Food is Not Trash

Redefining Wellesley's Waste Culture by Composting

Environmental Studies 300

Spring 2013

Environmental Studies Program, Wellesley College

Wellesley, MA

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Executive Summary

This spring, the Wellesley College Office of Sustainability requested Environmental Studies 300 to analyze food waste management. To do so, we estimate the amount of food waste, propose reduction methods, assess implementation strategies, and research alternatives to waste incineration. The bulk of our report consists of a comprehensive analysis of waste diversion options for the 220 metric tons of food waste produced annually by Wellesley College. This analysis is timely and urgent. In 14 months, Wellesley College must divert 100% of its food waste from incinerators to comply with the 2014 Organic Waste Ban established by the Massachusetts Department of Environmental Protection.

To comply with the Organics Waste Ban, food waste reduction programs must be a priority. We outline the anticipated effectiveness, cost, and social impacts of six reduction options. To significantly decrease food waste, we recommend educational campaigns for the student body combined with food monitoring systems in the dining halls. Similar programs at other educational institutions have lowered purchasing costs by 2-6% and reduced food waste volume by up to 50%.

While we assess food waste diversion methods for Wellesley's entire waste stream, we also address the specific needs and limitations for dining locations on campus. We consider the ways that Wellesley can implement organic waste diversion programs in dining halls, on-campus cafés, and at campus events. For dining hall implementation, we offer a critical comparison of student and staff separated post-consumer food waste and recommend a standard procedure across campus.

Wellesley will have to divert its food waste to a separate organic waste processing facility. We examine twelve methods, half on-campus and half off-campus, that we consider to be viable options for Wellesley. Methods range from traditional composting, such as piles and windrows, to more technologically advanced options, like dehydrators and anaerobic digesters. We complete an in-depth Life Cycle Assessment (LCA) of the environmental, costs, and social impacts of each method and draw conclusions across all three of these impact categories to determine the ideal options for the College.

We recommend that Wellesley implement its organic waste diversion in three stages. To comply with the Organic Waste Ban, we advise the College to immediately divert its organic waste to an off-campus windrowing, tumbling, or anaerobic digestion facility. These three options are not only the cheapest and quickest to implement, but also have very low environmental and social impacts. To further the values of innovation and social responsibility, we recommend the implementation of a small scale food donation program and a small scale educational vermicomposting project. Finally, over the next three to five years, we advise Wellesley College to build an on-campus tumbler for long-term, low-impact sustainable food waste management.

Now is the time for Wellesley College to join the ranks of its peer institutions by implementing a comprehensive and dynamic food waste diversion program. By doing so, it will not only comply with the law, but will also demonstrate a strong commitment to the environment and provide valuable educational and social benefits to the Wellesley community. As the July 2014 deadline rapidly approaches, Wellesley must take advantage of this opportunity to be a model institution for organic waste diversion and sustainability.

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Common Abbreviations

AVI Fresh - Foodservice company currently managing Wellesley College's dining halls
CO2 - Carbon dioxide
DEP - Department of Environmental Protection
EIA - Environmental Impact Assessment
EPA - Environmental Protection Agency
ERS - Economic Research Service
ES - Environmental Studies
GHG - Greenhouse gas
hp - Horsepower
kg - kilogram
kWh - Kilowatt hour
LCA - Life Cycle Assessment
LEED - Leadership in Energy and Environmental Design
MassDEP - Massachusetts Department of Environmental Protection
MDPH - Massachusetts Department of Public Health
mpg - Miles per gallon
MWRA - Massachusetts Water Resource Authority
NRDC - National Resource Defense Council
PHF - Potentially Hazardous Foods
RER - Electricity originating from the European region ecoinvent database
S (in SimaPro) - System process
SBOG - Schneider Board of Governors
SEMASS - Southeastern Massachusetts Resource Recovery
SSO - Source-Separated Organics
SWMP - Solid Waste Master Plan
tkm - Tonnes per kilometer
TRACI - Tools for the Reduction and Assessment of Chemical and Other Environmental Impacts
U (in SimaPro) - Unit process
USDA - United States Department of Agriculture
WEED - Wellesley Energy and Environmental Defense
2,4-D - Dichlorophenoxyacetic acid
°C - Degrees Celsius
(C:N) ratio - Carbon-to-Nitrogen ratio

I. Introduction

1.0 Introduction

1.1 Introduction to Wellesley College and ES 300

1.1.1 Wellesley College

Wellesley College is a private, four-year women's liberal-arts college located in Wellesley, Massachusetts, 12 miles west of Boston. A majority of the 2,300 students live on campus in Wellesley's 21 residential halls. In addition to residence and dining halls, the College has 20 academic and administrative buildings.[1] At Wellesley, there is a culture of highly driven, motivated, and passionate women who are engaged in the campus community through student organizations and jobs.

1.1.2 Environmental Studies 300: Environmental Decisionmaking

Each student who graduates from Wellesley College with a degree in Environmental Studies (ES) must complete ES 300: Environmental Decisionmaking, a capstone course that emphasizes project-based learning. Each year, the Office of Sustainability asks ES 300 to address a different environmental issue on campus.

Through this semester-long project, students bring together a variety of backgrounds within Environmental Studies to thoroughly understand the issue at hand, and to qualitatively and quantitatively assess the various solutions available to Wellesley. Students then establish a set of guidelines that would best allow the College to solve the original problem proposed by the Office of Sustainability.

ES 300 presents its findings annually to the Wellesley College Office of Sustainability and the College Administration. Although the course content varies significantly based on the project suggested by the Office of Sustainability, developing a framework for the College to make decisions and considering how Wellesley's unique qualities will impact success consistent each year.[2]

1.1.3 Introduction to the 2013 ES 300 Project

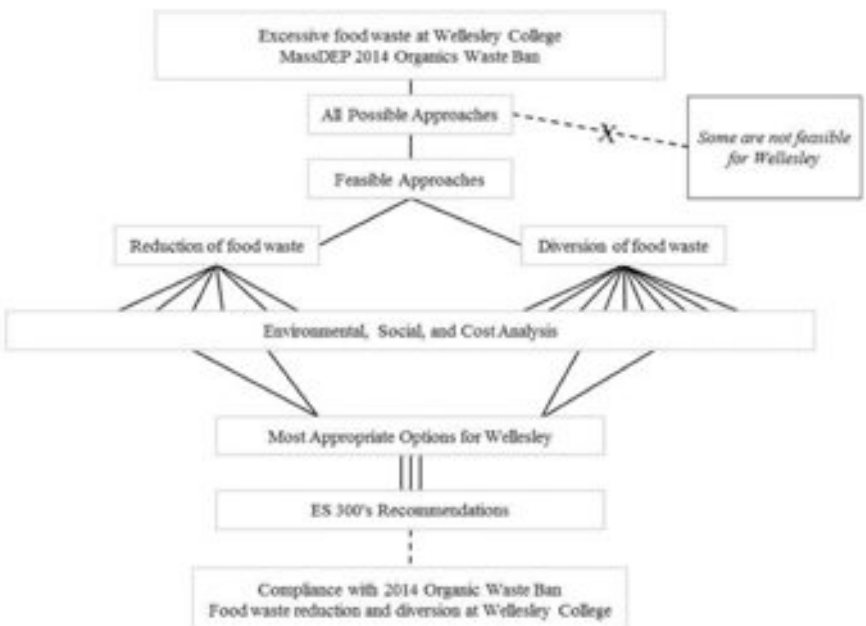
This year, the Wellesley Office of Sustainability asked ES 300 to research potential organic waste diversion methods. This research is prompted both by the enormous amounts of food

[1] Wellesley College. "Wellesley Facts." Accessed April 16, 2012. http://web.wellesley.edu/web/AboutWellesley/wellesleyfacts.psml.
[2] ES 300: Environmental Decisionmaking: Composting on Campus. "Syllabus." Accessed January 29, 2013. https://sites.google.com/a/wellesley.edu/es-300-01-sp13/syllabus.

waste produced by Wellesley College and the upcoming Massachusetts Organic Waste Ban, discussed in greater depth in section 1.2. To approach this task, we assess possible next steps for the College to divert organic waste from its traditional waste stream (Figure 1.1). We first survey all possible composting methods that Wellesley could implement, and then constrain our research to those that are most feasible for Wellesley. We focus on twelve ways to divert the food waste that the College will inevitably produce, and also discuss six methods of reducing the amount of waste produced

Each reduction and organic waste diversion option underwent rigorous analysis to determine the resulting environmental, cost, and social impacts. With these results, we ascertain which options are the most appropriate for implementation on Wellesley's campus. We conclude with a set of recommendations and a multi-year action plan that can be used by the College's administration. Implementation of these recommendations will allow the College to not only to comply with the upcoming Organic Waste Ban, but also to reduce the environmental impacts that Wellesley generates from its food waste.

Figure 1.1: Concept Map of ES 300 Project



1.2 Massachusetts DEP 2014 Organic Waste Ban

The Massachusetts Department of Environmental Protection (MassDEP) is working to significantly reduce the amount of waste produced in the state. Through the Solid Waste Master Plan (SWMP) for the years 2010-2020, it created a goal to divert 30% of the state's 2008 waste stream, totaling 4.5 million tons, from landfill disposal or incineration by 2020. MassDEP plans on achieving this goal through three methods. It will require an increase in recycling rates, a reduction in the consumption of disposable and non-biodegradable materials, and, most important for large institutions, the diversion of organic waste.[3]

Each year, Massachusetts produces 1.4 million tons of organic waste; currently, individuals in Massachusetts compost just 100,000 tons of this waste each year.[4] Beginning on July 1st, 2014, the MassDEP mandates that any facility that produces more than 0.9 metric tons of organic waste per week divert 100% of this waste from the traditional waste stream.[5] For this ban, organic waste is defined as vegetative material, food material, agricultural material, and yard waste. The ban does not include biodegradable paper and products.

Through this ban, Massachusetts can significantly reduce methane and other greenhouse gas emissions from incinerators, in addition to reusing valuable food waste as a fertilizer or as a clean energy source. This waste ban is not the first in the state; it comes as an addition to the existing bans on glass, recyclable paper, metal, cardboard, batteries, appliances, tires, leaves and yard waste, which have been banned from MA landfills and incinerators since 1990.[6] While it is forbidden for anyone, including households and commercial entities, to dispose of these materials in MA, the new 2014 organics legislation will only apply to large commercial and institutional entities with the hope that households will follow suit in the future.

The Organic Waste Ban will follow the same enforcement regimen as previous waste bans and will consist primarily of random visual inspection of hauling trucks. If any waste load destined for a landfill or incinerator consists of more than 10% by volume of food waste, the entire load will be rejected from the landfill and the sourcing institution will receive a state violation. The violation can cost the waste producer extra handling fees of $860 - $1,725 per load.[7] The penalty will also entail further enforcement actions from the state if the institution repeats the violation.[8]

1.2.1 How the 2014 Organic Waste Ban Affects Wellesley College

Wellesley creates 220 metric tons of food waste per year, or approximately 4.6 metric tons per week during the academic year.[9] Since the College produces more than 0.9 metric tons of food waste per week for this part of the year, Wellesley must comply with the 2014 Organic Waste Ban. Currently, a majority of Wellesley's food waste is scraped into the trash and sent to an

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[3] MassDEP. "Massachusetts 2010-2020 Solid Waste Master Plan (SWMP)." Accessed December 2012. http://www.mass.gov/dep/recycle/solid/mprev12.pdf.

[4] MassDEP. "Massachusetts 2010-2020 Solid Waste Master Plan (SWMP)." Accessed December 2012. http://www.mass.gov/dep/recycle/solid/mprev12.pdf.

[5] MassDEP. "MassDEP Organics Subcommittee Meeting Summary September 24, 2012." Accessed December 2012. http://www.mass.gov/dep/public/committee/oscsm924.pdf.

[6] MassDEP. "Waste Disposal Bans." Accessed December 2012. http://www.mass.gov/dep/recycle/solid/wastebans.htm#generator

[7] Restaurant Startup and Growth. "Massachusetts To Ban Solid Food Waste from Landfills From Large Foodservice Operations." Accessed March 31, 2012. http://www.rsgmag.com/public/425.cfm.

[8] MassDEP. "About MassDEP: Office of Enforcement." Accessed March 31, 2013. http://www.mass.gov/dep/about/organization/enfabout.htm.az.

[9] Estimation is explained below, in Section 1.4.

incinerator. Before July 2014, Wellesley must implement an alternative method of handling its food waste.

In the past, Wellesley has not implemented large scale composting or food waste reduction programs. The approaching MassDEP deadline provides Wellesley with the incentive and opportunity to capitalize on the benefits of reducing and diverting food waste.

1.3 Current Practices: Disposal of Wellesley's Organic Waste

In accordance with the 2014 Organic Waste Ban, Wellesley will have to divert 100% of its yard and food waste from the traditional waste stream by July 2014. We examine the current method of organic waste disposal before proposing alternatives.

1.3.1 Yard Waste

This report does not propose organic waste diversion methods for Wellesley's yard waste because the College already has a system to handle this waste. Wellesley accumulates 112 metric tons of yard waste (brush, grass clippings, leaves, aquatic vegetation, trees, plants) every year. The College transports all yard waste to compost piles on Service Drive to be processed and reused on the grounds.[10] In total, 99.84% of total yard waste is reused on campus.[11]

1.3.2 Food Waste

The majority of our report focuses on means of food waste diversion. Currently, Wellesley's food waste is treated as any other non-recyclable, non-hazardous waste. Students and dining hall workers scrape most of the post-consumer food waste into trash bins. A private contractor, Wellesley Trucking, picks up the bins at each dining facility and transports them 10.7 miles to a transfer station in Holliston, Massachusetts. From the transfer station, our food waste is sent to Southeastern Massachusetts (SEMASS) Resource Recovery, a waste-to-energy facility, for incineration.[12] At the facility, all of the waste is shredded and then combusted; during the combustion, two steam turbines convert the concentrated heat energy to electricity.[13] By sending our waste to the SEMASS facility, Wellesley avoids sending food waste to landfills and generates electricity. The situation is far from ideal, though, as the high water content of food waste makes it a poor quality fuel for the incinerator.

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[10] Environmental Studies 300, Spring 2012. *Waste Not, Want Not: An Environmental Impact Assessment of the Wellesley College Waste Stream and Steps for a More Sustainable Future.* Wellesley, MA: Wellesley College, 2012. 197-198.
[11] Environmental Studies 300, Spring 2012. *Waste Not, Want Not: An Environmental Impact Assessment of the Wellesley College Waste Stream and Steps for a More Sustainable Future.* Wellesley, MA: Wellesley College, 2012. 198-200.
[12] Environmental Studies 300, Spring 2012. *Waste Not, Want Not: An Environmental Impact Assessment of the Wellesley College Waste Stream and Steps for a More Sustainable Future.* Wellesley, MA: Wellesley College, 2012. 21.
[13] Environmental Studies 300, Spring 2012. *Waste Not, Want Not: An Environmental Impact Assessment of the Wellesley College Waste Stream and Steps for a More Sustainable Future.* Wellesley, MA: Wellesley College, 2012. 22.

Some food waste, chiefly food that has been prepared and is left uneaten, is sent through an in-sink disposal system to the anaerobic digesters at the Deer Island wastewater treatment plant.

1.4 Wellesley College Dining Service

Nearly all Wellesley students are required to be on a meal plan. The College contracts *Wellesley Fresh, AVI Fresh for Wellesley College* to provide its food.[14] Only 25 students, who generally live in co-operatives or off campus, may opt out of the meal plan each year.[15] The meal plan is an all-you-can-eat buffer with no restrictions on the number of times students may enter the dining halls during operating hours. As part of the meal plan, students receive eight guest meal passes per semester. The dining halls do not permit take-out containers, preventing students from taking food outside of the dining facility. [16]

The five main dining facilities on campus are Tower, Bates, Stone Davis, Pomeroy, and the Bae Pao Lu Chow Campus Center. The Campus Center is the only dining facility that is not located in a residence hall, and is designed to accommodate off-campus guests. It is the only dining hall that has a swipe system in place to monitor the number of customers who enter. Pomeroy offers only vegetarian and kosher options. Wellesley Fresh also operates three facilities that serve a la carte prepared food: Collins Café, the Emporium, and the Leaky Beaker. Additionally, guests and students may eat at two student-run food co-operatives on campus, El Table and Café Hoop.

A few small initiatives have been piloted to reduce the amount of food waste in the traditional waste stream. During the 2010-2011 academic year, all dining halls on the Wellesley College campus went trayless.[17] Trayless dining leads to less food waste because it discourages students from piling large amounts of food onto their trays. A study on trayless dining found a 25-30% monthly reduction in food waste at 25 colleges and universities.[18] At Wellesley, remaining trays are used primarily in Bates Dining Hall, to transport used dishes into the dish room on a conveyor belt.

In April 2013, the Wellesley College Office of Sustainability launched a composting project in collaboration with Wellesley Fresh.[19] The program diverts pre-consumer food waste from dining halls to an off-campus windrowing facility. The pilot project will help the College determine the feasibility of and best practices for larger scale organic waste diversion.

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[14] Wellesley Fresh Culinary Services. “Dining Services and Meal Plan.” Accessed April 4, 2013. http://www.wellesleyfresh.com/policies.html.
[15] Kris Niendorf, Director of Residential and Campus Life. Interviewed by Ellen Bechtel. November 2012.
[16] Wellesley Fresh Culinary Services. “Dining Services and Meal Plan.” Accessed March 9, 2013. http://www.wellesleyfresh.com/policies.html.
[17] The College Sustainability Report Card. “Wellesley College Dining Survey.” Accessed March 12, 2013. http://www.greenreportcard.org/report-card-2010/schools/wellesley-college/surveys/dining-survey.
[18] Levin, Amelia. “Green Tip: Trayless Dining.” Food Service Equipment and Supplies. Accessed May 10, 2013. http://fesmag.com/features/foodservice-issues/10237-trayless-dining.
[19] Conton, Ruby, and Xueying Chen. "Office of Sustainability launches compost program." Wellesley News. Accessed March 12, 2013. http://www.wellesleynewsonline.com/office-of-sustainability-launches-compost-program-1.2953570?pagereq=1#.UT-cLdV1i3Y.

1.5 Estimating the Size of the Food Waste Stream at Wellesley College

We approximate Wellesley College's total food waste to be **220 metric tons per year**, an assumption that will be used throughout the report.

To settle on this number, we incorporate a variety of methods including the Mass DEP equation for calculating food waste, other universities' food waste estimates, interviews with dining hall staff, and observations of events on campus (Table 1-2).

Table 1-2: 2013 Estimate of Total Food Waste at Wellesley

Estimation Category	Estimate of annual food waste (metric ton)
Dining Halls - Mass DEP Equation	**183.0**
Dining Halls - Academic Year (Bottom-Up)	**214.0**
Dining Halls Average - Mass DEP and Bottom Up	**198.5**
Dining Halls - Summer and Winter	**11.8**
Events	**7.0**
Other Sources	**2.7**
Total	**220.0**

1.5.1 Academic Year Dining Hall Waste: Mass DEP Equation

We first estimate dining hall waste during the academic year with a food waste equation provided by MassDEP,[20] which results in an estimate of 183 metric tons per year. We later test the robustness of this number with a different method relying on Campus Center swipe counts and dining hall staff interviews.

The MassDEP equation is:

Food waste (lbs/yr) = (0.35 lbs/meal)(N of students)(405 meals/student/year)

[20] Draper/Lennon Inc., for MassDEP Bureau of Waste Prevention. "Identification, Characterization, and Mapping of Food Waste and Food Waste Generators in Massachusetts." Accessed March 12, 2013. http://www.mass.gov/dep/recycle/priorities/foodwast.pdf.

We have modified this equation to better match Wellesley's profile. As nearly all students are required to be on the full meal plan but may skip an occasional meal or eat elsewhere, we estimate 18 meals per student per week. For a 212-day academic year,[21] this comes to 545 meals per student per year. Wellesley currently has 2300 students enrolled,[22] but we assume 2100 students are on campus at during a given semester, to account for those on leave or abroad. The modified equation for Wellesley's dining halls during the academic year:

Wellesley dining hall food waste (metric tons/yr):

= (0.16 kg/meal)(2100 students)(545 meals/student/year)
= 183,120 kg/academic year
= 183.12 metric tons of food waste/academic year

1.5.2 Academic Year Dining Hall Waste: Dining Hall Interviews

In order to estimate the academic year dining hall waste, we account for both pre- and post-consumer waste. We estimate the post-consumer waste in dining halls during the academic year. The first is to use the number of students that swipe-in to one dining hall to estimate daily post-consumer food waste. The other method is to use the number of washed dining hall dishes to find the daily post-consumer food waste. These daily quantities of food waste are then scaled to reflect the amount of post-consumer student waste in dining halls during the school year. To produce a more accurate estimate, we take the average of the two methods. Another component of post-consumer waste is the uneaten food left in the serving trays. In order to come up with an estimate for total post-consumer waste during the school year, we add the estimate for annual leftovers in trays to the annual average of the two student post-consumer estimation methods (swipe-ins and dining hall dishes).

In order to determine the amount pre-consumer waste, we find the volume that one dining hall produces per day and then scale this up to reflect the total waste of all five dining halls per academic year.

We make two key assumptions in the estimation of pre-consumer and post-consumer waste. The first is that the daily waste value can be scaled linearly to an annual basis. The second is that dining halls are fairly equal in popularity and the calculations found in one dining hall can be scaled up to represent the entire Wellesley dining system.

