# INTRODUCTION

Everyday, Skidmore College produces thousands of pounds of waste output in the form of horse manure, food scraps and lawn-maintenance byproducts, contributing to an ongoing dilemma of how waste should be disposed of in America. Addressing the management of organic waste at Skidmore is embedded in a broader environmental context of increasing amounts of waste; over 250 million tons of municipal solid wastes will be generated in the US in 2010, 10.9% will be food waste and 12.1% will be yard wastes, and all organic wastes will comprise about a quarter of all landfill waste (EPA 2010).

Disposal of organic wastes in landfills is a costly process. Organic wastes contaminate water supplies, generate greenhouse gas emissions, convert large amounts of land into virtually unusable space, and interrupt natural nutrient cycles on which ecosystems depend. The Environmental Protection Agency (EPA) estimates the total cost of municipal waste disposal is $100 per ton; therefore, the total cost of municipal waste disposal in the U.S. is about $25 billion. The U.S. has 3,091 active landfills and over 10,000 inactive municipal landfills; according to the EPA they will all eventually fail and leak. When landfills leak, nutrient-rich leachate enters water bodies and contributes to cultural eutrophication. Methane, a greenhouse gas 72 times more potent than carbon dioxide, is generated in landfills as organic waste decomposes under anaerobic conditions. Landfills are the second largest anthropogenic source of methane in the U.S., creating 23 % of all methane emissions (EPA 2010). Conventional waste management practices interrupt natural carbon, nitrogen and phosphorous cycles that are essential in maintaining balanced ecosystems.

These organic wastes, rather than being an environmental and economic problem, are capable of being converted into an environmental and economic asset through composting.

Composting systems embody both a symbolic and practical response to the unsustainable practice and philosophy surrounding US waste disposal methods of the 20th century. Composting is a means of converting organic waste material, such as food scraps, yard waste and manure, into a substance called humus, a nutrient-rich soil amendment. Humus is an essential element in maintaining healthy soil and plant life, making composting a useful tactic for nurturor90 Tw 1(90g6u)20(7(y)20gt)-2(ur)37(90uoi)-2nurtaftriant5.57w 1.22 0,(g)134(i)-2mstriat isagtpons2nt2 variety of options that Skidmore has in creating a composting system, and can be combined, reformed or implemented consecutively in the event that the Skidmore Community does decide to compost its organic waste. This study aims to demonstrate how Skidmore can financially, environmentally and educationally benefit from the implementation of a windrow composting system.

Skidmore is a residential college of 2,400 students in Saratoga Springs, NY. In recent years, the school has pursued a variety of programs to increase the schools sustainability and decrease its environmental impact. For example, the school has an extensive recycling program (of plastic, glass, and paper products), is currently undergoing a greenhouse gas inventory, and has invested in renewable geothermal heating and cooling (Sustainable Skidmore). Composting at the College offers an opportunity to further the community's environmental efforts while also investing in a cost-effective long-and nitrogen rich fecal matter create an ideal carbon-nitrogen ratio for composting. A 1,000 pound horse generates eight to ten tons of manure per year, accumulating at a rate of two cubic feet per day. A ton of fresh manure may contain approximately 13 pounds of Nitrogen (as N), 5 pounds of phosphorus oxide (as $P_2O_5$), and 13 pounds of potassium oxide (as $K_2O$) (Romano 2005).

The 30-year old Van Lennep Riding Center is one-half mile away from the College in a rural location in the town of Greenfield, NY. It is home to approximately 30 Skidmore owned horses, has the capacity to board an additional 37 student-owned horses, and currently boards an average of 60 horses year round. Horse stalls are bedded with fresh pine chips and the horse manure is approximately 50 percent feces and 50 percent bedding.

