rate. The discount rate has already been considered in my discussion of the social cost of carbon. Using a discount rate allows for benefits and costs incurred in different time periods to be converted into a common metric: present value. This is important since people have a preference for money now rather than later since our lives are finite and money could be invested instead. When using a constant discount rate, either the marginal rate of return on private investment (rz) can be used or the marginal rate of time preference for savers (pz). Rz reflects borrowers who have to pay a tax on profit and take risks whereas pz reflects savers who do not take risks and have safe assets. A justification can be made to pick a discount rate in the middle of pz and rz since it can reflect the behavior of both consumers and investors (Boardman et al., 2011, 249-253). Pz represents a lower bound while rz represents an upper bound for a discount rate. In the University of Miami's cost-benefit analysis, they used a discount rate of 3 percent, reflecting a value in the middle of the upper and lower bound (Smith, 2012, 41). I will plan on using the 3 percent rate for calculations given that it represents a middle value. Three percent is also the value used by the U.S. Interagency working group for determining the central value for the SCC and represents a common standard discount rate. However, I will also plan on conducting sensitivity analysis using discount rates of 1.4 percent, representing the lower bound presented by the Stern Review which emphasizes intergenerational impacts and 7 percent, which the Office of Management and Budget estimates for the opportunity cost of private capita (EPA, 2010, 18-19).

The discount rate will be essential for calculating net present values for the alternatives. The formula, as shown at right, is the present value of benefits minus costs (Boardman et al., 2011, 141). At a three percent discount rate, with a time of 10 years, the net present value of the Engebretson alternative can be calculated based on the $ - 6114.08 costs each year. This equates to a net present value of $ -52,151. For the windrow composting alternative, I will begin by using the central value of $85 for the SCC and a 3 percent discount rate. The central value of $85 must be multiplied by the two metric tons of carbon equivalent, equaling $170. Fixed costs (containers, training, tipping and mixing area, and temperature probe will be incurred in year zero while all other impacts will occur in years one through ten. In year zero, the total costs equate to $12,891.10. In years one through ten, the benefits (6,284.08) minus the costs ($1,162.50) equates to $5,121.60. Using the discount rate of 3 percent, the NPV equates to $43,738 - $12,891.10 = $30,846.9. Using these values represents a clear savings for the composting alternative. However, the next section will include sensitivity analyses to see if the recommendation holds under a variety of different assumptions.

$$\mathrm{NPV} = \sum_{t=0}^{n} \frac{(\mathrm{Benefits} - \mathrm{Costs})_t}{(1+r)^t}$$

where:
r = discount rate
t = year
n = analytic horizon (in years)

Sensitivity Analysis

Several different uncertain parameters should be considered before recommending an alternative. The most important parameter is likely the discount rate given that this will most directly impact how the campus views the alternatives. The SCC may also impact the results but is unlikely to hold as much weight given the small values. I will begin by calculating the NPVs under the $85 per metric ton of carbon dioxide SCC with a 1.4 percent discount rate. For the Engebretson's alternative, assuming $6,114.08 in waste hauling fees each year, the NPV equates to a total of $-56,685. For the composting alternative, assuming a cost of $-12,891.10 in year zero and a net benefit of 5,121.60 in years one through ten, the NPV equates to $47,484 – 12891.1 = $34,593. Again, the composting option is the clear winner. Finally, I will calculate the values for the 7 percent discount rate using the same methods as explained for the 3 percent and 1.4 percent discount rates. For the Engebretson's alternative, this equates to $-42,943. For the composting alternative, this equates to $35,912 - $12,981.10 = $22,991. As can be seen in Table 4, the effect of the discount rate is to narrow the gap between the alternatives.

Table 4: Net Present Values Assuming $85 per metric ton of CO2 for SCC

	1.4 % discount rate	3 % discount rate	7 % discount rate
Engebretson's alternative	$ - 56,685	$ - 52,151	$ - 42, 943
Composting alternative	$34,593	$30,847	$22,991

I will make one more sensitivity analysis using the worst possible scenario of a 7 percent discount rate using the lower bound of $21 per metric ton of carbon dioxide for the SCC. I will not calculate the upper bound for the SCC since it will only serve to amplify the differences between the baseline and the alternative and does not represent a standard SCC. For the $21 per metric ton scenario, the two metric tons of carbon dioxide equivalent calculated in the EPA's WARM model must be converted to equal $42. Under this scenario, the total benefits of the composting alternative would equate to $6,153.08. The net benefits for each year would equal the benefits ($6153.08) – the yearly costs ($1162.50) = $4,991. The fixed costs for year zero would still be $-12,891.10. For the composting alternative, this equates to $35,054 - $12,981.10 = $22,073. Table 5 shows the net present values assuming a $21 per metric ton of CO2 for a SCC.

Table 5: Net Present Values Assuming $21 per metric ton of CO2 for SCC	
	7 % discount rate
Engebretson's alternative	$ - 42, 943
Composting alternative	$22,073

Recommendation

Based on the sensitivity analysis I performed, I recommend continuing the composting project at the University of Minnesota, Morris. The composting alternative looks the best under the 1.4 discount rate assuming an $85 per metric ton of carbon dioxide for the SCC. However, the composting alternative is the clear winner even under the 7 percent discount rate using the $21 per metric ton of carbon dioxide. The series of calculations only serve to narrow the gap between a large negative net present value for the Engebretson's alternative and a significant positive net present value for the composting alternative. In addition, many of the costs and benefits were not monetized after discussing them in the section on impact categories. Un-calculated costs include the reduction in combustion efficiency caused by the addition or dense, wet food waste. Also, several benefits that were not calculated include the possible reduction in chemical fertilizer purchasing due to the use of finished compost as a soil amendment and the educational and existence benefits of composting to University staff and students. As the project progresses, it may be possible to collect data on the value of the composting project to campus stakeholders in terms of its ability to fit into the "renewable, sustainable education" theme. However, enough data has been accumulated to make a preliminary recommendation. While the composting project is still in its fledgling state, the data clearly stands to support its continuance.

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