Post-Consumer Waste Using Swipe-ins as a Metric

One method of estimating the number of dining hall meals is by calculating the number of swipes at Wellesley's only swipe-in dining hall (the Campus Center) and scaling up to the other dining halls. By interviewing staff members, we find the weekly average of swipe-ins by student

[21] Office of the Registrar, Wellesley College. "Academic Calendar." Accessed March 12, 2013. http://web.wellesley.edu/Registrar/20112016Calendar.pdf.
[22] Wellesley College. "Wellesley Facts." Accessed 12 March 2013. http://www.wellesley.edu/about/wellesleyfacts.

and staff. This value includes guest passes. This recorded value must be adjusted by 15% in order to account for the students that walk by without swiping through.[23]

We make several assumptions in this method of estimation. First, we assume that all of the dining halls have an equal number of visitors (i.e. if all dining halls had a swipe-in system, all would have a weekly average similar to the one of the Campus Center). We also assume that each swipe-in is roughly equivalent to one meal. While there may be cases where students swipe in to get beverages or to simply socialize, this value is generally balanced out by those who frequent the Campus Center more than three times a day or those who consume larger portions of food than their peers. Finally, we assume that each meal generates an average of 0.14 kg of waste, based on an Ohio University waste audit.[24]

Table 1-3: Recorded and Adjusted Weekly Swipe-Ins at Wellesley College's Campus Center

Per Week	Recorded	Adjusted by 15%
Jan 27 - Feb 2	6610	7601.5
Feb 3 - Feb 9	5386	6193.9
Feb 10 - Feb 16	6406	7366.9
Feb 17 - Feb 23	6427	7391.05
Average	6207.25	7138.34

Daily post-consumer food waste using swipe-ins as metric (metric ton/day):

= (number of dining halls)(weekly number of swipe-in/dining hall)(average kg waste/meal)
= (5 dining halls)(7138.3375 weekly swipe ins/dining hall)(.14 kg/swipe in)
= 4,996.836 kg/week
= (4,996.836 kg/week)(1 week/7 days)
= 713.83375 kg/day
= **0.71383 metric tons/day**

Food wasted per school year using swipe-ins as metric (metric ton/school year):

= (daily food waste kg/day)(days in the school year)[25]
= (0.71383 metric tons/day)(212 days/school year)

[23] Erin Shoemaker, Supervisor at Lulu Campus Center, and David Covill, Chef at Lulu Campus Center. Interviewed by ES 300 class. March 11, 2013.
[24] Moore, Anna. "Chew on this: The Problem of Food Waste." College Green Magazine. March 2010. http://www.collegegreenmag.com/chew-on-this-the-problem-of-food-waste. See further discussion and justification in Section 5.0.
[25] Office of the Registrar, Wellesley College. "Academic Calendar." Accessed March 12, 2013. http://web.wellesley.edu/Registrar/20112016Calendar.pdf.

= **151.33 metric tons/school year**

Post-Consumer Waste Using Dining Hall Dishes as a Metric

The second method of estimating number of dining hall meals is by using the number of dining hall dishes that Bates Dining Hall washes on a monthly basis to find the daily post-consumer food waste. In the month of February, Bates Dining Hall washed a total of 31,000 dishes: 7,900 at breakfast, 10,600 at lunch, and 12,500 at dinner.[26]

We make several assumptions in this method of estimation. First, we assume that all of the dining halls are equally popular (i.e. if all of the dining halls kept track of the number of dishes washed, this would be roughly equivalent to the monthly number at Bates). It is safe to assume that because much of the food is pre-plated, the Campus Center probably has a higher number of dishes per person per meal than other dining halls. We balance this difference by assuming that each dish at the Campus Center has a smaller food portion than in a buffet service style system. As a result, the amount of post-consumer food waste would be roughly equal in each dining hall. The second assumption is that each dining hall dish is the rough equivalent of one meal. Finally, as in the estimation using swipe-ins, we assume that each meal results in an average of 0.14 kg of waste.[27]

Daily post-consumer food waste using dining hall dishes as metric (metric tons/day)

= (number of dining halls)(dishes/dining hall/month)
(average kg waste/dish)(month/days)
= (5 dining halls)(31,000 dishes/dining hall/month)(.14 kg/dish)(1 month/28 days)
= 21.7 metric tons/month
= 0.775 metric tons/day

Food wasted per school year using dining hall dishes as metric (metric tons/school year):

= (daily food waste kg/day)(days in the school year)[28]
= (0.775 metric tons/day)(212 days/school year)
= **164.30 metric tons/school year**

Averaging the Two Methods

Both of these methods are rough estimates of the post-consumer food waste produced by the students. Averaging the two produces a more accurate estimate of post-consumer waste.

Post-consumer food waste per school year (metric ton/year):

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[26] Tolis Polihronis, Supervisor at Bates Dining Hall. Interviewed by Genia Nizkorodov. March 11, 2013.
[27] Moore, Anna. "Chew on this: The Problem of Food Waste." College Green Magazine. March 2010. http://www.collegegreenmag.com/chew-on-this-the-problem-of-food-waste.
[28] Office of the Registrar, Wellesley College. "Academic Calendar." Accessed March 12, 2013. http://web.wellesley.edu/Registrar/20112016Calendar.pdf.

= [(Food wasted per school year using swipe-ins as metric kg/school year)+(Food wasted per school year using dining hall dishes as metric kg/school year)]/2
= [(151.33 metric ton/school year + 164.30 metric ton/school year)]/2
= **157.82 metric ton/school year**

1.5.3 Incorporating Other School Year Food Waste

Pre-Consumer Dining Hall Food Waste

In order to estimate the pre-consumer waste, we find the volume of food that Tower Dining Hall throws away on a daily basis. We then use the density of food to find a daily pre-consumer waste value. This estimation is then scaled up to represent the annual waste production of all five dining halls. The key assumption made is that regardless of menu, the volume of pre-consumer waste remains the same. A second assumption is that this value does not change between dining halls.

Pre-consumer waste: ½ trash bin per day[29]
Bin Used: 44-Gallon Brute Trash Bin[30]
Density of Food scraps, solid and liquid fats: 412 pounds in a 55-gallon drum[31]

Necessary calculations:

Volume of One Bin:
= (44 quart)(1 gallon/4 quarts)(3.785 L/1 gallon)
= 41.635 L
Density [Food Waste]:
= (412 lbs/55 gallons)(1 kg/2.2.04 lbs)(1 gallon/3.785 L)
= 0.898 kg/L
Volume Waste/Bin
= 41.635 L * (.8980 kg/1 L)
= 37.386 kg/bin

Daily pre-consumer waste during the academic year (metric tons/day):

= (number of dining halls)(bins wasted/dining hall)(volume kg/bin)
= (5 dining halls)(.5 bins/dining hall)(37.386 kg/bin)
= 93.465 kg/day
= 0.0935 metric tons/day

Pre-consumer food waste per school year (metric tons/school year):

= (daily food waste kg/day)(days in the school year)[32]

[29] Bob Higgins, Tower Dining Hall staff. Interviewed by Genia Nizkorodov. March 11, 2013.
[30] Bob Higgins, Tower Dining Hall staff. Interviewed by Genia Nizkorodov. March 11, 2013.
[31] Miller, Chaz. "Food Waste." Waste 360. Accessed March 12, 2013. http://waste360.com/mag/waste_food_waste_2.

= (0.0935 kg/day)(212 days/school year)
= **19.81 metric tons/school year**

Incorporating Leftover Food from Dining Halls (in Pans)
We also incorporate the leftover food thrown out from serving pans after each meal. We used the Campus Center as the basis for this estimate. Roughly three half-full pans are thrown out after each meal. Each pan holds approximately nine quarts.[33]

Necessary calculations:

Volume of One Pan:
= (9 quarts)(1 gallon/4 quarts)(3.785 L/1 gallon)
= 8.516 L
Density [Food Waste]:
= (412 lbs/55 gallons)(1 kg/2.2.04 lbs)(1 gallon/3.785 L)
= 0.8980 kg/L
Volume Waste/Pan
= 8.516 L * (.8980 kg/1 L)
= 7.647 kg/pan

Post-consumer waste using pans as metric (metric tons/day):

= (waste kg/pan)(number of pans)(number of dining halls)(number of meals)
= (0.5)(7.647 kg/pan)(3 pans/meal-dining hall)(5 dining halls)(3 meals)
= 172.071 kg/day
= **0.172 metric tons/day**

Pre-consumer food waste per school year from pans (metric tons/school year):

= (daily food waste of pans kg/day)(days in the school year)
= (172.071 kg/day)(212 days/school year)
= 36,479 kg/school year
= 36.47 metric tons/school year

Total food waste per school year:

= Post-Consumer food waste per school year kg/school year + Pre-consumer Food waste per school year kg/school year + Pre-consumer Food waste per school year from Pans kg/school year
= 157.82 metric ton/school year + 19.81 metric ton/school year + 36.48 metric ton/school year
=**214.11 metric tons/school year**

[32] Office of the Registrar, Wellesley College. “Academic Calendar.” Accessed March 12, 2013. http://web.wellesley.edu/Registrar/20112016Calendar.pdf.
[33] Audrey Mutschlecner, Campus Center dining hall staff. Interviewed by Carly Gayle. March 10, 2013.

1.5.4 Summer and Winter Dining Hall Waste

In order to estimate summer and winter session dining hall waste, we use the monthly number of swipe-ins at Bates Dining Hall. We rely on the same assumptions used for estimating pre- and post-consumer waste during the academic year. Bates Dining Hall is the only operating dining hall during winter-session,[34] while Bae Pao Lu Chow Dining Hall at the Campus Center is the only one open during the summer.

Post-Consumer Food Waste for Winter and Summer Session

The recorded number of swipe-ins at Bates Dining Hall for January 2013 was 3,640.[35] This number grows to 4,186 when adjusted for the people who do not swipe in (15%). We use this value to find the daily post-consumer waste by students, and then scale it up to incorporate summer session as well.

Daily post-consumer waste during the summer and winter sessions (metric tons/day):

= (number of dining halls)(number of swipe-in/dining hall)(average kg waste/meal)
where one meal is the equivalent of one swipe-in
= (one dining hall)(4,186 swipe ins/dining hall)(.14 kg/swipe in)
= 586.04 kg/month
= (586.04 kg/month)(1 month/4 weeks)(1 week/7 days)
= 21 kg/day
= 0.021 metric tons/day

Post-consumer food waste during summer and winter sessions (metric tons/year):

= (daily post consumer food waste kg/day)(days in winter and summer session)[36]
= (0.21 metric tons/day)(153 days/winter and summer session)
= 3.20 metric tons/year

Pre-Consumer Waste During Winter Session and Summer Session

Pre-consumer waste is originally estimated for the academic year using the statistics for Tower Dining Hall.[37] Since we assume that all dining halls produce equal volumes of food, these values apply to Bates Dining Hall to find the total pre-consumer food waste during summer and winter sessions.

Daily pre-consumer waste during the summer and winter session (metric tons/day):

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[34] Tolis Polihronis, Supervisor at Bates Dining Hall. Interviewed by Genia Nizkorodov. March 11, 2013.
[35] Tolis Polihronis, Supervisor at Bates Dining Hall. Interviewed by Genia Nizkorodov. March 11, 2013.
[36] Office of the Registrar, Wellesley College. “Academic Calendar.” Accessed March 12, 2013. http://web.wellesley.edu/Registrar/20112016Calendar.pdf.
[37] Bob Higgins, Tower Dining Hall staff. Interviewed by Genia Nizkorodov. March 11, 2013.

= (number of dining halls)(bins wasted/dining hall)(volume kg/bin)
= (1 dining hall)(0.5 bins/dining hall)(37.386 kg/bin)
= 19 kg/day
= 0.019 metric tons/day

Pre-consumer food waste during summer and winter sessions (metric tons/year):

= (daily pre-consumer food waste kg/day)(days in winter and summer session)[38]
= (0.19 metric tons/day)(153 days/winter and summer session)
= **2.86 metric tons/year**

Incorporating Leftover Food During Summer and Winter Sessions
Waste from uneaten food on pans was originally estimated for the academic year using information from the Campus Center Dining Hall.[39] Since we assume that all dining halls produce equal volumes of food, these values apply to Bates Dining Hall to find the total pre-consumer food waste left on pans during summer and winter sessions.

Necessary calculations:

Volume of One Pan:
= (9 quarts)(1 gallon/4 quarts)(3.785 L/1 gallon)
= 8.516 L
Density [Food Waste]:
= (412 lbs/55 gallons)(1 kg/2.2.04 lbs)(1 gallon/3.785 L)
= .8980 kg/L
Volume Waste/Pan
= (8.516 L)(.8980 kg/1 L)
= 7.647 kg/pan

Post-consumer waste using pans as metric (metric tons/day):

= (waste kg/pan)(number of pans)(number of dining halls)(number of meals)
= (.5)(7.647 kg/pan)(3 pans/meal-dining hall)(1 dining hall)(3 meals)
= 34.4115 kg/day
= 0.034 metric tons/day

Pre-consumer food waste per school year from pans (kg/year):

= (daily food waste of pans kg/day)(days in winter and summer session)[40]
= (0.034 metric ton/day)(153 days/winter and summer session)

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[38] Office of the Registrar, Wellesley College. "Academic Calendar." Accessed March 12, 2013. http://web.wellesley.edu/Registrar/20112016Calendar.pdf.
[39] Audrey Mutschlecner, Campus Center dining hall staff. Interviewed by Carly Gayle. March 10, 2013.
[40] Office of the Registrar, Wellesley College. "Academic Calendar." Accessed March 12, 2013. http://web.wellesley.edu/Registrar/20112016Calendar.pdf.

= **5.26 metric tons/year**

Total food waste during summer and winter sessions:

= (Post-consumer food waste in winter and summer session kg/ year) + (Pre-consumer food waste in winter and summer session kg/year) + (Food waste from pans in winter and summer session kg/year)
= 3.20 metric tons/year + 2.86 metric tons/year + 5.26 metric tons/ year
= 11.87 metric tons/year

Robustness of Waste per Meal Data

As MassDEP's estimation of food waste per person per meal has unclear methodologies, we check it against other estimates to strengthen its validity. The estimate of 0.16 kg per meal is close to the pre- and post-consumer waste estimates of Ohio University and Carleton College. Ohio University's 2009 waste audit found 0.14 kg of waste per person per meal.[41] Though the majority of students are on a 14 meal per week plan, Ohio University has buffet style dining as Wellesley does, so the waste per plate and leftovers after meals are good approximations of Wellesley's food waste. Carleton College, a small liberal arts school in Minnesota, found that post-consumer waste was 0.113 kg per meal and pre-consumer waste was equivalent of 0.073 kg per meal, for a total of 0.186 kg of waste per student meal.[42] Most Carleton students are on a 12 meal per week plan, with buffet and à la carte options,[43] which could account for greater uncertainty in food consumed on a given day and therefore greater pre-consumer food waste. Carleton College and Ohio University's estimates are close enough to MassDEP's number to assure us that it is a valid metric.

1.5.5 Events; Small and Medium Scale, Academic and Special

Assumptions

We divide events at Wellesley into several categories, small-scale, medium-scale, academic department, and large-scale special events. Based on observations cited in the ES 300 2012 report, we make the general assumption that people consuming food at campus events waste approximately 10% of food on their plates.[44] Even if the food is not consumed during the scheduled event, it is generally left available for student consumption. Thus, we assume that food waste at campus events is from individual plates, and not wasted due to over-ordering in bulk.

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[41] Moore, Anna. "Chew on this: The Problem of Food Waste." College Green Magazine. March 2010. http://www.collegegreenmag.com/chew-on-this-the-problem-of-food-waste.
[42] Carleton College Environmental Studies Department. "Food Waste." Accessed March 12, 2013. http://apps.carleton.edu/curricular/ents/resources/stu_projects/global_change_2000/composting/food_audit/.
[43] Carleton College Dining Services. "Meal Plans and Prices." Accessed March 12, 2013. http://apps.carleton.edu/campus/dining_services/meal_plan/.
[44] Environmental Studies 300, Spring 2012. *Waste Not, Want Not: An Environmental Impact Assessment of the Wellesley College Waste Stream and Steps for a More Sustainable Future.* Wellesley, MA: Wellesley College, 2012. 17-22.
[44] Environmental Studies 300, Spring 2012. *Waste Not, Want Not: An Environmental Impact Assessment of the Wellesley College Waste Stream and Steps for a More Sustainable Future.* Wellesley, MA: Wellesley College, 2012.17-22.

Small-Scale Student Events

Scheduled events at Wellesley College appear on the Wellesley Events Calendar; in 2012's Environmental Impact Assessment (EIA), this calendar was used to estimate the number of events occurring on campus that would produce a significant amount of food waste.[45] Based on a typical week in 2013, we assume that there are three events per week that serve food to between 20 and 50 students. The ES 300 2012 report estimates that the food catered at these events amount to approximately five half-pan containers. We assume that the food ordered for small-scale events is in half-pan (12x10x4) containers, which have a food density of .8980 kg/L and a mass of 3.529 kg.

Annual waste from small-scale events:

= 90 events x 5(3.529 kg)
=1588.05 kg/year
= 1.59 metric tons/year

Medium-Scale Student Events

The 2012 EIA also estimates that there are three medium-scale events per month (between 75 and 125 students), or approximately seven per academic year.[46] According to their study, each of these medium-scale events cater eight full-pan containers. For medium-scale events, the report measures the food in full-pan (12x10x4) containers, which have a mass of 7.064 kg.

Annual waste from medium-scale events:

= 7 events x 8(7.064 kg)
= 395.584 kg/year
= 0.396 metric ton/year

Academic Department Meetings

We also account for the meetings and events that are not announced on the aforementioned weekly calendar. We approximate that there are 15 academic department meetings each week (one for each department, on a biweekly basis). Of these, we assume that half have food (eight meetings), with two half-pan (12x10x4) containers each.

Annual waste from department meetings:

= 240 meetings x 2(3.529 kg)
= 1,693.92 kg/year
= 1.69 metric tons/year

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[45] Environmental Studies 300, Spring 2012. *Waste Not, Want Not: An Environmental Impact Assessment of the Wellesley College Waste Stream and Steps for a More Sustainable Future.* Wellesley, MA: Wellesley College, 2012.17-22.
[46] Environmental Studies 300, Spring 2012. *Waste Not, Want Not: An Environmental Impact Assessment of the Wellesley College Waste Stream and Steps for a More Sustainable Future.* Wellesley, MA: Wellesley College, 2012.17-22.

Large Scale Events: Tanner Conference
For the Tanner Conference in 2012, student volunteers and the Office of Sustainability recovered 290 kg (640 lbs) of compostable waste.[47] We approximate that this was a 75% recovery rate. Thus, we assume the total organic waste from the Tanner Conference is 385 kg or **0.39 metric tons/year.**

Large Scale Events: Ruhlman Conference
We assume the total organic waste from the Ruhlman Conference is equivalent to Tanner, **0.39 metric tons/year.**

Large-Scale Events: Lake Day, Marathon Monday
We assume that both Lake Day and Marathon Monday produce less waste than Ruhlman and Tanner. We estimate that Lake Day produces **0.30 metric tons** and that Marathon Monday also produces **0.30 metric tons.**

Commencement
We assume that every senior attends Commencement, and that each senior brings two guests. Given a student body of 2300, the senior class is made up of approximately 600 students. We estimate that at least 1800 people attend Commencement. Calculations for Commencement assume 0.14 kg of food waste per person per meal.[48] There are four scheduled events with catered food associated with Commencement.

Senior Class Luncheon:

= (600 guests)(0.14 kg/person)
= 84 kg

Picnic Lunch, seniors and guests:

= (1800 guests)(0.14 kg/person)
= 252 kg

Breakfast for seniors:

= (600 guests)(0.14 kg/person)
= 84 kg

Complimentary light lunch following Commencement, seniors and guests:

= (1800 guests)(0.14 kg/person)

[47] Danielle A Gaglini, Wellesley College Office of Sustainability. Interviewed by Elli Blaine. October 31, 2012.
[48] Moore, Anna. “Chew on this: The Problem of Food Waste.” College Green Magazine. March 2010. http://www.collegegreenmag.com/chew-on-this-the-problem-of-food-waste.

= 252 kg

Total Commencement food waste:

= (Food waste from senior class luncheon kg) + (Food waste from picnic lunch kg) + (Food waste from senior breakfast kg) + (Food waste from lunch following Commencement kg)
= 84 kg + 252 kg + 84 kg + 252 kg
= 672 kg
= 0.672 metric tons

Reunion
Wellesley College Reunion happens the first weekend of each June, from Friday afternoon through Sunday afternoon. Four meals are served during Reunion, with the number of attendees at each meal tracked in 2011 and 2012.[49]

Friday Dinner:

= (1547.5 guests)(0.14kg/person)
= 216.65 kg

Saturday Lunch:

= (2080 guests)(0.14kg/person)
= 291.2 kg

Saturday Dinner:

= (2000 guests)(0.14kg/person)
= 280 kg

Sunday Lunch:

= (1467.5 guests)(0.14kg/person)
= 205.45 kg

During Reunion the alumnae and guests who stay in the dorms eat breakfast in the dorm dining halls. The following estimates are based on the 2011 and 2012 average number of guests in the dorms.[50]

[49] Sara Helmers, Reunion Reservationist at Wellesley College Alumnae Association. Email correspondence with Elsa Sebastian. March 31, 2013. 2012 attendance: 1427 Friday dinner, 1862 Sat lunch, 1809 Sat dinner, 1335 Sun lunch. 2011 attendance: 1668 Fri dinner, 2298 Sat lunch, 2191 Sat dinner, 1600 Sun lunch.
[50] Sara Helmers, Reunion Reservationist at Wellesley College Alumnae Association. Email correspondence with Elsa Sebastian. March 31, 2013. Reunion 2012 number of overnight guests: 966 Friday overnights, 1049 Saturday overnight. Reunion 2011 number of overnight guests: 1200 Friday overnight, 1267 Saturday overnight.

Saturday Breakfast:

= (583 guests)(0.14kg/person)
= 81.62 kg

Sunday Breakfast:

= (1158 guests)(0.14 kg/person)
= 162.12 kg

Total food waste from Reunion:

= (Food waste from Friday dinner kg) + (Food waste from Saturday breakfast kg) + (Food waste from Saturday lunch kg) + (Food waste from Saturday dinner kg) + (Food waste from Sunday breakfast kg) + (Food waste from Sunday lunch kg)

= 217 kg + 82 kg + 291 kg + 280 kg + 162 kg + 205 kg
= 1237 kg
= 1.237 metric tons

Total Waste from Events

Summing the waste generated by academic department meetings, small-scale, medium-scale, and large-scale events, we reach an estimate of **6.97 metric tons** of food waste per academic year.

Table 8-4: Annual Food Waste by Category

Event	Food waste (metric tons)
Small-scale events	1.59
Medium-scale events	0.40
Academic dept. meetings	1.69
Tanner Conference	0.39
Ruhlman Conference	0.39
Lake Day	0.30
Marathon Monday	0.30
Commencement	0.67
Reunion	1.24
Total	**6.97**

1.5.6 Other Sources of Food Waste

Aside from dining services and events, several other sources contribute to food waste on campus. These include the Collins Café, the Emporium, and the Leaky Beaker, which offer limited quantities of prepared foods, as well as the College Club and two student-run cooperatives, Café Hoop and El Table.