While the stables are a valuable part of Skidmore, the waste stream created by the Van Lennep Riding Center has created environmental and economic issues for the College. For many years, a combination of manure, stall bedding, and other stable waste was dumped behind the Van Lennep facility. While this strategy was economically cheap, it resulted in the leaching of nutrients and waste materials into an adjacent pond, and into the greater Kayaderosseras Creek Watershed. Currently, Skidmore pays the firm Springer Waste Management to haul the stables horse manure to a large scale composting site. The cost of this disposal is $165.00 per 30 cubic yard container, which is usually filled every three days (Cindy Ford, Personal Communication). Skidmore College spends approximately $20,065.00 to dispose of 3,650 cubic yards of horse manure per year. While this policy minimizes the environmental impact of stable waste on the local area, it is an economically costly solution for the College, and rather than taking an advantage of an available resource, it sends it to a firm that produces a value-added product for itself.

In addition, a substantial amount of human labor is required to clean manure from stalls and transport it to the holding container that Springer ships away. Four Van Lennep Riding Center employees (3 employees on weekends) spend around 5 hours per day mucking out stalls, placing the manure in buckets, moving it with a farm tractor (John Deere Tractor, LV5300E430371 1994), and then manually lifting it over a six feet height into the holding container. Composting would substantially decrease the amount of labor required to clean stalls and to transport manure. Instead of transporting and lifting manure into the Springer Waste holding container, manure could be collected in the stables dump wagon and driven to the compost site, without a need for collecting the manure in buckets and manually lifting it into the holding tank. In short, composting behind the Van Lennep facility could significantly decrease the amount of time necessary for cleaning the horse stables while also decreasing the occupational hazards of repetitive heavy lifting (Cindy Ford, Personal Communication).

Food Waste:

Skidmore College produces a substantial amount of food waste from the campus's main dining facility, the Murray-Aikens Dining Hall. A 2009 waste audit of the Dining Hall concluded that an average of

vehicles. Conversely, if the same amount of food waste were composted, it would yield a net greenhouse gas reduction of 6.3 MTCE per year, equivalent to taking 4.2 vehicles off the road[ii].

The garbage disposal used in the dining hall to shred the food waste and send it into the sewer system uses a substantial amount of water, contributing to the College's water footprint and the stresses on local water supplies. The current food waste disposal method uses 3,993,402 gallons of water a year, which comprises nearly 10% of the College's water use and costs the school approximately $800 a year.[iii] Switching to a composting system would substantially reduce these costs, saving the college money while also decreasing our carbon and water footprints.

Lawn Waste:

Skidmore's lawn maintenance by-products, such as leaves, grass-clippings and branches, are currently piled behind the Van Lennep facility—

222 cubic yards is produced every Spring and 50 truck loads, or 444 cubic yards is produced every Fall, for a total yearly yard waste production of 666 cubic yards (Erica Fuller, Personal Communication). Since this waste stream already is already regularly transported to the site behind the Van Lennep facility, it is likely that the same equipment and a similar amount of labor could be utilized to transport the food waste as well.

## METHODS

representatives. Technical information on composting system includes the cost, availability, operating hours required, space and infrastructure needs, and type of waste that can be used. Information regarding the operation of similar composting systems at peer institutions was obtained from websites, publications, conversations, and site visits at Middlebury College and Smith College.

# COMPOSTING TECHNOLOGIES

## What is Compost?

Composting is a means of converting organic waste material, such as food scraps and manure, into a valuable nutrient source and soil amendment, a substance known as humus. Humus is characterized by having short molecular chains and provides fertility to the soil by retaining moisture, forming good soil structure and containing the basic nutrients of a healthy soil (Modern Composting Technologies). Humus is an essential element in maintaining healthy soil and plant life, making composting a useful tactic for nurturing productive agricultural fields, ornamental plants and grasses.

Composting is carried out by various types of microorganisms, including bacteria, fungi, actinomycetes, algae, and protozoa. These aerobic microorganisms convert organic material and oxygen into compost, carbon dioxide, nitrate ($NO^{-}_{3}$), sulfate ($S0^{2-}_{4}$) , and heat (Chiumeti). In forest ecosystems, decomposition of organic matter naturally produces humus, which cycles nutrients and makes them available for plant life that are in turn available for animal consumption and, in turn, the entire food chain. Composting is a balanced and human-controlled biological process

There are a number of factors that contribute to the creation of healthy compost. These include oxygen levels, nutrient ratios, moisture level, pH, temperature and time. The success of the composting process in creating a healthy and nutrient-rich humus depends on the nutrients and elements within the materials being composted—namely carbon, nitrogen and phosphorous.

The optimal carbon-nitrogen ratio preventing nitrogen loss and proper composting is 30 to 1. To achieve this balance, different organic materials can be added (Modern Composting Technologies). In the case of the Skidmore stables, for example, the bedding.1le,2(l6 14-2(u( )Tj [(70.56 609.6

During windrow composting, organic material is piled in long, narrow rows between 4 feet and 12 feet tall. This shape allows for natural aeration and for the accumulation of sufficient amounts of heat within the piles, and also allows for easy access to the piles. Windrow systems can be roughly divided into passively aerated systems and actively aerated systems. In passively aerated systems, pipes or hoses are laid within the piles, allowing for increased air exchange. In actively aerated systems, the piles are periodically turned, usually with heavy machinery, to allow for aeration and proper mixing. Many different technologies are available for windrow composting, and are largely dependent on the scale of the operation (On-Farm Composting Handbook). For example, windrow turning can be accomplished with a front-end loader, or with a wide variety of specialized mechanical compost turners that can be attached to the side of a tractor or be self-propelled.

## In-Vessel Composting

In-vessel composting refers to any type of composting process that takes place within an enclosed vessel. There are a variety of in-vessel composting methods that utilize a number of

In vessel systems can be as simple as

Middlebury College, located in rural Vermont, is a private liberal arts college with approximately 2,350 undergraduate students and an endowment of 740 million dollars (June 2009). The College is well known for its focus on environmental sustainability, and was recognized for its sustainability by the *College Sustainability Report Card,* being one of only 26 schools to receive an A- rating in 2010. Its composting program is no exception, as the program was one of the first of its kind and began in 1993.

As part of an extensive recycling program, Middlebury College maintains a turned windrow composting system that processes up to 350 tons of food waste per year. A specially designed hook-lift truck picks up the food waste from several on-campus residential and dining areas twice a week and hauls the material to an off-campus site. Composting takes place on a piece of Middlebury property approximately one mile from its main campus. Although it is a rural location, the site is adjacent to a golf course and the compost operation is able to operate without causing odor or other problems.

At the site, a holding tank stores the materials until enough has been collected to create one complete windrow. The food waste is then mixed with wood chips, which are produced during landscaping projects and purchased from outside sources, and horse manure, purchased from a nearby farm, in the proportion of one part food waste to one part horse manure to three parts wood chips. A front-end loader is then used to align this mixture into windrows, long rows of compost that are about 10 feet wide, 10 feet tall and over 50 feet long. Windrows are constructed on a concrete pad, which creates a solid, dry surface for compost-1(e)4( m)-2s 72 405.6 Tompodee1 healthy moisture, temperature and consistency, allowing these bio-active piles to get as hot as 160°F and hence killing any unwanted weed seeds and harmful bacteria. Although the windrows will compost quicker in warmer temperatures (about 3-4 months per windrow in the spring), Middlebury continues to compost throughout the year; snow that accumulates on the piles melts within days because of the high temperatures reached through biotic processes. After the initial windrow composting process is completed, the compost is screened by an outside contractor, removing unwanted materials (such as lost forks from the Dining Hall), and ensuring a high-quality compost with a small particle size that can be used on College athletic fields. After screening, the compost is allowed to mature for one year, a process that ensures the development of a stable and nutrient-rich humus.

For Middlebury, composting makes both economic and environmental sense, as it both diverts waste from landfills and saves money that helps underwrite the larger recycling program. In 2009, Middlebury saved $94,000 in landfill fees by composting 750 tons of material, but

Apart from food waste, Smith College also generates large amounts of horse manure from their 36-horse stable and several truckloads worth of lawn-maintenance by-products. Currently, Smith sends a small amount of their horse manure to Montague to be composted, but in the coming months they plan on diverting all of it to Bridgemont Farm and thereby completely eliminate their current manure hauling expenses. The lawn-maintenance byproducts are piled and composted on campus, generating a mulch that the Smith Grounds crew uses in the campus greenhouse and grounds, although only as a supplement to the chemical fertilizer that the college purchases.