On Campus Cafés

The Leaky Beaker, Collins Café, and Emporium all offer à la carte selections. Faculty, staff, and guests frequent these venues more often than students, who can use dining points at these vendors. During the summer, the Leaky Beaker's leftover food consists of an average of ten 100-gram pastries per day, ten 200-gram sandwiches, and three 200-gram fruit cups per week for a total of about four kg, or .004 metric tons of waste per week. This food waste is not typically put into the trash; rather, AVI's staff members generally take excess food with them at the end of the day or leave it for students.[51] For this reason, we assume that any pre-consumer edible food at these three cafés will be consumed rather than wasted. The facilities produce no excess food scraps since they serve prepared food. Thus, we do not include food from the cafés in this study. We did not include food waste at the College Club in this study because it already diverts food waste to a local resident's pet pig and to the Metro West Harvest food rescue program.[52]

El Table and Café Hoop generate a negligible quantity of food waste. At these venues, students pay premium prices for made-to-order food, leading to insignificant quantities of food waste. Additionally, El Table composts its coffee grounds and food scraps.

Summer and Winter Personal Food Preparation in Dorms

Personal food preparation in the dorms during summer and winter sessions generates an estimated 2.7 metric tons of food waste. Throughout the academic year, nearly all students are on a mandatory full meal plan. During the summer and winter sessions, though, at least half of the students cook for themselves. Thus, in the residence halls, we assume the majority of food waste occurs during summer and winter sessions. 4200 swipe-ins during winter session (section 1.5.4) is equal to 140 people eating three meals per day in the dining hall. This number means that the other 200 winter session students on campus cook individually and/or order take-out for themselves. The average American discards 20 pounds of food each month, or 2.1 kilograms per week.[53] We assume that Wellesley students waste about half this much. Funding is generally tight for college students, and food for one person is easier to keep track of than food for a household, leading to fewer items forgotten and thrown away.

Total waste from other sources (metric tons/year):

= (200 students)(13 weeks)(1.05 kilograms/week)
= 2730 kg/year
= **2.7 metric tons/year**

1.6 Waste Diversion at Other Colleges

Part of our process of assessing the most feasible methods for Wellesley is researchingorganic waste diversion at other colleges. Colby College, Connecticut College, Cornell University, Dartmouth College, Grinnell College, Harvard University, Ithaca College, Kenyon College,

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[51] Based on student observations during summer 2012.
[52] Mark Roche, General Manager of the College Club. Interviewed by Audrey Mutschlecner. March 14, 2013.
[53] Kyle Rabin. "18 Little-Known Facts that will Motivate You to Cut Back on Food Waste." Civil East. August 16, 2012. Estimate taken from Gustavsson et. al, "Global Food Losses and Food Waste," United Nations Food and Agriculture Organization, 2011. Accessed 31 March, 2013.

Middlebury College, Mount Holyoke College, Oberlin College, Rutgers University, Skidmore College, Smith College, University of Connecticut, University of Massachusetts Amherst, University of New Hampshire, University of Vermont, Vermont Technical College, Wheaton College (Massachusetts), and Williams College were chosen due to their similarities to Wellesley College in at least one of the following categories: campus location, student population size, and seasonal climate.

1.6.1 Method Breakdown and Trends

Of the twenty-one colleges examined, nine compost entirely on campus or at an institution-owned facility, three pre-process organic waste on campus through pulping and/or dehydrating before sending it to an off-campus facility, and nine compost off campus without preparation. Table I-1 and Figure I-1 provide a breakdown of the methods consistently used, whether on campus or off campus.

The main factors in determining method selection across all colleges are cost and logistical concerns. The financial concerns partially explain the range of food waste diverted between colleges; some colleges divert almost 100% of their food waste while others divert less than 10%. The major drivers behind off-campus organic waste diversion are the ease of implementation and logistical reasons, such as space constraints.

Table I-1: Organic waste diversion methods used at the above colleges[54]

Method Used	Number of Colleges Using Method
Windrows	5
Donation	4
Pulper-Dehydrator systems	4
Pulpers	3
Bins	2
Biodigesters	2
Vermicomposting	2
In-vessel	1
Piles	1
Tumblers	1

[54] Inconsistently used or unspecified methods have been excluded. Note: some colleges may use more than one method; when a single college uses multiple methods consistently, all have been included.

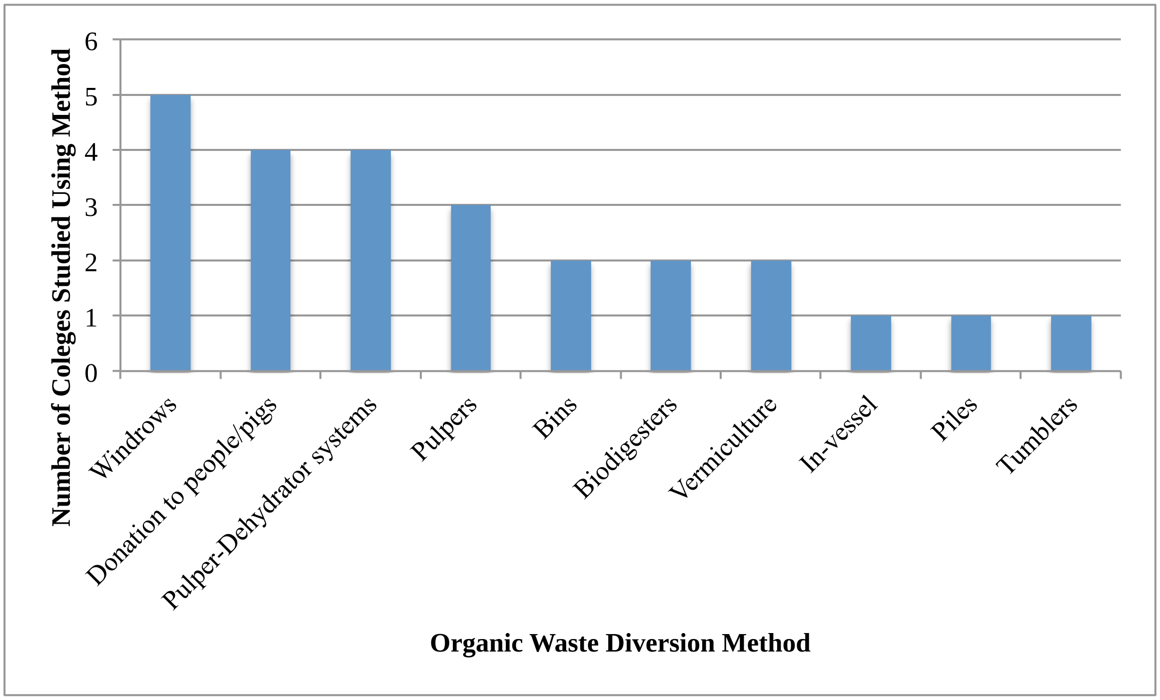

Figure 1-1: Breakdown of organic waste diversion methods used at colleges studied.

Windrowing, food donation, and dehydration are the most popular methods, especially among larger universities.

1.6.2 Important Lessons: Motives, Implementation, Challenges and Limitations

Researching waste diversion on other college campuses has given us insight into the challenges that Wellesley may encounter in the implementation and upkeep of food waste diversion efforts.

Key factors influencing college decisions on which method of food waste diversion to pursue were cost-effectiveness and constraints on space for infrastructure. Rutgers University found that donating its food waste to a local pig farm cost $30 per ton of waste - nearly half the cost of sending the material to the landfill, and less expensive than sending the waste to local composting facilities.[55] Smith College, Mount Holyoke College, Williams College, and UMass Amherst also send their waste to off-campus farms.[56] Though partnering with farms is a popular choice, Williams College and Rutgers University both indicate that their relationships with farms have been problematic.[57] Williams College found that it was hard to find farms nearby that

[55] U.S. EPA. "Wastes – Resource Conservation – Food Waste: Feed Animals." Accessed Spring 2013. http://www.epa.gov/foodrecovery/fd-animals.htm.

[56] Smith College. "Green Smith: Operational Initiatives." Accessed April 1, 2013. http://www.smith.edu/green/operations_dining.php; Mount Holyoke College. "Composting." Accessed March 2, 2013. https://www.mtholyoke.edu/dining/composting; University of Massachusetts Amherst. "UMass Amherst: Waste Management Report - Fiscal Year 2012." Accessed April 1, 2013. http://www.umass.edu/physicalplant/documents/wmrpt2012.pdf.

[57] U.S. EPA, with Rutgers University. "Feeding Animals – The Business Solution to Food Scraps." Accessed April 1, 2013. http://www.epa.gov/foodrecovery/success/rutgers.pdf;

would take the large amount of food waste it produced. After trying to establish relationships with multiple local farms, the University decided to partner with a farm nearly 30 miles from campus.[58] Rutgers University also finds it challenging to find local farmers interested in food waste disposal since it is in a large urban area where food scraps are abundant and farms are scarce.[59]

At many institutions, on-campus composting on a large scale may not be possible due to both space and odor concerns. UMass Amherst composted on campus in the past, but stopped in 2001 due to neighborhood complaints about bad odors.[60] Contamination of food waste has also been a problem at colleges that donate food to off-campus farms. While colleges try to encourage proper waste disposal behavior, non-compostable dishware and other inorganic items are often thrown out with food. A number of colleges find that educating the student body on how to properly dispose of food waste is challenging and problematic.

Colleges that pursue less common waste diversion methods, such as anaerobic digestion and piles, may base their decision on a set of unique circumstances that do not apply to Wellesley. Vermont Technical College diverts food waste to a commercial-scale on-campus anaerobic digester. At least 51% of the input is manure and crops from neighboring towns. The output gas generates electricity and heats on-campus buildings, while the solids are dried and used for animal bedding.[61] The college's place in the fabric of an agricultural community makes an anaerobic digester a logical choice. Kenyon College's rural setting allows it to compost pulped food waste in piles on campus, a method that is likely impossible to implement in an urban or suburban area.[62]

At some colleges, donations from alumni have helped to remove the financial barriers to implementing on-campus systems with high initial costs. Some colleges, such as Connecticut College,[63] have received large donations from alumni to begin organic waste reduction projects. Kenyon College purchased a food pulper system with money from a trustee.[64]

Robert Volpi, Williams College Director of Dining Services. Interviewed by ES 300. March 7, 2013.

[58] Robert Volpi, Williams College Director of Dining Services. Interviewed by ES 300. March 7, 2013.

[59] U.S. EPA, with Rutgers University. "Feeding Animals – The Business Solution to Food Scraps." Accessed April 1, 2013. http://www.epa.gov/foodrecovery/success/rutgers.pdf.

[60] Kulyabina, Kristina. "UMass Amherst reduces and composts food waste in new efforts." Food Dynamics. April 2012. http://kkulyabina.wordpress.com/2012/04/11/umass-amherst-reduces-and-composts-food-waste-in-new-efforts/.

[61] Vondrasek, Sandy. "VTC Seeks Permits for On-Campus Methane Digester." The Herald of Randolph. Accessed March 4, 2013. http://www.ourherald.com/news/2011-11-03/Front_Page/f09.html.

[62] Kenyon College Office of Sustainability. "Recycling and Composting." Accessed March 4, 2013. http://www.kenyon.edu/x57562.xml.

[63] Connecticut College. "Composting Program History." Accessed March 4, 2013. http://www.conncoll.edu/sustainability/history-composting-program.htm.

[64] Kenyon College Office of Sustainability. "Recycling and Composting." Accessed March 4, 2013. http://www.kenyon.edu/x57562.xml.

Like Wellesley, Kenyon College contracts AVI Fresh as its food service provider and is pursuing rigorous food reduction and waste diversion strategies with the company.[65] Local produce is more easily accessible in the surrounding farming community, and AVI Fresh is based in Ohio, so a similar program may be more difficult to implement at Wellesley. Their partnership indicates, though, that AVI Fresh is open to working with colleges who want to pursue food waste reduction and diversion programs.

1.6.3 Food Reduction Methods

Examining programs at other colleges informed us that a successful food waste diversion program at Wellesley College will necessitate improved record-keeping of food waste in dining halls and heightened awareness about the program among the student body. Wellesley can learn from these colleges' food waste reduction strategies as it develops an effective food waste management system.

Tracking Food Waste

Tracking food waste is one of the most commonly implemented food waste reduction measures. Successful reduction programs include keeping records of production amounts, customer counts, weights of pre- and post-consumer waste, and product movement. LeanPath and FoodPro are two popular programs that have been used to catalog food waste and minimize the amount of waste produced by following food inventory and planning menus.[66] Ithaca College has reduced food waste by measuring and labeling post-consumer food waste with the reason for disposal before it is thrown away, which can lead to better tracking and purchasing estimations.[67]

A few colleges, including UMass Amherst,[68] have implemented sustainable food programs that include a diverse range of food reduction and diversion methods. Many institutions have also joined the EPA's Food Recovery Challenge, a part of the EPA's Sustainable Materials Management Program.[69] The Food Recovery Challenge asks participating institutions to reduce as much food waste as possible. Colleges and universities participating in the challenge include Harvard University, Bates College, Clark University, Rutgers University, Middlebury College, and Massachusetts Institute of Technology.[70]

Modifying Food Preparation and Service

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65 Kenyon College Office of Sustainability. "Recycling and Composting." Accessed March 4, 2013. http://www.kenyon.edu/x57562.xml.

66 Aurora Information Systems. "FoodPro - The System," Accessed March 2, 2013. http://www.foodpro.com/; Mount Holyoke College. "Environmentally Friendly Practices." Accessed March 2, 2013. https://www.mtholyoke.edu/dining/practices.

67 Madison, Katelyn. Ithaca Dining Services. "Enough Waste for an Elephant?!" Accessed Spring 2013. http://ithacadiningservices.com/.

68 University of Massachusetts Amherst Dining Services. "Sustainability at UMass Amherst." Accessed March 3, 2013. http://www.umassdining.com/sustainability.

69 U.S. EPA Sustainable Materials Management. "Food Recovery Challenge." Accessed April 1, 2013. http://www.epa.gov/smm/foodrecovery/.

70 U.S. EPA Sustainable Materials Management. "Food Recovery Challenge." Accessed April 1, 2013. http://www.epa.gov/smm/foodrecovery/.

Changes to the way food is prepared and served can also affect the quantity of waste produced. These changes include discouraging grab-and-go systems, making food to order, and implementing smaller portions for self-serve systems. UMass Amherst achieves food waste reductions by using "just-in-time" cooking in some of their dining halls.[71] Many colleges, such as Rutgers, are actively seeking ways to repurpose leftover food into new dishes.[72]

Institution Wide Education and Awareness Programs

A dominant strategy for food waste reduction is to focus on education and awareness. Grinnell's "Student Sustainability Guide" and move-in information are excellent examples of education campaigns.[73] Many colleges conduct waste audits, campaigns, competitions and workshops to increase awareness of food waste. Other education and awareness measures include providing recycling and composting programs and certification, as Rutgers University does,[74] and making a website for information regarding the college's waste diversion programs. The University of Connecticut uses waste vegetable oil from dining halls to power shuttle buses, preventing carbon emissions from gasoline and raising awareness of the ability to view "waste" as a valuable resource.[75]

Creating opportunities for student involvement is one component of successful food waste diversion and recycling programs. At Connecticut College, students are able to work in the composting program through paid work-study programs.[76] Hiring student interns in their dining service to aid in education and creating a student position of "composter" in residential dorms helps to increase the connections between the student body and food waste management programs.[77] Several colleges have increased student participation by adopting sustainability, including waste reduction, as a key part of their campus culture. The University of Vermont's Zero Waste Program[78] and Middlebury College's commitment to sourcing all energy from carbon neutral sources by 2015 turn waste reduction into a source of pride and a common identity for students, motivating them to participate at the college and in the world beyond.[79]

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[71] University of Massachusetts Amherst Dining Services. "Sustainability at UMass Amherst," Accessed March 3, 2013, http://www.umassdining.com/sustainability.
[72] Rutgers University Dining Service. "FAQ." Accessed March 3, 2013. http://food.rutgers.edu/faq.
[73] Grinnell College. "Student Sustainability Guide: Grinnell's Environmental Impact." Accessed March 12, 2013. http://www.grinnellwiki.com/index.php/Student_Sustainability_Guide:_Grinnell%27s_Environmental_Impact
[74] Rutgers University, New Jersey Agricultural Experiment Station. "NJ Compost Operator Certification Course." Accessed March 5, 2013. http://www.cpe.rutgers.edu/courses/current/er0303ca.html.
[75] University of Connecticut Dining Services. "Sustainability Initiatives." Accessed March 12, 2013. http://www.dining.uconn.edu/local_routes_sustainability.html.
[76] Connecticut College. "Composting Program History." Accessed March 4, 2013. http://www.conncoll.edu/sustainability/history-composting-program.htm.
[77] Smith College Committee on Sustainability. "Sustainability and Climate Action Management Plan (SCAMP)." Accessed Spring 2013. http://www.smith.edu/green/docs/SmithCollegeSCAMP.pdf.
[78] University of Vermont Recycling and Waste Management. "'Zero Waste' and UVM." Accessed March 4, 2013. http://www.uvm.edu/~recycle/?Page=zero-waste/zero-default.html&SM=zero-waste/zero-waste-menu.html.
[79] Middlebury College. "Carbon Neutrality." Accessed March 7, 2013. http://www.middlebury.edu/sustainability/energy-climate/neutrality.

2.0 Food Waste Reduction

2.1 Introduction

Food waste reduction measures are widely known to be the first step to any waste management plan. Reducing organic waste at Wellesley College should be the first step to compliance with the Organic Waste Ban. Producing less food waste will reduce the downstream costs and impacts of food waste diversion. Moreover, there is a positive social impact to reducing food waste. Disposing of edible food is socially irresponsible and has become a national issue. The inclusion of waste reduction methods in an implementation ban to comply with the Organic Waste Ban would make the Wellesley College a model institution for environmental, financial, and social responsibility. The following reduction methods are discussed in this report: 1) Education and awareness, Institution-wide food monitoring systems, 3) Changing food preparation, service and presentation, 4) Event Waste Reduction, 5) Food redistribution to students, and 6) Changing the meal plan. In the following chapter, each reduction method is introduced, experiences with the method at other institutions and implementation at Wellesley College is discussed, and concluding remarks are made.

2.2 Education and Awareness

Education and awareness form the foundation of food waste reduction, and should be incorporated into any reduction strategy that Wellesley College pursues. Currently, many members of the Wellesley community are unaware of the large volume of food waste we produce. Education and awareness regarding food waste management would help reduce individual pre- and post-consumer food waste by providing students and staff with information on the harms of food waste. An effective awareness campaign would suggest behavioral changes that would promote food waste reduction. This information would be shared with the Wellesley community through direct presentations (seminars, posters, flyers, etc.) or through or through community-wide hands-on activities (programs during orientation, RecycleMania). With increased awareness and knowledge surrounding the issues of food waste, the student body will be responsive to institution-wide changes in food waste management.

2.2.1 Experience with Reduction through Education and Awareness

In the United States, the federal government funds waste reduction efforts. The United States Environmental Protection Agency (EPA) allocates grants to support curriculum regarding waste management practices in elementary, middle, and high schools; in fact, between 1992 and 2004, the EPA awarded 30 million dollars to various education institutions to implement educational waste reduction courses.[1]

A school in Kansas City, Missouri had the most successful EPA-funded waste reduction program. Beginning in 1993, the schools piloted a program with 16 hours of classroom instruction and discussion to facilitate waste reduction. In this program, students from kindergarten to twelfth

[1] Hasan, S.E. “Public Awareness is Key to Successful Waste Management.” *Journal of Environmental Science and Health, Part A: Toxic/Hazardous Substances and Environmental Engineering* 39.2 (2004): 483-92.

grade studied waste types, sources, disposal methods, recycling and waste reduction, and environmental laws. In 1994, Kansas City's education program was expanded to the college level when the Geosciences Department at the University of Missouri offered the course *Issues in Waste Management*. *Issues in Waste Management* does not have any prerequisites and is designed for non-science students. The course's primary goal is to promote a student-led discussion about on-campus food waste. The college reports that students from liberal arts, education, earth science, psychology, computer science, engineering, music, accounting, and business disciplines enroll in the course. *Issues in Waste Management* is also open to graduate students and members of the community.[2]

College campuses concerned with reducing waste often supplement educational programs with year-round awareness campaigns.[3] Mount Holyoke, for example, supplements its partnership with FoodPro - a consulting group that helps the college lower its food waste by tracking inventory and food processes - with active involvement in the Green Living Council. The Green Living Council is an organization composed of student volunteers that promotes sustainable behavior by developing education programs focused on green living within residence halls. Topics include climate change, water conservation, recycling, waste reduction, and sustainable agriculture.[4]

Some colleges promote direct student participation in all stages of dining service operations. At Berea College, for example, students coordinate the purchase and delivery of food for dining halls. The food is usually purchased from local farms. Along with promoting education and outreach programs, students at Berea also work on the 400-acre campus farm. There, students learn about the labor and resources required for food production and cultivate an appreciation for food.[5] Augustana College has a similar hands-on approach to education and awareness of food waste management strategies. Students visit or volunteer on nearby family farms to learn about sustainable, organic food production, and some food from these farms is used for dining hall food sourcing. Students who do not participate in the program are aware of the efforts of their peers through media publications, announcements, posters, and flyers.[6]

To supplement year-round education and awareness campaigns, colleges can participate in national events and competitions. The most popular competition promoting public awareness and education of waste reduction is RecycleMania. RecyleMania is a competition held over an eight-week period each spring during which colleges throughout the United States and Canada report the volume of recycling and trash collected at their campuses. Winners are chosen based on the highest recycling rates on a per capita basis, the lowest volume of total waste, and the highest recycling rate as a percentage of total waste. Winners are recognized nationally and receive an

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[2] Hasan, S.E. "Public Awareness is Key to Successful Waste Management." *Journal of Environmental Science and Health, Part A: Toxic/Hazardous Substances and Environmental Engineering* 39.2 (2004): 483-92.
[3] Connecticut College. "Connecticut College Dining Services." Accessed April 1, 2013. http://www.conncoll.edu/campus-life/dining/.
[4] Mount Holyoke College. "MHC Green Living Council." Accessed April 1, 2013. https://www.mtholyoke.edu/envstewardship/glc.
[5] Erickson, Christina, and David J. Eagan. "Generation E: Students Leading for a Sustainable, Clean Energy Future." Accessed May 2013. http://www.nwf.org/Campus-Ecology/Resources/Reports/Generation-E.aspx.
[6] Erickson, Christina, and David J. Eagan. "Generation E: Students Leading for a Sustainable, Clean Energy Future." Accessed May 2013. http://www.nwf.org/Campus-Ecology/Resources/Reports/Generation-E.aspx.

award made out of recyclable materials.[7] The goal of the competition is to engage college communities in waste reduction initiatives in a fun and competitive environment. The competition targets both organic and non-organic waste reduction and recycling. Colleges can choose to participate in select categories, one of which is a reduction of pre- and post-consumer food waste.[8] The results of the waste minimization category are calculated using the following equation:

(Weight of Recyclables + Weight of Trash)/Campus Population

The food waste minimization category is unique; it requires schools to undergo specific waste reduction techniques rather than merely reporting recycling and waste stream rates. Colleges participating in the food waste reduction competition are asked to sign a pledge promising that before and during the competition, they will attempt to implement long term waste reduction strategies on campus. Colleges may choose eight goals from the 18 provided by the RecycleMania program, or may write their own goals.[9]

Colleges often promote awareness of RecycleMania and waste reduction by advertising before the start of the competition and maintain community support by hosting a series of mini-events and activities. Towson University promotes student involvement by hosting a competition between dorm halls; the dorm with the highest recycling rate and lowest waste rate wins a cash prize. Residence directors and the college government are responsible for raising awareness for this competition.[10] The University of South Carolina (USC) hosts a Recyclympics to prepare students for RecycleMania. Each year, students compete in six events, including phone book shot put, a recycling bin obstacle course, and a wrapping paper tube javelin throw. Volunteers are dressed in “Recycle Guys” costumes and are responsible for garnering student attention and spreading information regarding waste reduction practices. Food waste reduction strategies also occur outside of Recyclympics. In order to promote food waste reduction, USC holds a competition focused on food reuse; the group that is able to reuse leftover food in the most creative manner is awarded a prize. The University also promotes education and awareness through bulletin board announcements and events in residence halls such as recycle and reduction “flash mobs.”[11]

Components of Successful Awareness and Education Campaigns

Studies show that effective strategies to increase public awareness on environmental issues have a particular campaign structure, are composed of clear messaging, distribute this message to community members, and create of a support network.[12]

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[7] RecycleMania Tournament. “About.” Accessed April 1, 2013. http://recyclemaniacs.org/about.