The organic waste disposal and composting program at Smith is a multi-faceted process that requires daily maintenance. Dining staff have to habitually transport 5-gallon buckets full of food waste and load toters, a driver has to transport the food waste to Montague's farm, lawn-maintenance byproducts are transported weekly to a site for composting and horse manure is also regularly collected and transported.

Despite this considerable amount of labor, however, the head of the Ground Crew at Smith, Bob Dumbkowski, asserts that the investment of time and money is worth it, saying that "if you look at what the investment is and what the return is, it's peanuts compared to what the college already spends [on waste disposal]". Apart from the huge savings in diverting waste from the landfill, Smith saves on fertilizer costs and, interestingly, plumbing fees. Several years ago, when the food waste was still simply flushed down the disposal, the College spent significant amounts of money on dealing with back-ups in the disposal and general disposal maintenance, not to mention the costs of water and power.

## COMPOSTING AT SKIDMORE

Why a Windrow Composting System is Best for Skidmore:

Composting Site Location:

After speaking with Paul Lundberg of Skidmore Facilities (3/24/10), we identified a parcel of land that is owned by the College and is located behind the Van Lennep Riding Center as an appropriate composting site (Appendix C). In keeping with New York Department of Environmental Conservation (NYDEC) regulations, the location is more than 200 feet from the nearest surface water body, potable water well, residence and place of business. Thus, the site minimizes potential environmental impacts of nutrient runoff, is sufficiently far away from other properties to prevent potential nuisance odor issues, and conveniently makes use of property that is already owned by the College. A storm water management plan must be implemented to minimize the effects of nutrient runoff from the compost site. This is an educational opportunity for the Skidmore community to research and implement an artificial wetland at the composting site. Whether it is a formal ecology class or as an independent study, a group of students would be able to learn through creating a useful bio-retention area that would mitigate any adverse environmental impact of the composting site. For example, Middlebury reports that they were able to build themselves an artificial wetland at little cost to the College.

Area Required:

The surface area that is required for the implementation and maintenance of a windrow composting system depends on the volume of the waste produced, the desired shape of the windrows and the space required to operate the equipment for turning the windrow. In addition to the space required for the windrows, the site also needs an area for the curing and storage of the finished compost—this is a smaller space since the volume of finished compost is about half the volume of the original waste material due to the loss of water and carbon (Dougherty 1999). In terms of composting at Skidmore the layout of the composting area is dependent on whether or not the College chooses to invest in a concrete pad (Scenario 3), crusher run (Scenario 2), or no impermeable surface at all (Scenario 1). Furthermore, the type of composting equipment that the college purchases will determine the height and shape of the windrow, curing and storage piles and, hence, the surface area required for the composting operation. For example, with the use of a front-end loader (Scenario 3), the windrows could be up to 12 feet tall and between 10-20 feet wide with at least a 20-foot space between the windows for operating the loader. On the other hand, with the Global Repair model #507 turner attachment that could fit on one of Skidmore's 50 horsepower tractors (Scenario 1), the windrows would be no more than 4 feet tall and 9 feet wide and could be formed in pairs with a small amount of space in-between and about 10 feet separating each pair. Below is a possible layout for this size of composting facility, with appropriate windrow, storage and curing pile dimensions:

**Figure 1:**

Example Layout for Composting Site; Scenario 1

Please see Appendix D for an example of how to determine the necessary dimensions of the surface area for a composting site for Scenario 1. The process for figuring out the lay out, as well as the crusher run/ concrete pad dimensions, for Scenarios 2 and 3 would be the same. In the example layout (again, see Appendix D), the overall square footage of the composting operation would be about 17,000 $feet^2$.

Collection and Transport:

*Horse Manure (All Scenarios):*

Horse stalls are mucked out each morning (approximately 7-11am) by stable staff. Horse manure will be transported to the compost site with a dump wagon and placed in a staging area.