[8] RecycleMania Tournament. “Divisions and Categories.” Accessed April 22, 2013. http://recyclemaniacs.org/participate/rules/divisions-categories.

[9] RecycleMania Tournament. “Waste Minimization.” Accessed April 22, 2013. http://recyclemaniacs.org/participate/rules/divisions-categories/waste-minimization.

[10] Towson University. “Go Green: RecycleMania.” Accessed April 1, 2013. http://www.towson.edu/adminfinance/gogreen/involved/recyclemania.asp.

[11] RecycleMania Tournament. “University of South Carolina.” Accessed April 1, 2013. http://www.recyclemaniacs.org/USC.

[12] Taylor, Shirley, and Peter Todd. “Understanding the Determinants of Consumer Composting Behavior.” *Journal of Applied Social Psychology* 27.7 (1997): 602-28.

The most important component of an effective campaign is its message. The goal of the message is to mobilize as many individuals as possible in support of the cause. The message must be short, accurate, easy to remember, and powerful. The second step in an effective awareness campaign is to relay the message to the community in a wide variety of means. The diversity of activities - educational seminars, events, posters, postcards, petitions, informational flyers, etc. - will allow the message to reach as many people as possible. The third component of the campaign is the diversity of the support network, which facilitates the spread of the message throughout the community.[13]

These components must be tailored specifically to the target audience and the scope of the issue. It is important to target young age groups of all ages, as studies show that campaigns that target young age groups are the most successful campaigns.[14] If individuals learn sustainable environmental behaviors early in their life, then they will be able to practice these behaviors throughout their lifetime; they can also pass these behaviors on to their children. If this pattern of learning continues, habits that promote sustainability will become social norms.

The message should focus on the societal benefits of waste management behavior, must be simple, and should provide a connection between individual actions and environmental impacts. A 2012 study found that the placement of short anti-waste posters and flyers in visible locations in dining halls reduced students' food waste by 15%. These flyers featured direct messages; adding flyers that advocated environmental sustainability and personal benefits of waste management did not impact waste reduction.[15] In fact, studies show that an appeal to personal benefits may reduce the effectiveness of an appeal to reduce waste.[16] If the environmental issue is perceived to be too complex or unclear, people will not adjust their behavior. In order to encourage waste reduction, a public awareness campaign should strive to provide clear information about net environmental benefits of reduction in the form of pictures, graphs, and case studies.[17] This material should also encourage action with a minimum time commitment, as individuals will be reluctant to drastically alter their behavior for an issue that will not personally affect them.[18] This educational material should not be presented in a controversial manner, as people are more receptive to information that supports their existing values.[19]

Kollmus, Anja, and Julian Agyeman. "Mind the Gap: Why Do People Act Environmentally and What Are The Barriers to Pro-Environmental Behavior?" *Environmental Education Research* 8.3 (2002): 239-60.
[13] Piekarz, Asia, Emily Cowan, and Brittany Finkeldey. "National and International Public Awareness Campaigns Against Human Trafficking and Sexual Exploitation." Accessed May 2013. http://g.virbcdn.com/_f/files/94/FileItem-149846-NationalAndInternationalPublicAwareness.pdf.
[14] Hasan, S.E. "Public Awareness is Key to Successful Waste Management." *Journal of Environmental Science and Health, Part A: Toxic/Hazardous Substances and Environmental Engineering* 39.2 (2004): 483-92.
[15] Whitehair, Kelly J., Carol W. Shanklin, and Laura A Brannon. "Written Messages Improve Edible Food Waste Behaviors in University Dining Facility." *Journal of the Academy of Nutrition and Dietetics* 113.1 (2013): 63-69.
[16] Taylor, Shirley, and Peter Todd. "Understanding the Determinants of Consumer Composting Behavior." *Journal of Applied Social Psychology* 27.7 (1997): 602-28.
[17] Kollmus, Anja, and Julian Agyeman. "Mind the Gap: Why Do People Act Environmentally and What Are The Barriers to Pro-Environmental Behavior?" *Environmental Education Research* 8.3 (2002): 239-60.
[18] Taylor, Shirley, and Peter Todd. "Understanding the Determinants of Consumer Composting Behavior." *Journal of Applied Social Psychology* 27.7 (1997): 602-28.
[19] Kollmus, Anja, and Julian Agyeman. "Mind the Gap: Why Do People Act Environmentally and What Are The Barriers to Pro-Environmental Behavior?" *Environmental Education Research* 8.3 (2002): 239-60.

2.2.2 Implementation of an Education and Awareness Reduction Program at Wellesley College

Events to Promote Awareness
Since younger audiences are more receptive to change and education, food waste reduction education programs should begin with prospective students. During Fall and Spring Open Campus, the College would set up opportunities for prospective students and their families to learn about Wellesley's recycling, waste disposal, and waste-reduction initiative. These events would provide an opportunity to showcase our composting efforts to prospective students and their families. If students were introduced to the College's food waste diversion method(s) before attending Wellesley, then they would already arrive on campus expecting to participate in sustainable food waste practices. Education and awareness campaigns would also be implemented during First Year Orientation. Wellesley College could provide educational and awareness opportunities at large events on campus. Lake Day would be a good chance to present students with fun and educational food waste and composting activities.

Wellesley College would also increase awareness and education in proper food waste management by providing higher incentives for participation in RecycleMania. While Wellesley currently participates, it only does so in a few categories. Wellesley would be able to increase education and awareness by participating in the waste minimization category of the competition. Currently, advertisement for the competition is minimal on campus; as a result, no behavioral change occurs when RecycleMania takes place. Wellesley College would also implement smaller-scale events - the Recyclympics, flash mobs, swag give-aways, etc. - that would provide the opportunity for the whole student body to participate.

Access to Educational Resources
A crucial step in promoting education of food waste management would be to establish a course in the Environmental Studies Program similar to the *Issues in Waste Management* course at the University of Missouri. More generally, posters and table tents in the dining halls would be important tools to raise awareness about food waste reduction and diversion programs. These posters and table tents would include information such as how much food waste is generated by Wellesley College per week, how food is most commonly wasted by students, and useful strategies for reducing food waste. As Wellesley reduces its food waste, the posters would be updated with current information and new goals for reduction.

Food Waste Reduction Estimate
If Wellesley implements a successful food waste education and awareness campaign, 15% of pre- and post- consumer food waste could be reduced.[20] This reduction is equivalent to 33 metric tons of food waste per year.

Estimated reduction in annual food waste (metric ton/year)
= (annual food waste metric tons/year)(.15)
= (220 metric tons/year)(.15)

[20] Whitehair, Kelly J., Carol W. Shanklin, and Laura A Brannon. "Written Messages Improve Edible Food Waste Behaviors in University Dining Facility." *Journal of the Academy of Nutrition and Dietetics* 113.1 (2013): 63-69.

= 33 metric tons/year

Implementation Difficulties

Time: Low

Overall, our proposed education and awareness strategies would not take long to implement. Advertisements would be the fastest to implement time and would only require printing and distribution.

Dining Hall Staff Behavior: Low

In terms of the dining hall staff, there would be a low amount of behavioral change, since the education and awareness campaign would be aimed at students.

Regulations and Contracts: Low

It is not necessary for us to alter our current regulations and contracts in order to implement our education and awareness strategies.

Cost: Low

Our proposed strategies would have minimal costs. The only costs we would have would be for paper, ink, and toner, which are currently provided by the College. The amount of money that would be saved from the amount of food waste reduced by our education and awareness strategies would more than offset these minute costs.

Campus Culture: Low

The successful implementation of education and awareness programs would allow prospective students, incoming and current students, alumnae, faculty, and staff to recognize Wellesley's commitment to reduce and to divert its food waste in a sustainable manner. Over time, a paradigm shift will occur and sustainable food waste management will become a component of the Wellesley culture. Since sustainability is only one component of the Wellesley College campus culture, effective education and awareness efforts will lead to the development of a new norm of sustainability but the impact on overall campus culture is low.

2.2.3 Conclusions

Education and awareness is a crucial component of any environmental movement that seeks to alter unsustainable behavior. If people are unaware of the negative impacts of their actions, then they will not participate in any food waste reduction strategy. Therefore, regardless of the reduction strategy Wellesley College implements, it is important that this method is supplemented with education and awareness. Through education and awareness, we would achieve not only our goal of food waste reduction, but we would also be providing further opportunities for community building within Wellesley College. In the long run, the habits developed from this method of reduction would ideally carry over into the lives of the members of the College community.

2.3 Institution-Wide Food Monitoring Systems

Understanding food waste quantities and types is a crucial step towards reducing institutional food waste. General waste audits inform institutions about their waste habits, and enable them find solutions to reducing their waste. In the same way, food monitoring systems provide data about all aspects of food waste disposal. They capture valuable information regarding what types of food are wasted and why those inefficiencies exist. This knowledge allows institutions to make better choices that affect recipes used, ingredients purchased, and overall amount of food prepared. Results from other institutions show up to a 50% reduction in volume and 2-6% reduction in food purchasing costs with the implementation of food monitoring programs.[21]

Food monitoring systems track both pre- and post-comsumer food waste. In the tracking process, food preparers record the type, volume, and reason for food disposal. Weighing and recording stations are set up in convenient locations near areas where workers prepare and dispose of food. There are many methods for recording food disposal, ranging from low-tech manual paper logs to high-tech touch screen terminals. The data collected through these methods is synthesized to show food waste trends and patterns, eventually highlighting inefficiencies in the food preparation process. Gathering information and pinpointing the largest contribution to waste allows kitchen managers and dining hall staff to prevent waste during the food purchasing and preparation process.[22] The level of complexity of the food monitoring system affects the level of detail in collected data. Several businesses, such as LeanPath and Trim Trax, market food waste monitoring systems to institutions. Additional food waste monitoring resources are available through the EPA.[23]

LeanPath

LeanPath is a private institutional food waste reduction company that markets automated food waste tracking systems. It is the leader in creating food waste reduction strategies for US-based companies. LeanPath's fully automated tracking system measures and records food waste in institutional kitchens. A staff member places food waste on a scale and selects the appropriate type of food, the reason for disposal, and the type of container on an automated touch screen terminal.[24] From the collected data, reports are generated and shared among team members in order to set specific goals for improvement and test waste prevention ideas. [25]

LeanPath provides a variety of plans (from "Basic" to "Platinum") that range in cost and level of service. "Basic" systems can track twenty preconfigured food types, whereas the popular "Silver" level can track 200. The "Platinum" plan offers the biggest number of tracking stations, the most comprehensive food type database, a customizable tracking system, and thorough customer support. All plans include coaching from a LeanPath staff member and on-site training. Costs for implementing LeanPath are calculated based on annual food purchases. Most of LeanPath's college and university clients choose to implement two tracking stations at the "Silver" level.

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[21] Haugan, Janet, LeanPath Marketing Manager. Maia Fitzstevens. April 30, 2013.
[22] StopWaste. "Food Waste Prevention: Campus Kitchens Get Smart on Food Waste." Accessed March 29, 2013. http://www.stopwaste.org/home/index.asp?page=1229.
[23] U.S. EPA. "Wastes – Resource Conservation: Food Waste Reduction and Prevention." Accessed May 4, 2013. http://www.epa.gov/foodrecovery/fd-reduce.htm.
[24] StopWaste. "Food Waste Prevention: Campus Kitchens Get Smart on Food Waste." Accessed March 29, 2013. http://www.stopwaste.org/home/index.asp?page=1229.
[25] LeanPath. "Pomona College Tracking Food Waste." Accessed March 29, 2013. http://blog.leanpath.com/2010/10/pomona-college-tracking-food-waste/.

This level offers four software licenses, 200 food types, and twelve months of coaching; it costs $21,650 up front, with $3,000 per year in annual support. While LeanPath is primarily used to track pre-consumer waste, it can also be used to audit post-consumer plate waste and food waste from catered events. LeanPath prides itself on its successful track record with college and university clients, who experience a reduction in food purchasing costs, create less waste, and offer meal options that better reflect customer preferences.[26]

Trim Trax

Trim Trax is another private food waste reduction company. With this system, each dining hall worker is assigned her/his own specific food waste bin. Food preparation staff manually record all disposed items by type and volume. These results are entered online at the end of each day. Reports generated from this data provide kitchen managers and dining hall staff with information on food waste trends.[27]

Non-Commercial Food Waste Monitoring Options

On its food waste reduction and prevention website, the EPA provides a sample waste logbook that records the time, employee name, food type, reason for food loss, and amount of food loss.[28] This logbook and the resources on the EPA website offer a low-cost and low-tech way to track food waste disposal.

2.3.1 Experience with Reduction through Institution-Wide Food Monitoring Systems

All colleges and universities that implement LeanPath and Trim Trax report significant reductions in food waste volume and purchasing costs. The majority of monitoring work is delegated to dining hall workers as they collect and measure food waste during the meal preparation process. The process of data collection does not require a significant amount of extra time and attention. The data would have to be synthesized by the dining hall managers in order to ascertain the largest sources of food waste. These tracking systems would have little to no effect on student life (apart from their possible inclusion in awareness campaigns).

LeanPath seems to be the most well-known and widely implemented food tracking system on the market. By using LeanPath, the University of Massachusetts reduced food waste by 25%, while the University of North Dakota and UC Berkeley reduced food waste by 30%.[29] Michigan Technological University reduced food waste by 50%, the largest waste reduction achieved by a university with this method.[30] One of its customers includes foodservice management company Sodexo, which launched its “Stop Wasting Food” pilot program on eight college campuses around the US in September 2010. The goal of this program is to educate students about food

[26] Haugan, Janet, LeanPath Marketing Manager. Maia Fitzstevens. April 30, 2013.
[27] Wrap. “Compass Group UK & Ireland: Eliminating Kitchen Waste.” Accessed May 2013. http://www.wrap.org.uk/content/compass-group-uk-ireland-eliminating-kitchen-waste.
[28] U.S. EPA. “Waste Logbook.” Accessed May 4, 2013. http://www.epa.gov/epawaste/conserve/pubs/food-waste-log.pdf.
[29] LeanPath. “Food Waste Prevention Spotlight: University of Massachusetts.” Accessed March 28, 2012. http://www.leanpath.com/wp-content/themes/weaver-ii-pro/docs/LeanPath_Case_Study_UMass.PDF.
[30] LeanPath. “Food Waste Prevention Spotlight: Michigan Technological University.” Accessed March 28, 2012. http://www.leanpath.com/wp-content/themes/weaver-ii-pro/docs/LeanPath_Case_Study_MichiganTech.pdf.

waste and to analyze pre-consumer food waste in the kitchen in order to account for unnecessary use. An integral part of this program is to monitor food waste at the preparation level through LeanPath. After six months, the eight colleges (Linfield; Marist; Coe; Juniata; Pomona; University of California, Davis; University of Wisconsin, River Falls; and California State University, Monterey Bay) had collectively reduced food waste by 47%.[31]

University of Massachusetts at Amherst reported a 25% reduction within four months of implementing a LeanPath system, which translated into $70,000 in savings.[32] Pomona College, a small private liberal arts college with an enrollment of 1,600 undergraduate students, also reduced its food waste by 25% through LeanPath.[33] Michigan Technical University has 7,000 enrolled students, though only 2,100 of them participate in the dining program. The number of students with a meal plan and the unlimited buffet-style dining are quite similar to the situation at Wellesley. Within six weeks of its pilot waste-tracking program with LeanPath, Michigan Technical University had reduced food waste by 50%. The University has since implemented the system in all four dining locations and saves around $1,000 in food costs per month. It was able to recoup the money spent on LeanPath equipment in less than a year and now experiences net savings with the system.[34]

Trim Trax is a lesser known food tracking system, though it is implemented at Stony Brook University, DePaul University, Trinity College, and Worcester State University. There is no readily available data on food waste reduction on these campuses, though the system works similarly to that of LeanPath.[35]

At Olin College of Engineering, a student intern created a set of spreadsheets that were used to create a food monitoring system. The spreadsheets include waste types, recipes, number of servings, and amount of disposed food. The spreadsheet also calculates how much money is lost per serving. Sodexo is considering implementing this method of pre-consumer food waste monitoring on other college campuses nationwide. AVI Fresh could potentially form its own monitoring system similar to what was created at Olin, instead of depending on commercial systems such as LeanPath or Trim Trax.[36]

2.3.2 Implementation of Institution-Wide Food Monitoring Systems at Wellesley College

This method would be implemented in the kitchens of each dining hall at Wellesley to reduce pre-consumer waste, which includes food preparation scraps and uneaten food remaining in

[31] Executive Business Media, Inc. “On-Campus Hospitality.” Accessed March 30, 2013. http://www.leanpath.com/wp-content/uploads/2012/12/OCHApril.pdf.
[32] LeanPath. “Food Waste Prevention Spotlight: University of Massachusetts.” Accessed March 28, 2012. http://www.leanpath.com/wp-content/themes/weaver-ii-pro/docs/LeanPath_Case_Study_UMass.PDF.
[33] Executive Business Media, Inc. “On-Campus Hospitality.” Accessed March 30, 2013. http://www.leanpath.com/wp-content/uploads/2012/12/OCHApril.pdf.
[34] LeanPath. “Food Waste Prevention Spotlight: Michigan Technological University.” Accessed March 28, 2012. http://www.leanpath.com/wp-content/themes/weaver-ii-pro/docs/LeanPath_Case_Study_MichiganTech.pdf.
[35] Wrap. “Compass Group UK & Ireland: Eliminating Kitchen Waste.” Accessed May 2013. http://www.wrap.org.uk/content/compass-group-uk-ireland-eliminating-kitchen-waste.
[36] Nadreau, David, Olin College Dining Hall Manager. Ben Chapman. April 3, 2013.

serving pans at the end of meals. Every item thrown away by foodservice workers would be recorded on either a paper logbook or in an automated food waste tracking system such as LeanPath or Trim Trax.

Amount of Food Waste Reduced

Dining hall waste at Wellesley (excluding food waste from events) is estimated at 214 metric tons per year—including spring and fall semesters, summer break, and winter break. Post-consumer waste amounts to 158 metric tons per year while pre-consumer waste, including food waste from food preparation and uneaten prepared food thrown out in pans at the end of the day, sums up to 56 metric tons per year. If we assume that Wellesley College will reduce its pre-consumer food waste by 30% by implementing food monitoring systems, we would reduce our food waste by 32 metric tons per year.

Implementation Difficulties

Time: Medium

Installing a food monitoring system would take time. Dining hall worker contracts would need to change in order to incorporate food monitoring responsibilities and corresponding staff training sessions. The summer would be an ideal time for initial implementation; it will allow workers to streamline the system for when students arrive in the fall. After initial implementation, the collected data would shed light on necessary changes in subsequent food preparing processes. Therefore, food waste monitoring will be a continual process over time rather than an immediate change.

Dining Hall Staff Behavior: Medium

In order for this method to be successful, all staff working in the kitchens must incorporate the additional step of weighing and recording food waste before dumping it in a trash bin. This additional step would likely require between twenty seconds and one minute of time per batch of food waste disposed. It also means that all current and new dining hall staff must undergo training to learn how the monitoring system works.

Regulations and Contracts: Medium

Contractual changes would have to reflect the additional jobs required of dining hall staff: the weighing and recording of disposed food, collection and processing of waste data, presentation of gathered data at staff meetings, and subsequent changes to ordering and preparing food.

Cost: Short-Term Cost, Long-Term Savings

Food monitoring would ultimately save money by reducing the total amount of food purchased. Start-up costs would be high if we choose to use LeanPath or a similar commercial, high-tech tracking system, but will provide insight for better food purchasing choices. This means cutting costs by not buying food that would otherwise go unused or be thrown away. In the long term, pre-consumer food waste monitoring would to save money by informing food purchasing decisions.

Campus Culture Change: Low

Campus culture change required for this method is low, since it only occurs in the kitchens of dining halls and will not affect the way Wellesley students eat meals. Because the monitoring occurs behind closed doors and concerns the daily operations of kitchen staff, it provides little to no visibility for the campus as a whole.

2.3.3 Conclusions

Institution-wide monitoring systems allow institutions to collect information about its own food waste practices. The data trends lifted from this information are able to reveal inefficiencies in the food preparation process. This resulting knowledge allows food preparers to prevent food waste and reduce spending by understanding what is going to waste. The two types of monitoring systems used by peer institutions include Trim Trax and LeanPath. Institutions that implement the LeanPath program reduce food waste by up to 50%. If Wellesley seeks a low-cost option to monitor food waste, it could seek a basic LeanPath option in only one of the dining halls and apply to results of that audit to other dining halls. It could also use a paper logbook such as the one created by Olin College or the EPA.

Wellesley College has many choices in ways to implement food waste monitoring. Whether Wellesley chooses a low- or high-cost method, we recommend some form of food waste monitoring. Food waste monitoring is as important to reducing food waste as waste audits are to reducing waste. If AVI Fresh becomes more informed about the types of food waste that are most common, it will save money and significantly reduce the volume of food waste created.

2.4 Changing Food Preparation, Service, and Presentation

Food preparation, serving, and presentation affect the production volumes of both pre- and post-consumer organic waste. Organic waste from food preparation can be due to non-optimized reuse of food resources, inventory miscalculations, poor food storage, and poor cooking practices. Waste from food serving and presentation can come from pre-plated options that contain excess amounts of food or undesirable food items (e.g. rarely eaten garnishes) and self-serve options where consumers serve themselves more food than necessary. Changing the way food is prepared, served, and presented within Wellesley College’s existing meal plan could significantly reduce organic waste, especially since the greatest percent of campus organic waste is generated through post-consumer food waste.

There are four primary categories of strategies related to this reduction method, with various adaptations according to the dining or institutional context. They include: 1) trayless dining; 2) just-in-time prepping, cooking, and ordering; 3) optimization of food usage (including food reuse and improved food storage); and 4) smaller portioning. Out of the four categories, we suggest the implementation of following three reduction methods: 1) just-in-time prepping, cooking, and ordering; 2) optimization of food usage; 3) and smaller portioning.

Just-in-time preparing, cooking, and ordering includes all methods in which food is prepared but not cooked until it is needed. This way, dining services can store prepared food to cook another time if it is not used. Food can also be cooked in smaller batches with a “just-in-time” system. Additionally, students can customize their order, reducing undesirable food items. Another component of "just-in-time" involves waiting to garnish or dress food until right before the food is served. This tactic allows for the greatest opportunity to reuse unserved dishes.[37]

Optimization of food usage consists of preserving food ingredients. Taking care of food ingredients can be done by employing adequate food storage methods, such as ensuring the use of oldest food first by rotating food stock, arranging food preparation and storage areas to facilitate easy access and rotation, and improving labeling of leftover food and storage in airtight containers to minimize spoilage.[38] As another option, optimizing food ingredients can be practiced through secondary food usage (reusing unused food - both pre-consumer trimmings and post-consumer items) for new dishes. Using food that is still good but not necessarily aesthetically pleasing, taking out spoiled ingredients more selectively, and changing presentation styles to reduce unwanted food items also help to minimize food waste.

Smaller portioning involves preparing, serving, and presenting smaller food portions. This method can be achieved by reducing the size of serving utensils and dishes. The smaller utensils and dishes make students more likely to serve themselves a food amount closer to what they are capable of eating and return for additional servings only if necessary, thus wasting less food.

2.4.1 Experience with Reduction through Changing Food Preparation, Service, and Presentation

The U.S. EPA indicates that "just-in-time" (or "à la carte") ordering, cooking, and preparation systems for food could significantly help reduce pre-consumer waste.[39] Salisbury University includes a cook-to-order component as part of its dining sustainability initiatives.[40] In one of Ithaca College's dining halls, all food is made to order specifically to reduce the amount of waste.[41] University of California Berkeley's dining service, Cal Dining, estimates that a à la carte system reduces 10% of food waste that is generated with buffet-style serving.[42] Both Babson College and Colby College have adopted a strategy of "just-in-time" food preparation and experienced an 80% reduction in pre-consumer food waste.[43]

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[37] U.S. EPA. "Wastes – Resource Conservation: Food Waste Reduction and Prevention." Accessed May 4, 2013. http://www.epa.gov/foodrecovery/fd-reduce.htm.
[37] Haugan, Janet. "Waste Reduction Tips from the LeanPath Community." Accessed May 2013. http://blog.leanpath.com/2013/03/waste-reduction-tips-from-the-leanpath-community/.
[38] Northeast Recycling Council. "Food Service/Cafeteria Waste Reduction - Suggestions and Guidance." Accessed May 2013. http://www.nerc.org/documents/schools/FoodServiceWasteReductionInSchools.pdf.
U.S. EPA. "Wastes – Resource Conservation: Food Waste Reduction and Prevention." Accessed May 4, 2013. http://www.epa.gov/foodrecovery/fd-reduce.htm.
[39] U.S. EPA. "Wastes – Resource Conservation: Food Waste Reduction and Prevention." Accessed May 4, 2013. http://www.epa.gov/foodrecovery/fd-reduce.htm.
[40] Salisbury University. "University Dining Services Sustainability Initiatives." Accessed March 31, 2013. http://www.salisbury.edu/dining/sustainability.html.
[41] Ithaca College Dining Services. "Towers Dining Hall." Accessed March 31, 2013. http://ithacadiningservices.com/dining.html.
[42] Lam, Yuting. "Why Do UC Berkeley Students Waste Food at Dining Halls?" Accessed March 31, 2013. http://nature.berkeley.edu/classes/es196/projects/2010final/LamY_2010.pdf.
[43] Bloom, Jonathan. "From Traylessness to Demand Tracking: Ideas and Innovations to Reduce Food Waste" in *American Wasteland: How America Throws Away Nearly Half of Its Food (and What We Can Do About It)*, 239-62. Cambridge: Da Capo Press, 2010.

The EPA and Northeast Recycling Council suggests redesigning dining menu cycles so that menus are pre-planned for secondary food use.[44] Northern Arizona University has been able to reduce a significant amount of its vegetable waste through secondary use.[45] Though not mentioned in most of the reduction methods publicized by universities, the Northeast Recycling Council and the EPA urge institutions to focus on improving food storage methods.[46]

Another successful strategy is to encourage proper consumer portioning. This strategy has led to significant reduction in post-consumer food waste, and is included in many universities' food waste reduction measures, including at Bates College and Salisbury University.[47] George Mason University reports that it reduced overall dining food waste by 15% by using smaller plates, smaller serving utensils (1 to 3 oz. range), and reduced portions.[48]

2.4.2 Implementation of Changing Food Preparation, Service and Presentation at Wellesley College

We discuss a three-pronged approach to waste reduction via food preparation, service, and presentation. First, AVI could adjust the serving size and composition. Second, the managers could optimize food usage. Third, AVI Fresh could implement a "just-in-time" cooking and/or an ordering system.

Serving size and composition at Wellesley varies by dining hall. In some cases, food is entirely self-serve buffet style. This serving style can lead to excessive waste when students overestimate the amount of food they want. In other cases, meals are pre-plated, with the composition and servings of foods already chosen for students. This style can also cause excessive waste when students do not want all items on the plate or prefer different portion sizes and do not request a different plate.

The two potential solutions that would lead to a reduction in overall waste are smaller serving utensils and smaller portioning of "made-to-order" food. Smaller serving utensils would reduce the size of servings chosen and likely reduce overall waste.[49] The serving utensils could be labeled with volume measurements (for example, one cup or half a cup), so that students would

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Colby College Sustainability Initiatives. "Waste Reduction and Prevention." Accessed March 30, 2013. http://www.colby.edu/campus_cs/dining_services/upload/ds_sustainability_report.pdf.

[44] U.S. EPA. "Wastes – Resource Conservation: Food Waste Reduction and Prevention." Accessed May 4, 2013. http://www.epa.gov/foodrecovery/fd-reduce.htm.

[45] Haugan, Janet. "LeanPath Community Spotlight - Executive Chef Timothy Cunningham, Northern Arizona University." Accessed May 2013. http://blog.leanpath.com/2013/03/leanpath-community-spotlight-executive-chef-timothy-cunningham-northern-arizona-university/.

[46] U.S. EPA. "Wastes – Resource Conservation: Food Waste Reduction and Prevention." Accessed May 4, 2013. http://www.epa.gov/foodrecovery/fd-reduce.htm.

[47] U.S. EPA. "Best Management Practices for Colleges and Universities: Bates Waste Management." Accessed May 2013. http://www.epa.gov/region1/assistance/univ/pdfs/bmps/BatesReformat1-8-07.pdf.
Salisbury University. "University Dining Services Sustainability Initiatives." Accessed March 31, 2013. http://www.salisbury.edu/dining/sustainability.html.

[48] George Mason University Dining Services. "Campus Sustainability Programs and Initiatives." Accessed March 31, 2013, https://gmu.sodexomyway.com/planet/local.xhtml.

[49] George Mason University Dining Services. "Campus Sustainability Programs and Initiatives." Accessed March 31, 2013, https://gmu.sodexomyway.com/planet/local.xhtml.

have a visual understanding of the quantity of food they serve themselves. If servers plated food upon request, they would still serve measured portions of each item. Depending on the availability of dining staff to serve food, a combination of these approaches could be used at Wellesley.

Changing the presentation of food could reduce pre-consumer food waste. Serving containers, such as those in the salad bar, could be made smaller. While changing the size would require the dining hall staff to refill the salad bar containers more often, using smaller containers would ultimately reduce the amount of food thrown away at the end of the night. In addition, we could reduce pre-consumer waste by training dining staff to use food that is still good but no longer aesthetically pleasing.

To further optimize food usage, food that is no longer aesthetically pleasing but still edible could be repurposed for other meals; in fact, a dining hall's entire menu could be structured in such a way that the following day's menu would make use of leftovers from the day before.[50] Examples of this secondary food usage include using bruised or overripe fruit from one day in the next day's desserts, reusing vegetables from the salad bar in soups and turning leftover bread into croutons.[51]

Preparing all food in a just-in-time system would require additional time, labor, and equipment resources. It would also require a significant behavior change for students; it would be challenging to provide the same flexibility and quick service as the current system. If there is excess pre-prepared food, then it can be stored for later, rather than be thrown out. A partial "just-in-time" system could allow for a more accurate tailoring of food production amounts to student demands.

An ordering system for food service could reduce waste by catering to consumers' specific preferences. A computerized system that students would use to order meals, such as the NEXTAP self-service kiosks[52] used in the Sodexo Food On-Demand system,[53] could be used for specific stations in the dining halls. The student would then receive exactly the meal they ordered at the kiosk. This approach has been implemented at other colleges in order to reduce waste[54] and is suggested by the EPA.[55]

Since the kiosk ordering approach would likely cause a net reduction of waste, it would be a beneficial program to implement partially in at least one or two dining halls. It would be important to make sure that students are able to make their meals as "customized" as possible

[50] Northeast Recycling Council. "Food Service/Cafeteria Waste Reduction: Suggestions and Guidance." Accessed March 30, 2013. http://www.nerc.org/documents/schools/FoodServiceWasteReductionInSchools.pdf.
[51] U.S. EPA. "Wastes – Resource Conservation: Food Waste Reduction and Prevention." Accessed May 4, 2013. http://www.epa.gov/foodrecovery/fd-reduce.htm.
[52] NEXTAP Systems. "Self Order Kiosks." Accessed April 20, 2013. http://nextepsystems.com/kiosks.
[53] Baxter, Missy. "Case Study: Kiosks Increase Efficiency of Dining on College Campuses." Accessed May 2013. http://nextepsystems.com/pdfs/Sodexo-FoD-Case-Study.pdf.
[54] Salisbury University. "University Dining Services Sustainability Initiatives." Accessed March 31, 2013. http://www.salisbury.edu/dining/sustainability.html.
[55] U.S. EPA. "Wastes – Resource Conservation: Food Waste Reduction and Prevention." Accessed May 4, 2013. http://www.epa.gov/foodrecovery/fd-reduce.htm.

while still working within a limited range of entrée options. A partial ordering system could still be an important step towards reducing the amount of waste thrown away from food that is put out on the serving line. (Usually, after being put out, food that is not eaten is considered "contaminated" and has to be thrown out.) Food left over from an ordering system can also be properly stored and reused. In implementing a partial ordering system, it would be important to restructure the service method and dining infrastructure to align with this new method of food preparation.

Amount of Food Waste Reduced

We assume that our method could reduce pre-consumer waste specifically by 80% and overall food waste by 30%, following trends set by other colleges.

The 30% reductions in overall waste would be realized through the combination of using smaller plates and portioned utensils (15% reduction),[56] practicing "just-in-time" ordering (10% reduction), and optimization of food items (assumed at 5% reduction). The 30% reduction would result in a decrease of 64.2 metric tons of food waste per year, reducing overall dining hall waste from 214 metric tons per year to 149.8 metric tons. The 80% reduction in pre-consumer waste would be achieved by not cooking food items until ordered by students.[57] The 80% reductions in pre-consumer waste would result in a decrease of 44.8 metric tons per year, thereby reducing pre-consumer waste from 56 metric tons annually to 11.2 metric tons. When combining the reductions achieved to assess our method as a whole, Wellesley College would attain a reduction from 214 metric tons to 161 metric tons produced annually, for an overall reduction of approximately 25%.

Implementation Difficulties

Time: Medium

Small changes, such as choice of serving utensils and containers, would not take long to implement. Broader changes, such as optimizing food usage, would take more time to implement, especially if AVI has to redesign its menus to make use of food waste from the day before. Menu redesign would still be feasible by the 2014 deadline. Implementing a partial ordering system or "just-in-time" station within each dining hall would take longer and might not be implemented by the 2014 Organic Waste Ban. Though the College currently owns kiosks for ordering,[58] it would need to order new software for the system. It would also take time to restructure the dining halls' equipment and staff positions such that the system would be compatible with the current meal plan and students' dining behaviors.

Dining Hall Staff Behavior: High

There would be a high level of difficulty associated with changing dining hall staff behavior. Staff would need to be retrained if dining halls at Wellesley were to adopt a system of custom-

[56] George Mason University Dining Services. "Campus Sustainability Programs and Initiatives." Accessed March 31, 2013, https://gmu.sodexomyway.com/planet/local.xhtml.
[57] Bloom, Jonathan. "From Traylessness to Demand Tracking: Ideas and Innovations to Reduce Food Waste" in *American Wasteland: How America Throws Away Nearly Half of Its Food (and What We Can Do About It)*, 239-62. Cambridge: Da Capo Press, 2010.
[57] U.S. EPA. "Wastes – Resource Conservation: Food Waste Reduction and Prevention." Accessed May 4, 2013. http://www.epa.gov/foodrecovery/fd-reduce.htm.
[58] Kesterson, Kevin, Wellesley College Bates Chef Manager. Eliana Blaine. April 22, 2013.

plated food. In addition, if food were to be ordered through a computer system and prepared on demand, an entire staff retraining and union staff position bidding process[59] would be required for the new method of food service.

Regulations and Contracts: Low

There would likely be no contract or regulatory change needed for increasing food reuse options and smaller portioning. If the dining service were to implement a partial ordering system, there may be some contract negotiations and bidding by union workers for the restructured dining staff positions.[60]

Cost: Medium

Changing serving utensils and containers would not be cost-intensive, only mandating the purchase of these supplies. Changing the way food is served and presented would likely cost the College more money than it would save. Changing the self-service system to a system in which food would be plated by request for students might incur additional labor costs. A computerized ordering system would cost the College in terms of both the hardware and software required, but these implementation costs would be offset over time. Savings incurred by reducing food waste would occur in a two-step process. First, the college's food service company would save money on ordering costs. With these reductions in cost over time, the college would eventually be able to re-negotiate the price of its food service contract and therefore bear the savings of the food waste reduction program.

Campus Culture Change: Medium

Using different serving utensils or containers would not change student behavior; but students would likely have to wait longer than usual if they were to request specific items of food. A computerized system, even in only one dining hall, would require a change in campus culture, both because the time required to obtain meals would be significantly longer and the shift would eliminate the current buffet-style dining entirely.

2.4.3 Conclusions

Our three-pronged approach tackles the problems of both pre- and post-consumer waste. Implementing smaller serving tools and plates requires little to no change in behavior for students and dining hall staff members, while an ordering system would require the staff training and students adjustment. Optimization of food waste and "just-in-time" cooking would require staff cooperation but little student adjustment. This approach depends on the involvement of dining hall workers. Overall, this method of reducing waste focuses on making it difficult for students to waste food rather than actually educating them on the consequences of food waste, ensuring its effectiveness.

2.5 Event Waste Reduction

[59] Kesterson, Kevin, Wellesley College Bates Chef Manager. Eliana Blaine. April 22, 2013.
[60] Kesterson, Kevin, Wellesley College Bates Chef Manager. Eliana Blaine. April 22, 2013.

Large-scale catered events are a significant source of food waste; waste is generated from leftovers on plates and an excess of food ordered for the event. There are a number of strategies that could reduce food waste from large campus events. It is likely that a variety of these strategies could be implemented in conjunction with each other; it may take some experimentation to find the combination that is most appropriate for specific events at Wellesley College.

Some of these methods of reduction may already be used for campus events, but it is important that there is an institutionalized policy to ensure that these tactics are used for every campus event. Many reduction approaches would allow event attendees to have more control over the amount and type of food that they consume while also placing a cap on the quantity of food a single guest can take. If event attendees are able to select only the foods they want, and only in small or self-selected portions, then there will ultimately be less food waste.

2.5.1 Experience with Reducing Event Waste

College event waste reduction is less of a priority than dining hall waste reduction, and in some ways more difficult to standardize. Colby College published a document on their efforts to coordinate a "green graduation." Since 2005, Colby has served trustees food served on china with cloth napkins, an effort that reduces the flow of "compostable" utensils and plates into the food waste stream. Such an approach illustrates that reduction methods must be adapted for the event in question. For other events, which are larger in scale and less spatially contained, disposable or biodegradable plates might still be more practical, but attention should still be given to portion size, plate size, and other reduction options. The effects of event waste reduction methods at colleges and institutions have not been studied in isolation from other factors; therefore it is difficult to determine how much reduction actually occurs from these methods. Like other colleges and institutions, events at Wellesley are varied, and Wellesley's approach to event food waste reduction will need to be flexible.

2.5.2 Implementation of Event Waste Reduction at Wellesley College

Wellesley would most likely use multiple strategies to reduce its food waste from events depending on the size of the event. At small- to mid-sized events, an institutionalized RSVP system could reduce the amount of waste that accumulates from ordering too much food to begin with. With larger events such as the Ruhlman or Tanner Conferences, the College would not want to discourage students from attending by requiring them to RSVP to the event, and thus large events require a different strategy for waste reduction. Simple changes make an impact in the amount of food waste generated at large on-campus events such as the Tanner or Ruhlman Conferences. Self-service would allow attendees to select a wider variety of food while minimizing the amount of partially eaten meals that go into to the organic waste stream. The food served to event attendees should be in smaller portion sizes; reducing portion sizes could mean that event attendees could have the choice of selecting a quarter or a half of a sandwich, instead of a whole. It might also mean that baked goods are served in bite-sized portions. Wellesley should also provide smaller plates to students. We believe that by having smaller plates and smaller size food items, food waste from events could be reduced by 25%.

Implementation Difficulties

Contract Changes: Medium

This strategy could be implemented immediately and would require no contract change or shift to abide by different regulations.

Cost: Neutral

The College and event hosts would likely not be financially impacted by these changes. Event hosts would not shift how much food they order for their events, but would shift what type of items. It is likely that these items would have negligible price difference in either direction.

Campus Culture: Low

Our recommendations for reducing food waste from campus events would require a minimal shift in campus culture. Students would only notice a slight change in dining experiences.

2.5.3 Conclusions

Although events only make up about 5,000 kg of food waste, or two percent of total food waste at Wellesley College, all reduction possibilities should be accounted for in a comprehensive food waste management scheme. Smaller portion sizes, such as finger foods, in addition to smaller plate sizes in a more casual, luncheon-style setting would be an easy change that would surely please students and reduce wasted food that results from pre-packed boxed meals or self-serve style lunches with large portions.

2.6 Food Redistribution to Students

In the United States, the norm for buffet-style dining requires the same amount of food to be presented at closing time as there is at opening time, ensuring that at the end of each day, much food will be wasted. By instituting a redistribution system in which students can take home extra food, the uneaten food will be distributed in appropriate portions to individuals who want it and have the ability to store it. Policy changes could take place either during the dining hall hours (where diners could use take-out containers at any time), right at the closing hour of the dining hall (where diners could take the excess food that would normally be stored as leftovers), or after the normal open hours (where staff could leave food out in public for a period of time and diners could help themselves at any time during open hours).

One drawback to the approach may be an increase in food waste in the dorms. Students might not eat the food that they take from the dining halls before, during, or after dining hall closings, which would not change the overall volume of food wasted if the food had not been redistributed. Food redistribution would not be effective if no food waste collection bins are placed in the dining halls.

State and local health agencies strictly regulate the removal of food in takeout containers due to health concerns, posing another drawback to this method of food waste reduction. Health codes and sanitation requirements prevent cross-contamination of bacteria or allergens. The Massachusetts Department of Public Health (MDPH) explicitly prohibits the serving of leftovers in residential kitchens, but it is unclear whether the dining halls are subject to this requirement.[61] It is also unclear as to when food becomes "leftovers." AVI Fresh has noted that leaving out food after hours "is not an approved practice nor is it acceptable food safety-wise."[62]

The MDPH Food Code does cite an opportunity to distribute food without temperature control for potentially hazardous foods (PHF). These foods may be held without temperature control for up to four hours. The Food Code permits the use of time only (rather than time *and* temperature) as a public health control in low-risk situations when the PHF will be cooked and/or held for immediate consumption. In Massachusetts, a variance, or permit, from the Board of Health is required prior to using time as a public health control. One must apply for a variance in order to deviate from a standard set of rules that would normally be in place. Under this variance, it is possible for food to be left outside of temperature control for up to four hours with a sticker indicating its shelf life.[63]

In order to comply with all requirements, other variations of this approach could include 1) Allowing Tupperware in the dining hall at all times, 2) Providing free disposable containers in which students could take the end-of-day food before the close of the dining, and 3) Providing reusable containers that students could buy and use to take the end-of-the-day food.