*Pre-consumer Food Waste (Scenario 1 & 2)*:

The dining hall staff will strategically place 5-gallon buckets for pre-consumer waste in kitchen preparation areas and at the six food stations. These buckets are easy to move, do not present an occupational hazard due to weight, can be cleaned in the facilities' dish machine without difficulty, and are free to the dining hall. When full, they will be emptied by kitchen staff into 60 gallon toters located on the loading dock. The compost manager will pick up the 60 gallon toters each morning, at approximately 8am, in a truck currently owned by Skidmore and system while reducing the amount of water and electricity used in the process. Both the pre-consumer and post-consumer food waste would be placed in an enclosed bin at the loading dock. Each morning, the compost manager would empty the bin by means of a truck with a hydraulic lifter, purchased by the composting program. The compost manager would then transport the waste to the compost site and compost it

*Turning Windrows*

The compost manager will turn each windrow as needed, approximately once per week. Windrows must be turned periodically to ensure proper moisture, temperature, and oxygen levels. How often the windrows should be turned or aerated depends on the oxygen, temperature, and moisture content of the windrows, and upon the current weather conditions. The windrows can be turned as often as anywhere between 2 days to 3 weeks. Because the decomposition rate is greatest at the beginning of the process, the frequency of turning decreases as the windrow ages. The composting system at Middlebury College suggests that, once a windrow system is established, the piles will be turned once per week. Through experience, the operator will gain a feel for the turning schedule and be able to ascertain when turning is needed.

*Curing and Storage:*

The curing and storage of the composted material takes place in an area adjacent to the windrows. In determining the area required for curing, it is important to note that the volume of finished compost will be 50% less than the volume of the raw materials (i.e. the initial input of the three waste streams). The curing process is when the second stage of decomposition occurs and the materials are humified. When temperatures drop in the windrow and all of the material has been decomposed and stabilized, with a moisture content of 40-50%, then the compost is ready for curing; this can take up to 3 months. One easy method to determine whether the compost is ready for curing is to thoroughly wet a small sample of the material, seal it in a plastic bag and then wait a week—if the compost in the plastic bag does not emit an odor after one week, then it is ready for curing. Curing provides maturity, with a slower rate of microbial activity than the initial composting process. The curing piles should be smaller than the windrows, no higher than 8 feet, to prevent anaerobic conditions at the center of the piles that cause phytotoxic compounds, pathogens and odors to develop. The curing piles should be aligned so their length runs parallel with the slope of the pad surface, allowing for adequate drainage and prevent wet, anaerobic conditions. If the curing piles are odorous or producing excessive heat, turning or a reduction in pile size may be necessary. The curing piles can be closely spaced, as there is no longer a need for regular turning (Dougherty 1999).

After the curing process, the material should be stored in a well-drained area in order to accommodate for the time between when the compost is ready and when it is used. The storage piles cannot be ignored and should be managed to avoid pathogen or weed contamination as well as fire hazards for more woody substances. The storage piles can be taller than the curing piles, however, especially if the material is wet, anaerobic decomposition can still be a threat, so it is recommended that the piles be no higher than 12 feet. A breathable, fleece cover can be used to protect storage piles, maintaining a favorable moisture content and deterring birds or other animals. Also, a few weeks prior to use of the compost, the storage piles should be restacked into smaller piles so that the final, humified compost can aerate naturally and any leftover phytotoxic compounds are dissipated. Open-sided buildings are another ideal place to store finished compost. New York DEC regulations stipulate that on-site product storage is limited to 24 months (Dougherty 1999).

*Screening*

After the composting process is completed and the material has been cured, screening is necessary to remove unwanted objects from the compost like plastic or metal and to ensure that particles have a small, uniform size. Prior to screening, water may need to be added to the compost to achieve a moisture content of 35-45% in order to prevent the creation of dust that can be a health hazard. A screener will be rented for two days annually to screen the year’s compost.