2.6.1 Experience with Food Redistribution to Students

There are many schools that have implemented some form of food redistribution policy. In the Spring of 2011, the University of Vermont started a new initiative under Sodexo Dining Services that provides a program in which students can buy a reusable container from dining services for $7.50. These used containers can be returned to dining halls in exchange for clean ones. This "Eco-Ware" program is financially self-sufficient, but has not been proven to reduce food waste.[64] It is difficult to measure the food waste reduction rates of the practice of redistributing food. Typically the practice is informal, and few tests have been run on the effectiveness.

2.6.3 Implementation of Food Redistribution to Students at Wellesley College

We believe that if the take-out policy is behavioral, then most food redistribution policies can be implemented immediately within the existing constraints of the College. We suggest that the dining halls should put out all leftover food approximately 10-20 minutes before closing, so that students can store the food for later consumption. We call this a "Last Call" policy.

If the dining hall food is taken during dining hall hours and put into a pre-approved sanitized take-out containers directly from a temperature-controlled location, there is no violation of health codes. It has yet to be clarified by AVI Fresh or MDPH whether it is a violation of health codes

[61] Massachusetts Department of Public Health. "State Sanitary Code Chapter X – Minimum Sanitation Standards for Food Establishments." Accessed May 1, 2013. http://www.mass.gov/eohhs/docs/dph/regs/105cmr590.pdf.
[62] Tyger, Cherie, AVI Fresh Director of Operations. Ellen Bechtel. April 30, 2013.
[63] Massachusetts Department of Public Health. "State Sanitary Code Chapter X – Minimum Sanitation Standards for Food Establishments." Accessed May 1, 2013. http://www.mass.gov/eohhs/docs/dph/regs/105cmr590.pdf.
[64] University of Vermont. "Ecoware: Reusable Take-Out Containers." Accessed May 6, 2013. http://www.uvm.edu/~recycle/?Page=zero-waste/eco-ware.html&SM=zero-waste/zero-waste-menu.html.

for consumers to use their own take-out containers. If city health codes require food to be taken out in sanitized take-out containers, the number of steps required and the costs necessary to implement this policy will certainly increase, but the redistribution practice will still be practical. Wellesley College could mimic the University of Vermont's Eco-Ware exchange program, which would involve taking out excess food from the Last Call (a financially sustainable program) or supply single-use disposable containers (less financially sustainable). AVI Fresh does not allow students to bring food storage containers into the dining hall.[65] Instead of requiring the College to supply the containers, a major policy change could allow the use of personal take-out containers in the dining hall during the Last Call period. In the scenario where food is left out after dining hall hours, a strict adherence to the heath codes would not result in a violation of state health requirements. As such, considerable safety measures must be considered in the implementation of a redistribution policy.

We estimate that 20% of all prepared food served each day in a dining hall will end up being thrown away, or 20kg per dining hall per day. Wellesley College could realistically redistribute approximately 75% of its prepared food to students via the Last Call policy, since not all foods can be redistributed, due to health policies.

Time: High

Acquiring state variances for each individual food item, working with AVI Fresh to change their policies, and obtaining a supply of pre-approved take-out containers will take time.

Dining Hall Staff Behavior: Medium

Dining hall staff would be required to implement and enforce the Last Call policy. This would mean monitoring when and where students are allowed to have their take-out containers, marking food to be left out, disposing of it, and assuring that safety policies are not violated.

Regulations and Contracts: High

To comply with MDPH regulations and health codes, a significant amount of safety measures must be met. Additionally, the College must acquire variances for individual food items before the redistribution policy is implemented.

Cost: Negative (Saving)

Allowing students to bring their own take-out containers to dining halls would reduce the amount of food waste that Wellesley College would pay for through diversion.

Campus Culture Change: Medium

If Wellesley implemented a new policy for food waste redistribution, a medium campus culture shift would occur, since food culture is such an important aspect of overall campus culture.

2.6.4 Conclusions

Overall, this redistribution practice could be useful as a way to reduce the overall amount of food waste produced by Wellesley College, but it will also be difficult to implement and maintain.

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[65] AVI Fresh for Wellesley College. "Dining Service and Meal Plan." Accessed May 2013. http://www.wellesleyfresh.com/menus.html.

Implementing this redistribution practice while complying with state regulations will most likely be a tedious and expensive process. The most serious drawbacks to the policy are concerns with the Board of Health and a potential for no measurable food waste reductions. Even if the redistribution of leftover food is permitted through variances from state health and safety regulations, the practice may require the college to buy a larger supply of single-use containers or enact a program similar to Eco-Ware. Students may take food without eating it, which would be not be an issue if food waste bins were placed in dorm hallways.

2.7 Changing the Meal Plan

Unlike many other education institutions, Wellesley's meal plan does not limit the number of swipes or meals per student per week. The buffet system likely leads students to take more food than they can realistically eat. This starts a cycle in which more food is prepared than can be eaten, causing more pre-consumer waste. Changing the “all-you-can-eat” meal plan could help the college scale back the amount of food that is thrown away.

Different Types of Meal Plans
Many colleges require students to swipe in for each meal. This system provides students with a variety of meal plans with varying numbers of swipes per week. AVI Fresh would adjust the amount of food produced according to the number of meals allocated to students per week.

Students Pay for What They Eat
Paying by weight and paying by item place a monetary value on the amount of food that students eat. If students had to pay accordingly to how much food they place on their plates, there would likely be a significant reduction in food purchasing and waste. In some cases, paying by weight and paying by item are both used in the same facility.

1) Paying by weight. This method is often seen in hospital cafeterias and other buffets. Placing a monetary value on the amount of food taken encourages people to only take as much as they plan to eat. This method works especially well for buffet-style entrées, soups, and salads.

2) Paying by item. As with a pay-by-weight system, people have the incentive to take only as much as they plan to eat. An “à la carte” system would likely require more packaging, which would generate more waste. This method is most commonly seen in smaller facilities such as coffee shops.

3) Tickets for entrée. Mary Baldwin College uses a ticketing system. When students swipe into the dining hall, they receive a ticket that they can exchange for one entrée and two sides. Salad, desserts, cereal, and beverages are unlimited.[66] Set portions reduce waste by preventing students from taking more than they can actually eat. Students are not prevented from going back to ask for another ticket. We chose this scenario for our analysis as a method to reduce waste without making large changes to the current dining food system.

2.7.1 Experience with Reduction through Changing the Meal Plan

[66] Mary Baldwin College. “Sustainable Meal Plan: Reducing the Waste while Reducing the Waist.” Accessed March 28, 2013. http://ebmpubs.com/OCH_pdfs/och1012_MaryBaldwinCollege.pdf.

The abundance of post-consumer waste results from the lack of incentives for customers to restrain themselves at the buffet line. The number of choices available frequently leads the customer to pile on a bit of every dish, accumulating a large quantity of food.[67] There is no cost to the customer of sampling many dishes and discarding food that is not to her liking. Similarly, people often pile large quantities of food on their plates in the name of getting their money's worth.[68] When college students pay per item of food purchased, students feel they cannot afford to take more food than they need, and post-consumer waste is decreased.[69] If a buffet system is unavoidable because of the cost of alternatives or because of a school's contract, policies encouraging voluntary restraint can work to some effect. At the New Mexico State University (NMSU) Taos all-you-can-eat Dining Hall, students are strongly encouraged to take only one entrée at a time, which reduces food waste.[70] At Mary Baldwin College, perishable hot food consumption is limited and access to the salad bar, cereal and beverages is unlimited. This approach has saved the college six to eight percent of its food budget over its previous system of an all-you-can-eat buffet.[71]

2.7.3 Implementation of Changing the Meal Plan at Wellesley College

Wellesley College could consider implementing a system similar to the one in place at Mary Baldwin College to reduce six to eight percent of its total food waste. To access prepared hot food, each student would be given a ticket upon swiping into the dining hall, and each ticket would be exchanged for one entrée and two side dishes. Students can request another ticket if they need more food. Salads, beverages, and cereals would not require a ticket. Reusable plastic tokens could be used instead of paper tickets.

Implementation Difficulties

Time: Medium

This method could be implemented by 2014 Organic Waste Ban deadline. Stations would be implemented in each dining hall to hand out tokens to students.

Dining Hall Staff Behavior: Medium

Staff members would monitor stations, hand out tickets, and exchange tickets for entrées.

Regulations and Contracts: Medium

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[67] Bloom, Jonathan. "From Traylessness to Demand Tracking: Ideas and Innovations to Reduce Food Waste" in *American Wasteland: How America Throws Away Nearly Half of Its Food (and What We Can Do About It)*, 239-62. Cambridge: Da Capo Press, 2010.

[68] Bloom, Jonathan. "From Traylessness to Demand Tracking: Ideas and Innovations to Reduce Food Waste" in *American Wasteland: How America Throws Away Nearly Half of Its Food (and What We Can Do About It)*, 239-62. Cambridge: Da Capo Press, 2010.

[69] Bloom, Jonathan. "From Traylessness to Demand Tracking: Ideas and Innovations to Reduce Food Waste" in *American Wasteland: How America Throws Away Nearly Half of Its Food (and What We Can Do About It)*, 239-62. Cambridge: Da Capo Press, 2010.

[70] New Mexico State University. "NMSU Campus Dining Meal Plan Information." Accessed March 29, 2013. http://www.nmsu.edu/~dining/corbett/meal_plan.html.

[71] Mary Baldwin College. "Sustainable Meal Plan: Reducing the Waste while Reducing the Waist." Accessed March 28, 2013. http://ebmpubs.com/OCH_pdfs/och1012_MaryBaldwinCollege.pdf.

Some contract changes may be necessary.

Cost: Negative (Saving)
Four additional employees, ideally students, would be hired to monitor ticket stations, at a cost of $9 an hour. This increase in employment would cost $180 per day, or approximately $40,000 per academic year.[72] Purchasing paper tickets or plastic tokens would be an additional, but negligible, cost. Food costs are currently $20,000 per week at the Lulu; multiplied by five dining halls, and then multiplied by 30 weeks in the academic year, this puts the yearly food cost at Wellesley at $3,000,000. The savings of this method, with the labor costs factored in, would come to $140,000 - $200,000 per year.

Campus Culture: Medium
The meal plan change would require behavioral shifts among students.

2.7.4 Conclusions

Waste could be reduced without fundamentally changing Wellesley's food culture. The "entrée ticket" reduction method used by Mary Baldwin College could be a viable option to reduce food waste without drastically changing the dining facilities or meal plan. Additionally, by reducing the *quantity* of entrées produced, Wellesley could redirect money into improving the *quality* of its entrées. The primary disadvantage of this method is that it would require a change in the dining process.

2.8 Conclusion to Food Waste Reduction

Food waste reduction is the first step to food waste management. We propose that Wellesley College consider implementing education and awareness campaigns, reducing amounts of food provided at events, a campus wide food monitoring system, modification of food serving size, presentation and preparation, and a food redistribution system for students, and changes to the meal plan as food waste reduction mechanisms. Food waste monitoring is especially important for the College to consider: it could reduce food waste volume by 30-50%. Food preparation and presentation provides the next highest reduction percentage of 25%. Other methods only reduce food waste up to 10%. Education and awareness campaigns are the cheapest and fastest methods to implement, and make up a key underlying tactic in any food reduction scenario. Other methods, such as changing the meal plan, redistributing food to students, and adjusting the way food is served would be harder to implement due to cultural changes required in the student body as well as adjustments to dining staff procedures and operations, but should still be considered as potential reduction tactics.

[72] Assuming two hours of lunch and three hours of dinner.

3.0 Implementation of Food Waste Reduction and Diversion at Wellesley College

3.1 Introduction

Wellesley College will likely change existing on-campus dining structures to accommodate the separate collection of food waste. These structural, spatial, and cultural changes in dining halls to aid food waste collection will occur no matter what food waste diversion method is chosen, and are thus considered in this chapter. Each of Wellesley's dining halls has different hours of operation, kitchen layouts, menus, and staff sizes. Standardized arrangement and labeling of food waste bins in all dining halls will aid proper separation of food waste. Either students, staff or a combination can separate food waste. A new food waste diversion program at Wellesley College may impact on the campus culture; these impacts are considered in this chapter.

3.2 Implementation in Wellesley College Dining Halls

In this section we discuss the layout of each dining hall, the infrastructure for returning dishes and disposing of waste, the anticipated challenges to implementing food waste diversion systems, and potential solutions to those challenges.

3.1.2 Bates

Figure 3-1: Floor plan of Bates dining hall

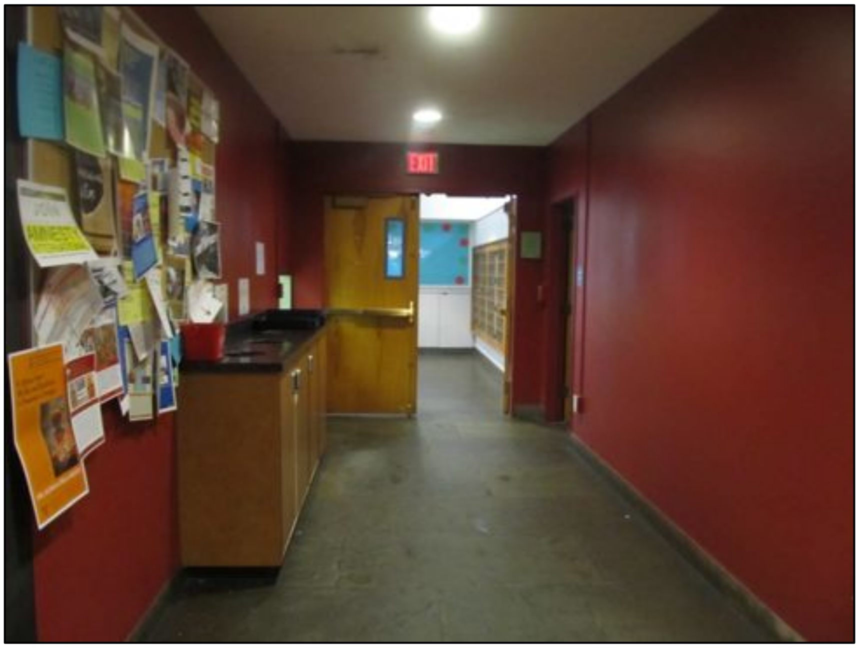

Figure 3-3: Tight quarters in the dish return hallway in Bates

The floor plan of the Bates dining hall is shown in Figure 3-1. Bates serves students who live on the east side of campus and who eat meals between classes at the Science Center. It is open from 7 a.m. to 7 p.m. on weekdays, and 8:30 a.m. to 6:30 p.m. on weekends. The food service area consists of two pre-plated stations, where staff put individual portions onto separate plates, and one entrée buffet station. Soup, salad, cereal, and dessert bars are self-serve. Students separate paper napkins and silverware into labeled holes, place their dishes on a tray, and place their tray on the conveyor belt (Figure 3-3). Students are not expected to scrape their plates before placing them on the conveyor belt. The dish return area is in a fairly narrow hallway (Figure 3-3).

3.2.2 Tower

Figure 3-4: Floor plan of Tower dining hall

Figure 3-4 shows the layout of the Tower Court dining hall. The food service area consists of a stir-fry station, hot food (main dish) station, pizza station, salad bar, cereal bar, sandwich bar, an ice cream station, and a beverage area. Meals at the stir-fry station are pre-plated, but otherwise students can serve themselves food from buffet style serving lines. Tower Court is a nut-free dining hall. The dishwashing area has two windows, one on each side of the dining hall, for students to drop off their plates, cups, and silverware for cleaning. Students set plates, cups and bowls in the window and place silverware into a plastic bin filled with soapy water. As students approach the window, they see a trash bin which serves as a visual cue to throw away excess food and paper napkins. No signs indicate whether students should throw away their own waste or leave it on their plates. The small area for dish drop-off gets congested, and lines form during meal times.

3.2.3 Stone-Davis

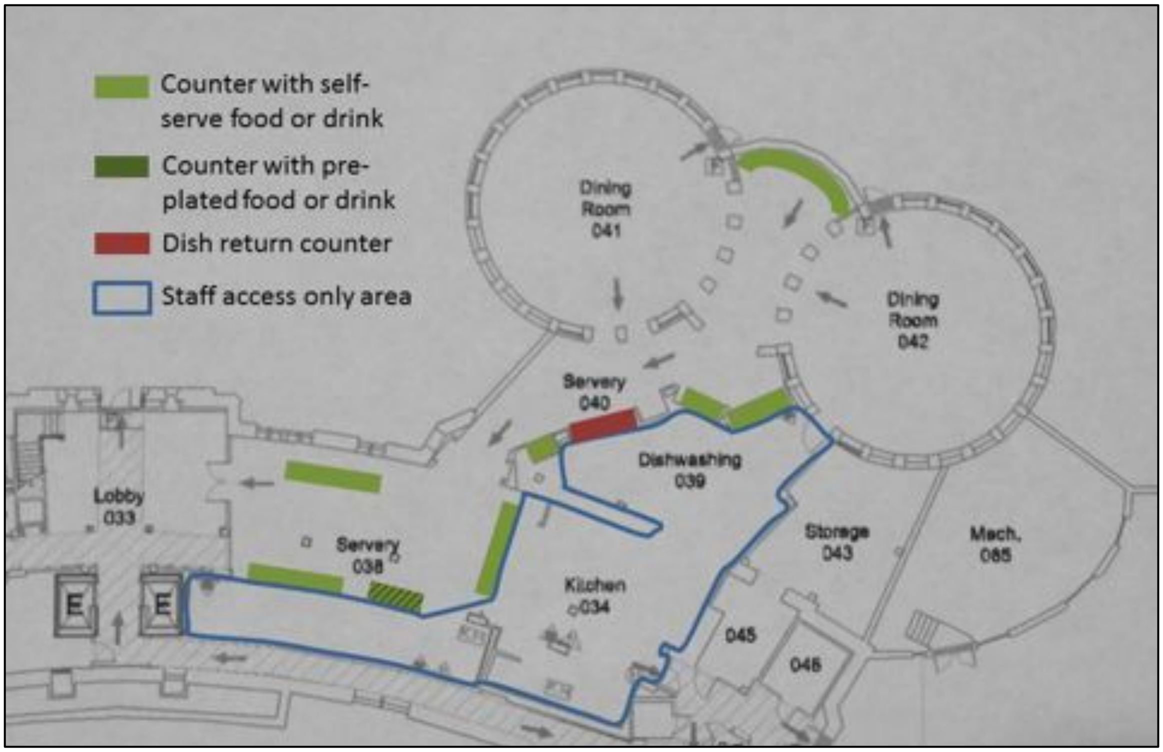

Figure 3-5: Floor plan of Stone-Davis dining hall

Figure 3-6: Stone-Davis dish return area on right

Figure 3-7: Section of the Stone-Davis dish return counter

Figure 3-5 shows the layout of the Stone-Davis dining hall. Stone-Davis is a spacious dining hall. The salad bar, deli sandwich station, soup, pizza, dessert and hot food are all self-serve. The grill station offers pre-plated and self-serve food. The dish return area is less congested than other dining halls, as shown in Figure 3-6. Students drop dishware and waste at a wide counter with two designated areas for glass return, two holes in the counter for food and paper waste, and two holes for silverware. Plates are set on the counter between these areas, as seen in Figure 3-7. We suggest that the current stainless steel counter could be replaced with a lower surface, on which transparent food waste collection bins could be placed, especially if Wellesley College chooses a diversion method with low contamination tolerance. This would provide a visual cue and would thus reduce contamination of food waste with silverware and vice versa. If structural change is not possible, signs with visuals should be implemented. Alternatively, staff could sort all plate waste and silverware.

3.2.4 Pomeroy

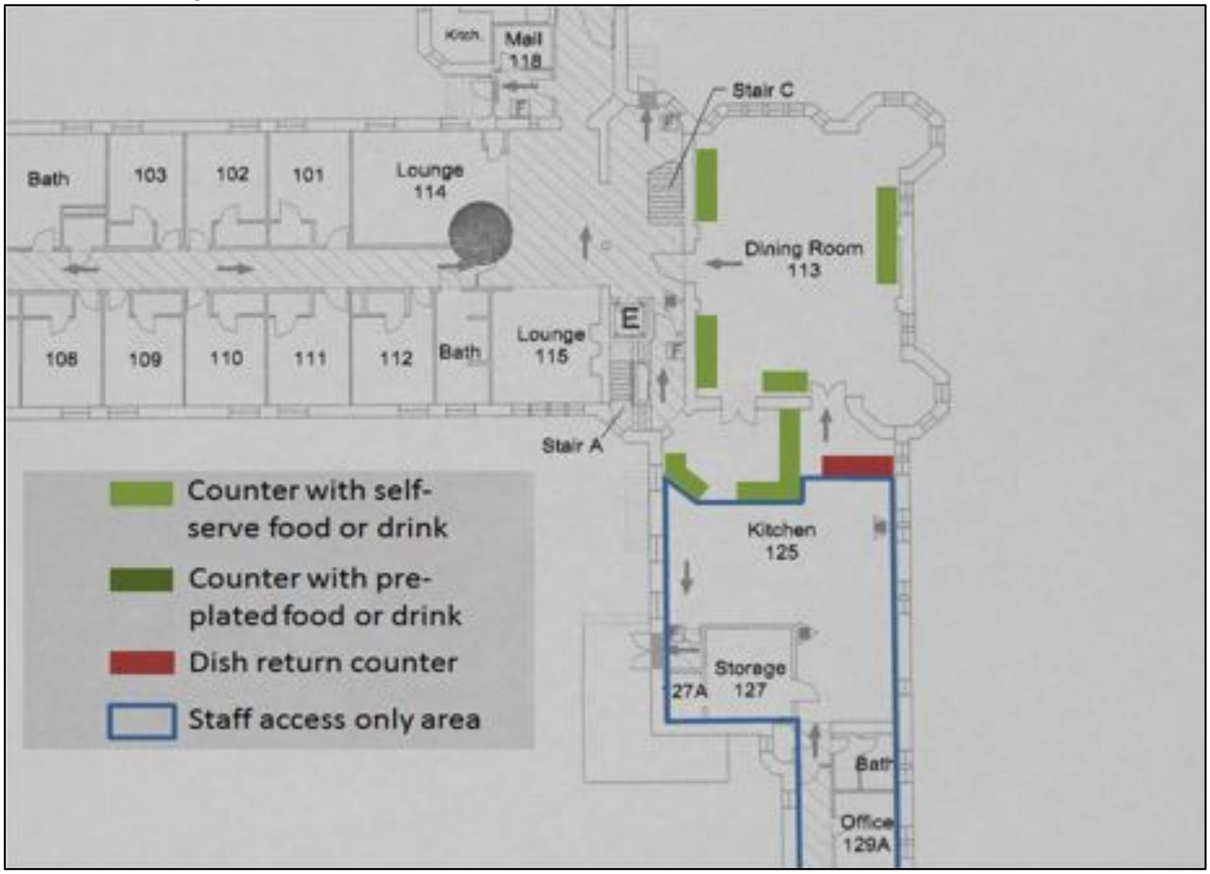

Figure 3-8: Floor plan of Pomeroy dining hall

Figure 3-9: Pomeroy dish return counter. All trash, primarily consisting of food waste, is scraped into the trash can to the right of the counter.

Figure 3-8 shows the layout of Pomeroy. Pomeroy is the smallest dining hall on campus, and offers only kosher and vegetarian food. To maintain kosher laws, students cannot enter the dining hall with their own dishes, and cannot take dishes outside. Hot food is served for two hours at each meal; brunch is served for two and a half hours on weekends and replaces lunch. The dining hall is mostly self-serve, although occasionally certain hot foods are pre-plated. The dish contains a trash bin for scraping waste, a tray for cups and glasses, a bucket for liquid waste, a silverware bin, and a plate drop-off area. Students must scrape or drain their dishes, and then place dishes in the appropriate place. Pomeroy's plate return could be easily adapted to accommodate food waste sorting by students. Students are already required to scrape their plates, and a food waste bin could easily be added to the current food waste disposal scenario.

3.2.5 Lulu Chow Wang (Campus Center)

Figure 3-10: Floor plan of Lulu Chow Wang dining hall

Figure 3-12: Lulu Chow Wang dining hall dish return area

Figure 3-10 shows the layout of the Lulu Chow Wang dining hall, located on the 4th floor of the Lulu Chow Wang Campus Center. It is the only publicly accessible dining hall on campus. It requires students to swipe in with their OneCard, and accepts cash payment for individual meals. The salad bar, soup, pizza, and dessert are all self-serve. The grill station, deli sandwich station, and hot food are sometimes pre-plated and sometimes self-serve. Students drop off their plates, cups, bowls, and napkins at a dish return area with a conveyor belt (Figure 3-12). Silverware is placed into a plastic bin filled with water and soap next to the dish return area. The Campus Center dining hall may face challenges in proper separation due to its off-campus clientele. Monitoring contamination levels will determine the extent to which this is a problem. The Campus Center may find that staff members are best suited to separate waste. In this case, students would be encouraged to leave food on their plates when placing them on the conveyor belt, as they currently do. This would be especially important if the College chooses to pursue a composting method with a low tolerance for contamination.

3.3 Implementation in other Cafes, at the Wellesley College Club, and During Special Events

Our analysis considers the waste generated by smaller dining facilities and during large special events on campus. See Chapter 2 for a full description of these facilities. Three categories of on campus events are included in our analysis: campus-wide student picnics, multi-day catered programs, and daylong student conferences. These waste streams combined produce 9.7 metric tons of food waste per year. While this amount is only a small portion of Wellesley’s annual food waste, it is still important to incorporate these locations and events in Wellesley’s food waste reduction and diversion plan. In order for Wellesley College to embrace a culture of sustainable food waste management, food waste must be reduced and properly diverted in every location on campus, and not merely at dining halls.

3.3.1 Collins Café

Figure 3-13: Collins Cinema Café

In order to divert food waste from Collins Café, we would place a second bin next to the trash bin for customers to discard of any post-consumer food waste. The trash bin would only be for paper products such as napkins and paper plates. The food waste bin and any pre-consumer waste would be collected on a daily basis and taken to either the Campus Center or Tower. Collins Café employees would take the extra pre-consumer items at the end of the week and make sandwiches and other food items in dining halls for consumption there. These would then be put out for students to eat in Sage Lounge and also the Campus Center.

3.3.2 Emporium

Figure 3-14. The Emporium on the second floor of the Lulu Chow Wang Campus Center.

All ready-to-eat food in the Emporium is prepared by AVI Fresh in the Campus Center dining hall kitchen. The only possible reduction would be in the number of perishable ready-to-eat products that are thrown away each night. This reduction can be achieved through monitoring and donation of leftover food. While demand is already indirectly monitored through the purchase log, this information is not shared directly with AVI Fresh. The supply of perishable food would also need to be increased on days when events are taking place on campus, and reduced on days where demand is frequently low. Rather than throwing away these leftover food at the end of the day, the Emporium could donate food to a local food recovery program (see Chapter 5). If it is safe to do so, staff members would also leave out food for students studying in the Campus Center late at night. These steps would ensure that food waste at the café is minimal.

3.3.3 The Leaky Beaker

Figure 3-15. The Leaky Beaker in the Science Center.

In order to reduce food waste at The Leaky Beaker, we would implement a monitoring system similar to the one described for the Emporium. Staff from The Leaky Beaker would communicate directly with AVI Fresh, thus ensuring that food supply would match demand, thus minimizing waste. Like the Emporium, the Leaky Beaker is obligated to throw away all refrigerated ready-to-eat products. Rather than throwing these leftovers away, staff members would collaborate with other cafés to donate food. Staff members would also leave food out in the Science Center Focus for students to snack on while finishing assignments. Finally, we would also ensure that the pre- and post-consumer food waste for The Leaky Beaker is directed towards the waste stream of a dining hall, and not of Sage Lounge. This extra step would ensure that as much food waste as possible would be diverted.

3.3.4 El Table

Figure 3-16. El Table

Unless a customer specifically asks for a to-go cup or a container, food and drinks are served in ceramic dishes. When individuals finish their meals, they return the dishes to the counter. These dishes are then collected by a server and washed in the backroom. Excess scrap ingredients for sandwiches and meals comprise a majority of the pre-consumer waste. The café has been composting its own food scraps since 2009 ;[1] therefore, it would not need to make any changes to its food waste management. Once the College begins large-scale composting, the café would have the option of diverting its food waste to the nearest dining hall - most likely Stone Davis - for composting.

[1] Conton, Ruby, and Xueying Chen. "Office of Sustainability launches compost program." *Wellesley News*. Accessed April 14, 2013. http://www.wellesleynewsonline.com/office-of-sustainability-launches-compost-program-1.2953570#.UWsLK7VQFrM.

3.3.5 Café Hoop

Figure 3-17. Signs on the entrance to Café Hoop

Pre- and post-consumer waste at Café Hoop is already low, but any food waste produced there can be added to Wellesley's food waste stream. Collection bins for food waste and non-food waste would be placed in the café; bins with food scraps would be collected at the end of each day and combined with the waste stream of the Campus Center's dining hall.

3.3.6 Wellesley College Club

Figure 3-18: Wellesley College Club dining room set up for a special event[2]

Food waste reduction and diversion implementation scenarios are limited for the College Club, as it already undertakes several initiatives to reduce and divert its food waste.[3] Food that can be donated is sent to Metro West Harvest, a food rescue program in Framingham; the majority of this food waste is unused prepped food items.[4] The College Club keeps all food that can be donated in a cooler in the refrigerator.[5] Metro West Harvest picks up this cooler every Sunday and replaces it with an empty one.[6] Food that cannot be donated to people is given to a private individual in South Natick who raises pigs; most of this food is produce and food prep items. This food is stored in a five-gallon pail in the refrigerator and picked up at the end of each workday (Tuesday through Sunday). As a result of these donations, the College Club's only pre- and post-consumer waste is meat, which cannot be donated. In order to reduce food waste further, the College Club would need to add a third bin in the washroom to collect meat. At the end of the day, the contents of this bin would be collected and taken to the nearest dining hall - either Stone Davis or Bates - and added to its waste stream. No other adjustments would be necessary, as the washroom is already the right size to accommodate cleaning up after the number of patrons that frequent the College Club.

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[2] The Wellesley College Club "Cover Photos." Accessed May 12, 2013. http://www.wellesleycollegeclub.com/index.html.

[3] Mark Roche, General Manager at Wellesley College Club. Interviewed by Audrey Mutschlecner. March 14, 2013.

[4] Mark Roche, General Manager at Wellesley College Club. Interviewed by Audrey Mutschlecner. March 14, 2013.

[5] Mark Roche, General Manager at Wellesley College Club. Interviewed by Audrey Mutschlecner. March 14, 2013.

[6] Mark Roche, General Manager at Wellesley College Club. Interviewed by Audrey Mutschlecner. March 14, 2013.

3.4 Food Waste Separation

3.4.1 Pre-Consumer Food Waste Separation by Staff

Any food waste diversion scheme that is implemented will need to take into account the food waste that is created during food preparation. This waste consists of food scraps, such as onion skins, fruits and vegetable peels, and meat carcasses and bones, as well as expired or outdated items. Such waste will be referred to as "pre-consumer food waste." For this aspect of implementation to be successful, dining staff will possibly need to change their routine and adjust kitchen layout by including disposal of food waste into separate bins. Systems will need to be put in place to improve the ease of the processes for dining staff, so as to keep operations in dining halls running smoothly.

Figure 3-21: Food being prepared in the kitchen of Pomeroy dining hall.

Food Waste Separation Process

As of early April, all dining facilities at Wellesley started diverting their pre-consumer waste. Each facility shares similar methods of collection. First, kitchen workers put aside trim waste in smaller bins that are located close to the food preparation area (Figure 3-21). As these bins get full, they are taken out through the back door and outside to larger trash bins that are labeled "Food Waste Only" (Figure 3-22). Dining hall workers still need to figure out the best timing for emptying the bins.[7] If the bins take less than a week to fill up, they will have to be emptied more often; if they fill up less quickly than that, workers will have to figure out how long they can leave the waste out before it starts decomposing and producing unpleasant odors. Contamination of pre-consumer waste and difficulty of implementation for dining hall staff members is expected to decrease as workers become more familiar with the separation process. All dining

[7] Employee at Pomeroy Dining Hall. Interviewed by ES 300. April 12, 2013.

halls currently implement pre-consumer food waste separation designated for compost in new composting pilot projects. This aspect of food waste diversion will no doubt be implemented by the Organic Waste Ban.

Figure 3-22. Larger bins outside the Pomeroy kitchen that will collect a week's worth of pre-consumer food waste

Processes Needed for Implementation

Providing conveniently located bins and clear signage helps staff easily discard food waste. Staff will need to create proper procedures for food waste, such as emptying the smaller food bins once a day. These bins can be directly dumped into outdoor food waste disposal bins or refrigerated if they are not completely full. Clear signs in both English and Spanish will support staff throughout separation procedures and will help avoid contamination. Signage should include recognizable items used within the kitchen space. Making it difficult for staff to dispose of food waste in non-food waste bins will also prevent contamination. For example, kitchens can have five-gallon food waste bins on top of garbage can lids to ensure bins are easier to reach than the regular trash, or cover in-sink waste disposal outlets.[8] Since this procedural change will require action from staff, certain changes are needed to ensure proper training and compensation for their efforts. New employee training and workers' contracts should include education on how to separate food waste from other waste. Current employees will need to be trained in proper separation. Workers should lead the decisionmaking process regarding the placement of bins since they manage food preparation. There may be a lag time with implementing pre-consumer food waste disposal as the workers learn how to separate waste. Depending on the reduction method chosen by Wellesley College, procedural changes for dining staff and adjustments to kitchen layout will vary.

3.4.2 Post-Consumer Food Waste Separation by Staff

[8] Employee at Olin College Dining Hall. Interviewed by ES 300. Spring 2013.

In this section we will discuss the possible future implementation scenarios for Wellesley College that would use staff labor in the separation of post-consumer food waste from the traditional waste stream. This scenario will generally involve the collection of students' un-scraped dishes so that staff can effectively and efficiently collect the food waste while avoiding contamination by dishware, utensils, and other non-compostable items. This staff collection can take many forms, but would most likely function in the form of a conveyor-belt collection of plates or students placing their un-scraped dishes in a specified collection location. While we understand that each dining hall on campus has a unique layout and structure, when assessing the implementation of food waste diversion by staff we assumed that regardless of these differences, all staff will be required to change to a uniform process with regards to food separation. Here we will make general recommendations for the staff separation process that can be adapted for each unique layout.

Food Waste Separation Process

The additional labor required from Dining Hall staff depends on which method of diversion is implemented. All diversion methods in this report require separation of dishware and utensils, since none of the methods we identified can handle these materials. See Chapters 5-16 for details on separation requirements for each method.

Culture of Composting and Creation of Identity

The creation of a composting culture amongst the staff who are directly involved with the separation will occur. Because no students or other members of the Wellesley community have a direct hand in the separation procedure, there will be no change in student culture or identity.

Level of Contamination

Because staff will be trained specifically to separate the food waste and will be the only ones who are responsible for the separation, the risk of contamination (due to unwanted food products like meat or dairy for a certain composting methods, or to silverware or other non-compostable items) will be low.

Education Value

Students would not gain any educational value from this process, because it would be done completely by staff.

Processes Needed for Implementation

Training

Training must include a detailed explanation of the types of food waste allowed in food waste bins. It would also benefit the composting waste diversion program to explain to staff why they need to separate out certain foods so that they understand the importance of their work.

Bins

Staff will need access to composting bins in the dishwashing area of each dining hall for all composting options compiled in this report. Staff-led separation bin placement would likely be easier than if students were responsible for separating food waste because they would require fewer bins and less strategic placement. The location of bins within the dishwashing areas of each dining hall would be largely dependent on the spatial convenience and preferences of staff members. The food waste bins should also be visibly different from trash barrels to easily facilitate separation and minimize accidental contamination.

Figure 3-24: Pre-consumer food waste separation bins in the Pomeroy kitchen

Signs

Visual signs should be posted above each food waste and non-food waste bin to remind staff of what can be separated into each bin. The color for permitted food waste signs should also be consistent with the color of the bins.

3.4.3 Post-Consumer Food Waste Separation by Students

Consistent student participation will be vital to the success of any system of food waste diversion. Ideally, direct involvement in a well-established food waste separation system will help educate students on the value of food waste diversion, highlighting the amount of food thrown away on campus and their own contribution to the waste diversion process. Depending on the food waste diversion methods chosen, separating food waste properly may be challenging at first. This scenario explores the factors involved in food waste separation by students. A combination of education campaigns and an intuitive, simple separation system will ensure that students properly separate food waste.[9] The physical separation process can be streamlined to reduce contamination, and will be influenced by the separation required by the waste diversion method. Informational, normative, and other social influences shape human behavior and compliance with a system: for example, the time a student perceives she has will affect whether she is effective at separating her food waste. If the waste separation process takes a long time and is

[9] Thøgersen, John. “A Model Of Recycling Behaviour, With Evidence From Danish Source Separation Programmes,” *International Journal of Research in Marketing* 11 (2) (March 1994): 160.

complicated, students that are in a rush will be unlikely to fully comply with the separation system, especially during peak hours. Also, people have many different behaviors and backgrounds, and are not all necessarily familiar with composting or food separation. We suggest that the dining halls implement a uniform bin system. Consistency will contribute to compliance.

Facilitating Student Plate Scraping Behavior

In all dining halls at Wellesley except the campus center, students currently scrape their plates to some degree prior to putting them on a conveyor belt or passing them across a counter to be handled by dining hall employees. This existing behavior will likely help reinforce post-consumer separation by students. Currently, there are varying levels and methods of scraping in each dining hall. As mentioned above, it is important that these are made consistent. In Pomeroy dining hall, students are acculturated the most to separation due to their current system. The campus center dining hall necessitates the biggest physical modifications to accommodate student post-consumer separation. Since research shows that models help facilitate proper waste separation,[10] we suggest beginning any on-campus composting program that incorporates student separation by having one of AVI's student employees act as a model for post-consumer separation within each dining hall. This student would remain near the site where students place dishes after eating. The student would kindly remind people to scrape and separate their plate waste and show them how to do so if they are not familiar with the process. The student would also assist others with explaining proper scraping, especially during peak dining hours, in order to minimize contamination and increase efficiency.

Uniform Separation Bins and Storage

With the student separation system, we suggest a centralized waste disposal station within each dining hall to streamline the process. Separation bins should be located close to dish drop offs, and the space should be large enough to accommodate the daily lunch and dinner rushes. Designating a location where students can drop off unscraped plates during lunch and dinner rushes for a staff member to scrape later will decrease contamination. Bins should be large, easy to carry, transparent, shaped according to their intended waste material,[11] and color coded to the type of waste they are intended for. These bins should be uniform across all dining halls.

Clear, Visual and Educational Signage

[10] Sussman, Reuven et al., "The Effectiveness of Models and Prompts on Waste Diversion: A Field Experiment on Composting by Cafeteria Patrons," *Journal of Applied Social Psychology* 43.1 (2013): 24-34.

[11] Duffy, Sean and Michelle Verges, "It Matters a Hole Lot: Perceptual Affordances of Waste Containers Influence Recycling Compliance," *Environment and Behavior* 41 (2009): 741-749.

Figure 3-26: Signs at the Pomeroy dish return counter.

Signs are important to ensure proper food waste disposal. Signs should be visual, clear, located near waste bins, and should guide the disposer through each step of disposal. Signs should be consistent across dining halls. These signs could contribute to education and awareness campaigns (see Chapter 2 for more details), which will help students understand the importance of their actions.[12] Signs could include data on the number of students who properly dispose of food waste and data on the food waste practices of other colleges. This information may compel students to dispose of food waste properly.

Creation of Culture and Identity
Proper food waste separation could be added to the Honor Code to ensure that it becomes an ingrained part of student culture.[13] If the Honor Code council were to apply the Honor Code system to not only larceny and plagiarism, but to food waste diversion as well, the Wellesley community would take on-campus sustainability efforts more seriously.

3.5 Conclusion

The implementation of a waste diversion method will depend on its particular requirements, but certain considerations will apply regardless of the method chosen. Effective post-consumer separation will need to be addressed for almost every method. Either students or staff can

[12] Sussman, Reuven et al., "The Effectiveness of Models and Prompts on Waste Diversion: A Field Experiment on Composting by Cafeteria Patrons," *Journal of Applied Social Psychology* 43.1 (2013): 24-34.
[13] Wellesley College. "The Honor Code," Accessed April 2013. http://www.wellesley.edu/studentlife/aboutus/honor.

perform this separation; there are unique benefits and challenges associated with each option. Another consideration is the connection between education and the ease of sorting correctly. Education is critical to fostering good intentions, but ultimately it is the ease of performing a task correctly that will lead to good performance. Food waste diversion must be culturally ingrained within the student body in order to become fully integrated into the Wellesley identity. These are all factors of implementation that will be important regardless of the method of diversion that is chosen.

II. Food Waste Diversion Methods

4.0 Introduction to Waste Diversion Methods

In preparation for the 2014 MassDEP organic waste requirement, the following section of the report provides detailed results of research on 12 organic waste diversion methods for Wellesley College.

All waste diversion methods can process a significant portion, if not all, of Wellesley's 220 metric tons of organic waste and their processes are analyzed using Life Cycle Assessment. Most of the analyzed methods in the report encompass composting, the breaking down of organic waste into nutrient-rich plant matter.

Each method includes an introduction of the method process, its implementation logistics, and its environmental, economic, and social impacts upon implementation. The introduction gives an overview of how the method operates and the implementation discusses how the method could be used as part of Wellesley's waste diversion efforts. The environmental impacts analyze climate change, human toxicity, and ecosystem toxicity impacts through a Life Cycle Assessment, and the economic impacts tally the direct, operational, equipment, and offset costs associated with each method. Finally, the social impacts are considered through metrics which examine the method in terms of implementation difficulty, educational value, social justice effects, and campus experience.

4.1 Defining Compost

The degradation and recycling of organic material by microorganisms into plant-usable forms is a fundamental ecological process that occurs in every forest worldwide.[1] Compost, a mixture of decayed organic material, is the end product of this natural process. In addition to occurring in nature, compost is intentionally created by people from leaves, grass clippings, and food waste as a favorable alternative to other waste disposal methods, such as landfilling, as it contributes greenhouse gases to the atmosphere, and incineration, which requires energy inputs and causes air pollution.[2]

Compost is used widely by gardeners and farmers for its water-holding and aeration capacity and carbon and nutrient content, which helps to regenerate poor quality soils and improve soil structure.[3] Compost contains nitrogen, phosphorus and potassium. These nutrients become

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[1] Wilkinson, David M. *Fundamental Processes in Ecology: An Earth Systems Approach.* New York, NY: Oxford University Press, 2006.
[2] Miller, Lauren. "Compost vs. Fertilizer." Accessed March 11, 2013. http://homeguides.sfgate.com/compost-vs-fertilizer-39096.html.
[3] Bocco, Diana. "Pros and Cons of Composting." Last modified August 4, 2010. Accessed March 11, 2013. http://www.livestrong.com/article/193315-pros-cons-of-composting/.

available for plants over a long time scale and in small amounts.[4] It does not act as quickly as chemical fertilizers do but offers a plants a balance of both macro- and micro-nutrients,[5] control or pathogens which cause plant diseases,[6] provides food for diverse soil life, including bacteria, fungi, worms, and insects and reduces runoff and erosion.[7]

Successful composting relies on the proper 1:3 mixture of Nitrogen-rich "green" materials and Carbon-rich "brown" materials: "Green" materials include food scraps and fresh garden waste, while "brown" materials include wood chips, dead leaves, straw and sawdust.[8] Other factors also influence the rate of decomposition, including aeration, temperature, moisture, soil pH, and the carbon: nitrogen ratio. Maintaining these factors in ideal conditions ensures that decomposing fungi and bacteria are working optimally.[9] Composting methods scale from small backyard piles accommodating household food and yard waste to large-scale municipal level facilities that process thousands of tons of waste per year.