For its yard waste composting operation, the City of Saratoga Springs rents a screener least once per year for a month at a time. There is a likely possibility that Skidmore could share the cost of renting the screener with the Saratoga Springs Department of Public Works (DPW). The DPW currently rents its screener from the company *Rock and Recycling* (a division of Vermeer) at a rate of $13,485 per month. Assuming the reasonable estimate that Skidmore would need two days to screen all of its yearly finished compost, and that a deal could be worked out with the DPW, we can say that it would cost the College around $900 per year to screen its compost.[iv]

Use of the Compost:

It is estimated that the three waste streams result in a total of 4521 cubic yards of organic waste a year. During composting, the volume of the material will decrease by approximately half, resulting in a total of 2260 cubic yards of finished compost per year.

The finished compost will be able to be used during landscaping of the Skidmore College campus, both as a fertilizer and as a soil amendment, in the place of mulch. Currently, 378 yards of dark landscaping mulch is used on campus per year, at the cost of $7986 (Erica Fuller, Personal Communication). Approximately 60 cubic yards of compost is used on the organic garden, at the cost of $1477. The school uses 175 lbs of tree and shrub fertilizer and 2500 lbs of grass fertilizer a year, for a total cost of $921.80 (Erica Fuller, Personal Communication). It is extremely likely that Skidmore compost would replace all mulch and compost used on campus. It will also be able to replace some amount of the fertilizer used, but the exact amount will be dependent on the characteristics of the finished compost, such as nutrient content and particle size. For example, Middlebury College compost has replaced all fertilizer use on campus, including on their varsity athletic fields, but this transition process took several years as the

[iv] This figure represents the amount Skidmore would pay to supplement the DPW's monthly rental fee for a screener and was derived by dividing $13,485 by 30 (days per month) and then multiplying by 2 (days).

composting program perfected its composting process (Melissa Beckwith, Personal Communication). A conservative estimate for fertilizer use is that compost, in the initial years of the program, would be able to provide 50% of tree and shrub fertilizer, and no grass fertilizer.

**Site Preparation:** In addition to the bucket loader described in Scenario 2, composting will take place on a steel reinforced concrete pad. This will provide a very solid and durable surface for composting. The disadvantages to this system are that it requires a very high capital investment and that is not easily reversible if the system needs adjustment or if another composting method proves more appropriate.
**Food Waste:** As described previously, the purchase of a pulper, holding tank and dump truck would allow for the inclusion of post consumer food waste.
**Financial Outcomes:** Over a 10-year period, the net present value of the investment return is a loss of $113,263 not selling compost or a gain of $154,346 selling compost in 2010 dollars. The payback period would be 18 years and 7 years respectively.

| **Capital Investments:** | **252,200** |
| --- | --- |
| Front-end loader | 60,000 |
| Dump Truck with hydraulic lifter | 60,000 |
| Pulper | 25,000 to 75,000 - 50,000 |
| Site preparation -Steel Reinforced Concrete Pad 100’ x 200’ | 72,000 |
| Storm-water management | 1,500 |
| Holding tank for post-consumer waste | 5,000 |
| Compost testing materials | 200 |
| **Annual Costs** | **20,900** |
| Compost Manager – 20 hours per week | 20,000 |
| Compost Screener – rent 2 days/year | 900 |

# Appendix A:

## Composting Programs at Selected Peer and Aspirant Institutions

| College | Type of Composting | Cdlection Methods/Labor | Amount Composted/ Type of waste | Costs/Funding | [redacted] | Operational Since | Where does it go? |
|---|---|---|---|---|---|---|---|

## Appendix B

## Appendix C: Proposed Composting Site
## Behind the Van Lennep Riding Center

The proposed site is located behind the Van Lennep Riding Center, less than a mile from Skidmore's main campus. The site is marked by the blue polygon. This is the site where Skidmore Facilities currently dumps campus yard waste—they would not have to change this practice were a composting operation to be implemented here. The gray rectangle represents the approximate area that must be cleared for the actual composting operation (whether there is a crusher/ concrete pad or not). That is, all of the space within the blue polygon is not necessary for the composting operation, although this space is available.

# Appendix D:

EXAMPLE LAYOUT

Scenario 1: Tractor with turner attachment

Determining the necessary dimensions for a composting site

Assumptions:

- Use of turner attachment with 50 horsepower tractor (Global Repair Model 507)
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