While municipal waste composting is just now taking hold in the United States, Europe has a well-developed system for diverting organic waste to create compost that farmers can use. In Europe, 1,900 compost plants[10] create 9 million tons of compost each year from 12 million tons of collected organic waste. This represents 35% of the total waste stream.[11] Kitchen waste plays an important role in cost optimizing source separation of waste, and quality assurance systems help market compost to gardeners and farmers.[12]

In the United States municipal composting programs are far behind those in Europe. Although 30% of the municipal waste stream is organic and potentially compostable, only animal manure and wastewater treatment plant solids waste streams are regulated, and only 13 states have

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[4] Encyclopædia Britannica Online, s. v. "compost." Accessed April 2, 2013. http://0-www.britannica.com.luna.wellesley.edu/EBchecked/topic/130177/compost.
[5] Belyeu, Samantha. "Compost Vs. Fertilizer." Accessed March 11, 2013. http://www.ehow.com/info_7994347_compost-vs-fertilizer.html.
"Compost Fundamentals: Compost Benefits." Accessed March 11, 2013. http://whatcom.wsu.edu/ag/compost/fundamentals/benefits_benefits.htm.
[6] "Benefits of Using Compost." Accessed March 11, 2013. http://earth911.com/news/2007/04/02/benefits-of-using-compost/.
[7] "Compost Fundamentals: Compost Benefits." Accessed March 11, 2013. http://whatcom.wsu.edu/ag/compost/fundamentals/benefits_benefits.htm.
"3 Reasons Why You Should Compost." Accessed March 11, 2013. http://blog.seattlepi.com/naturalmedicine/tag/compost-vs-fertilizer/.
[8] "The Basics of Home Composting." Accessed March 12, 2013. http://www.dep.state.pa.us/dep/deputate/airwaste/wm/recycle/compost/Home3.htm.
[9] "Basics of Composting." Accessed March 12, 2013. http://www.thegardenofoz.org/composting101.asp.
[10] Gilbert, Jane. "Composting Across Europe." Accessed May, 2013. http://www.environ.ie/en/Environment/Waste/ProducerResponsibilityObligations/RecyclingConsultativeForum/FileDownLoad,16399,en.pdf.
[11] Gilbert, Jane. "Composting Across Europe." Accessed May, 2013. http://www.environ.ie/en/Environment/Waste/ProducerResponsibilityObligations/RecyclingConsultativeForum/FileDownLoad,16399,en.pdf.
[12] Brinton, William F. "Compost Quality Standards and Guidelines: An International View, Final Report." Last modified December, 2000. Accessed May, 2013. http://www.elaw.org/system/files/compostqual.pdf.

organic waste recycling laws.[13] Several US cities - including Portland, Oregon; Austin, Texas; and San Francisco, California - have planned or instituted three-bin collection systems and composting facilities. On a smaller scale, many colleges and universities have implemented a composting program, such as Harvard College, Cornell University, Oberlin College, Grinnell College, and Mount Holyoke College. The commitment of these institutions represents the importance of changing our waste habits and finding ways to repurpose organic waste for reuse by creating compost. Wellesley College's current need to change its organic waste disposal methods provides an exciting opportunity to make a meaningful contribution to sustainability efforts on campus and in the world.

4.2 Defining Life Cycle Assessment (LCA)

Completing a Life Cycle Assessment (LCA) is an objective way to calculate the total environmental and health impacts of a product or system over its entire lifetime, from raw material extraction to end of life disposal. The completion of an LCA requires identifying a system's materials and processes, creating an inventory of all the inputs and outputs for those materials and processes, and then identifying the contributions of those inputs and outputs to the environment.

We use LCA in our study to assess and compare the environmental and health impacts of twelve organic waste diversion methods for Wellesley College. Using LCA gives us common units for comparison and lets us more objectively develop recommendations for the College. In addition, comparing stages of the lifecycle is useful in this project because it allows us to identify what stage of each process leads to the greatest impact. We can therefore examine whether varying the implementation of the method could reduce those impacts.

4.2.1 System Boundary

Performing a Life Cycle Assessment requires drawing boundaries to define the scope of the study. Our LCA includes impacts from equipment necessary for the method, the transportation of both organic waste, the operation of the method, and any disposal processes involved for the equipment used. In addition, our analysis accounts for positive benefits, or offsets. For example, one disposal method produces a natural gas-like fuel as a useful byproduct. Producing the biofuel can offset the negative impact of extracting an equivalent amount of natural gas.

Because the purpose of this assessment is to compare organic waste diversion methods, there are components that we exclude from the scope of our study. We do not include any material that would need to be used independent of organic waste diversion method, such as post-consumer food collection bins and bin liners, in our environmental, cost, or social analysis. We also exclude impacts on existing infrastructure, such as roads and large pipes. We assume that the impacts to infrastructure from Wellesley's organic waste diversion program would be negligible compared to the overall wear-and-tear, and therefore, do not include it in the boundaries of our study. We also exclude impacts that are secondary byproducts of organic waste diversion and do not directly link to the amount of food waste diverted by Wellesley. For example, we do not

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[13] Brinton, William F. "Compost Quality Standards and Guidelines: An International View, Final Report." Last modified December, 2000. Accessed May, 2013. http://www.elaw.org/system/files/compostqual.pdf.

include the emission of methane on a pig farm accepting donations from Wellesley in our analysis because we assume the pigs would be alive and emitting methane independent of Wellesley's donation of food waste to the farm. Finally, we exclude impacts that we deem significantly removed from our activities, such as those from the transportation of workers and the secondary transportation of compost after off-campus processing.

4.2.2 Functional Unit

When performing an LCA, we make comparisons by choosing a specific quantity of the desired outcome; this is called the functional unit. Having a common unit allows us to compare impacts consistently across all the methods. It also permits us to scale our results to different amounts of annual food waste. The result of our LCA for each organic waste diversion method describes the environmental and cost impacts from diverting one metric ton of food waste.

4.3 Environmental Impact Analysis

In this study, we examine three types of environmental impacts: global warming potential, ecosystem toxicity, and carcinogenic human toxicity. The functional unit of this study is one metric ton of food waste diverted. All non-negligible materials and processes for each composting method are included. The life cycle inventory conducted for each method includes materials, energy, and water inputs. Some materials, such as food waste storage bins and compostable bin liners, will be required for any waste diversion method implemented at Wellesley College. Although these materials will have environmental impacts, including them does not contribute to the goal of this study, which is to compare the impacts of different methods. Thus, they are outside the boundaries of this impact study and not included in our analysis.

This study employs SimaPro7 to model a Life Cycle Assessment for each organic waste diversion method. SimaPro7 contains different data systems that measure the comprehensive environmental impacts of different materials, energy inputs and processes. We chose the EPA Tools for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI2)[14] to measure environmental impacts. An analysis using TRACI2 results in a graphical representation of environmental impacts across a variety of categories. Inherent in the program is a process that normalizes the results, making them comparable across all 12 organic waste diversion methods. In addition to the SimaPro analysis, we assess the water needed for each organic waste diversion method, since water use is not included in SimaPro7.

For the purpose of this study, environmental impacts (with the exception of water) are reported as effects per metric ton of food waste diverted. We examine global warming potential, carcinogenic harm, and ecotoxicity. These impacts are measured using different units, which alone are difficult to understand or contextualize. Comparing the environmental impacts of a process to the impacts of coal is a common process in LCA, since the environmental impacts of coal are familiar and tangible. Thus, we evaluate the environmental impacts of coal to

[14] "Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI)." Last modified 2013. Accessed March 10, 2013. http://www.epa.gov/nrmrl/std/traci/traci.html.

contextualize our findings. By understanding the global warming, carcinogenic, and ecotoxicity potential of coal, we better understand the magnitude of the environmental effects of our diversion methods.

Information on the environmental impacts of the life cycle of each organic waste diversion method will help Wellesley make an informed decision. Analyzing environmental impacts for each method allows us to compare emissions across diversion methods by providing a comparable estimate of each one's environmental benefits and drawbacks. This type of comparison provides decisionmakers the necessary quantitative data to select a method based on the impact category that they prioritize. Analyzing environmental impacts for each method also provides an understanding of which portions of the life cycle are the most harmful to the environment. This data enables us to adjust our methods accordingly to reduce environmental impacts. For example, if transportation accounts for 50% of the global warming potential, we can seek a closer diversion location.

4.3.1 Global Warming Potential

Global climate change occurs as people emit large amounts of greenhouse gases, such as carbon dioxide, into the atmosphere. These gases exacerbate the existing greenhouse effect, trapping excess heat near the Earth's surface. As human processes emit more greenhouse gases, the atmosphere traps a higher quantity of heat, causing the global climate to warm. The negative impacts of the greenhouse effect on global climate change are well understood by scientists, and this human-induced climate change already affects millions of people around the globe.

In order to understand the impact that Wellesley's organic waste diversion will have on the global climate, we assess the global warming potential of each option. This metric estimates global warming potential by outlining the amount of greenhouse gases emitted at each stage of the diversion process. Global warming potential translates the effects of all environmental impacts into an equivalent amount of Carbon Dioxide emissions. This is a useful metric because climate change is often measured by the amount of CO2 released into the atmosphere.

4.3.2 Ecotoxicity

There are numerous materials and processes that contain a host of toxic chemicals, which can have a detrimental impact on the natural environment. To normalize the impacts of all of these toxic chemicals, TRACI2 reports this ecotoxicity in the equivalent of 2,4-dichlorophenoxyacetic acid (2,4-D). 2,4-D is a chemical commonly used in commercial herbicides. The National Pesticide Information Center reports that the acute toxicity of 2,4-D for pheasants is 472 mg/kg (2) or .000472 kg 2,4-D per kilogram of body weight. Aquatic plant life, however, face a much lower exposure threshold, mainly because the chemical is marketed as an herbicide. The effective concentration needed to kill 50% of duckweed is .58 mg/L[15] or .00000058 kg per liter

[15] Gervais, J. A., and Luukinen, B., et al. "2,4-D Technical Fact Sheet." Last modified 2008. Accessed March, 2013. http://npic.orst.edu/factsheets/2,4-DTech.pdf.

of water. The EPA regulates 2,4-D at its the maximum contaminant level, or highest concentration allowable in drinking water, which is .07 mg/L or .00007 kg 2,4-D/L water.[16]

4.3.3 Human Toxicity

For the purpose of this project, we measure human toxicity through the carcinogenic potential of each composting method. While there are a host of carcinogenic chemicals, TRACI2 normalizes these impacts and reports carcinogenic potential in kilograms of benzene equivalent released for each metric ton of food waste diverted. Benzene is a volatile organic chemical that is often released as a byproduct of burning gasoline or smoking a cigarette.[17] The EPA regulates benzene in drinking water when it is present at levels above 5 ppb or 0.000005 kg Benzene per liter of water.[18]

4.3.4 Water Consumption

There is no mechanism in SimaPro to analyze the amount of water consumed during the life cycle of a process. We analyze the amount of water used by each method separately from SimaPro and report the total water use in liters per metric ton of organic waste diverted. Our study only includes water used operationally to support the function of an organic waste diversion method. The boundaries of our system do not include water used to prepare food that is then wasted. For example, we would include the water needed to fill an anaerobic digester, but not water used to prepare pre-consumer food.

4.4 Cost Analysis

The cost measurement is used to determine the relative financial burden of each composting method. Cost is measured in US dollars and includes direct costs, operational costs, and offset costs. We look at both costs that the College will pay and costs that will be avoided due to the method employed. The final value is the sum of these parts.

The purpose of this measurement is to provide a clear and accurate estimation of the cost associated with implementing each organic waste diversion method at Wellesley College. Costs that are taken into account represent what Wellesley College would need to pay for each method, to our knowledge, at the time of the publication of this report. Though this measurement is not the sole consideration in determining the ideal organic waste diversion method, it will be an important factor in the College's decisionmaking process.

4.4.1 Direct Cost

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16 "Drinking Water Contaminants." Last modified 2009. Accessed March 10, 2013. http://www.epa.gov/safewater/contaminants/index.html.

17 "Basic Information on Benzene." Last Modified 2013. Accessed March 10, 2013. http://water.epa.gov/drink/contaminants/basicinformation/benzene.cfm#four.

18 "Basic Information on Benzene." Last Modified 2013. Accessed March 10, 2013. http://water.epa.gov/drink/contaminants/basicinformation/benzene.cfm#four.

Direct costs are any fees that the College pays to an external actor or agency. Primary direct costs are those of external facilities for processing the organic waste, and externally provided transportation, which will truck the organic waste from Wellesley to an off-campus facility. For externally provided transportation, we assume a cost of $45 per metric ton of food waste.

4.4.2 Operational Cost

Operational costs are those incurred on campus and paid at regular intervals. Examples of operational cost include on-campus transportation, labor fees, and water. To be an operational cost, Wellesley employees must complete on-campus transportation. We calculate the cost of labor based on institution-specific data, including any staff of the College who will be involved in the composting process. This includes dining facilities staff as well as maintenance and facilities staff. We assume water costs at $0.00001984 per liter on campus; off-campus water costs are included as part of the tipping fee.

4.4.3 Equipment Cost

Equipment costs are fixed costs that are incurred on campus as a composting method is implemented. Examples of equipment costs are trucks used to transport waste and construction materials for building a diversion facility on campus.

4.4.4 Offset Cost

Offset costs measure costs that would have been incurred had a composting method *not* been implemented. These are negative figures subtracted from the total cost of a method's implementation. The generation of methane from an on-campus anaerobic digester is an example of an offset cost because it alleviates the College's need to purchase biogas. We do not include fertilizer as an offset, since the generation of compost would not offset the need to buy fertilizer for on-campus landscaping purposes.

4.5 Social Impacts Analysis

Each of the composting methods in this report includes an analysis of potential social impacts. Examining social impacts in our analysis allows us to systematically assess how a diversion method will affect the lives of individuals and at the community level. The social impacts are chosen to represent Wellesley's values, needs, and priorities, and are specific to Wellesley College.

This study considers the following social impacts: campus experience, educational benefit, difficulty of implementing the methods, and social justice. In order to streamline these analyses, we created a social impact metric. Campus experience, educational benefit, and difficulty of implementation are measured on a three-point scale, and social justice is measured on a six-point scale.

We examine the social impacts of organic waste diversion methods to gain a holistic understanding of their consequences. Some methods have the potential to lead to a greater social good, which should be accounted for in decisionmaking. In addition, it is important to ensure that organic waste diversion practices will not result in excessively unpleasant or negative externalities that will lower the quality of life for those involved. None of the methods assessed in this report have social impacts that would prevent the implementation of the method, but this analysis will help decision-makers compare the twelve methods assessed here to each other.

4.5.1 Campus Experience

This metric examines effects on the student experience and Wellesley's reputation. The campus experience metric outlines how composting could positively or negatively affect students, as student residential life is an important component of the small liberal arts college experience. Positive impacts include a sense of pride in implementing innovative, environmentally friendly composting on-campus, opportunities for good public relations, and additions to the aesthetic landscape and general beauty of the campus. Negative impacts include a sense of shame from poor implementation and/or results, the potential for unpleasant smells and pests, and from negatively impacting the campus aesthetic. Based on these criteria, we categorize each method as having a positive, neutral, or negative social impact.

4.5.2 Educational Benefit

We analyze each composting method based on the educational opportunities that it could provide to Wellesley students. We assign an education score based on a 3-point scale of negative, neutral or positive. We determine the score based on whether methods are visible and whether they offer academic opportunities to the students. We define visibility by the degree of student interaction with the composting method. We assume that if a composting method is visible to students in their day-to-day lives, that that will have educational value in and of itself. A high level of visibility may mean that students and on-campus student groups could work directly with dining services on the food waste diversion program. Educational opportunities might include methods that would open opportunities for student research or provide professors with the opportunity to integrate a method into course curriculum.

A method receives a high rating if is not visible and cannot provide new academic opportunities, or if it makes an impact that is too small to make a difference. Off-campus methods generally merit a high rating unless a strong argument could be made otherwise. Organic waste diversion methods receive a medium rating if is visible *or* offers new academic opportunities, but not both. Finally, it receives a low rating if it offers visibility and new academic opportunities.

4.5.3 Implementation Difficulty

We also research the difficulty of implementing and running the method. This study divides difficulty into four parts: separation, permitting and regulations, time until implementation, and risk. Each subset of the difficulty metric earns a low, medium, or high rating.

The first subset is separation, specifically the separation of certain kinds of food waste from the larger organic waste stream, including animal bones, meat, oils, dairy, or compostable waste. Low ratings require no change because the method is able to take all food waste. Medium ratings mean that the method has two of the aforementioned things that cannot go into the waste stream and need to be sorted out. High ratings require a separation of more than two of the items, or demand the separation of something difficult, such as high sodium food.

The second subset is permitting and regulation. Some methods may require permits from the state. Furthermore, regulations on how organic waste is stored or treated could affect the amount of work that goes into running the method. Low scores imply that all of the composting occurs off campus, therefore requiring no regulatory attention from Wellesley. Medium scores mean that the method would require some change in permitting or regulations. High scores apply to a method that would require the maximum amount of permitting and regulation, such as building an anaerobic digester on campus.

The third subset is the time scale before the organic waste diversion method could be fully implemented. Low scores apply to methods that could be implemented immediately, such as transporting the organic waste off campus to existing facilities. Methods that receive medium scores, such as building windrows on campus, can be implemented by the 2014 Organic Waste Ban deadline. Finally, those methods with high scores require more than two years for implementation.

The final subset of the difficulty measure is risk. Because composting deals with waste, there is a chance these methods may negatively affect people and the environment both on and off campus. Two examples of risk include an anaerobic digester explosion and food poisoning for those who eat Wellesley's donated food. This study determines risk based on two factors: (1) probability of harm and (2) severity of harm. A low score denotes that there is low potential and low severity associated with the method; a medium score means low probability and high severity, or high probability and low severity; a high score implies high probability and high severity.

4.5.4 Social Justice

We consider social justice as an important social impact of organic waste diversion. For our analysis we weight the social justice implications of each method equal to the combined impact of campus experience, difficulty, and lack of educational opportunities. For social justice, we examine each method to determine whether people would directly benefit or suffer from its implementation. Prominent considerations include encroaching on peoples' spaces (i.e. building something in their yard), protecting the rights of the workers who would be involved in the composting process, and posing a risk to those who may not have the means to defend themselves. Each method has a unique social justice component. This metric is based on a six-point scale, and giving each method with either a positive or negative score of six points.

5.0 Donation to People

5.1 Introduction to Donation to People

Donating excess food to hungry people in the Greater Boston Area could effectively and responsibly divert food waste from incineration, creating the dual benefit of contributing to hunger reduction and reducing environmental impacts from waste disposal. A food donation system has the power to turn trash into treasure by looking at food waste as a usable resource rather than as waste. Food donation can be thought of as the first step in the food waste hierarchy; feed people first, then animals, and finally compost.[1]

Food donation to people is when people rescue edible, wholesome, and delicious food that would otherwise be wasted and donate it to hungry people in the community. On a college campus, food donation would begin with establishing a partnership between the College's food service and a local food recovery organization and/or establishing an on-campus program that directly delivers the food to local homeless shelters, food banks, churches, or other organizations where the food will be stored and distributed to those in need. Food recovery organizations take excess perishable and prepared food and distribute it to agencies that serve hungry people, whereas food banks typically collect non-perishable foods such as canned goods which can be stored for longer periods of time. Pine Street Inn in Boston is one example of a shelter that accepts perishable food delivered by food recovery organizations.[2]

For a food donation system at Wellesley, dining hall staff would package food that is still in good condition at the end of each day. After the food is packed, it would be transported to nearby shelters and food banks by either a food recovery organization or by the College itself. The food is then distributed, by means of a drop-off or pickup system, to hungry people in the community.

Because there are risks associated with food distribution, there are rules and regulations that protect both donors and recipients of food aid. In 1996, President Clinton signed the Bill Emerson Good Samaritan Food Donation Act, which protects manufacturers, retailers, and wholesalers from liability when donating food to a non-profit organization. It protects donors from civil and criminal liability if the product donated in good faith later causes harm to a recipient and additionally sets a liability floor of "gross negligence" or intentional misconduct for persons who donate food.[3]

Donors also must abide by food donation guidelines to ensure that food provided to the needy is safe. These guidelines often vary depending on how perishable the donated food is. Food banks will often only take canned, packaged, and other non-perishable goods whereas a recovery organization will take fresh produce and other food needing refrigeration. Some common guidelines would include making sure the item is within its "use by" date, that the food is

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[1] USDA. "Waste Not, Want Not: Feeding the Hungry and Reducing Solid Waste Through Food Recovery." Accessed May 2013. http://www.epa.gov/wastes/conserve/pubs/wast_not.pdf.
[2] Rathi, Rachana. "At Pine Street Inn, holiday spirit serves many." Boston Globe.
[3] Feeding America. "Protecting our Food Partners." Accessed May 2013. http://feedingamerica.org/get-involved/corporate-opportunities/become-a-partner/become-a-product-partner/protecting-our-food-partners.aspx.

packaged in an airtight container, and that the food has been safely stored and handled.[4] Part of a successful food donation program on any college campus would be one in which staff are well trained to ensure that the donated food is safe as well as nutritious for those in need.

5.2 Implementation at Wellesley

5.2.1 Overview of Implementation at Wellesley

We estimate that 15% of Wellesley's food waste could be donated to people. According to the observations of a student dining hall worker at the Campus Center dining hall, three half-full pans of safe and edible food are discarded after each lunch and dinner.[5] We estimate that half as much food is discarded at breakfast, because of the popularity of nonperishable items such as cereal and the tendency of many students to skip breakfast. Assuming an academic year of 212 days, and that the Campus Center dining hall is an average sized dining hall, 33,900 kilograms (33.9 metric tons) of food waste could be donated per academic year.

4.26 liters food / pan[6] * avg. 2.5 pans /meal * 3 meals / day * 5 dining halls * 1 kg / 1 L[7]
= 160 kg of food waste per day.
160 kg food waste / day * 212 days / academic year
= 33,900 kg food waste per academic year.
33,900 kg eligible for donation / 220,000 kg total food waste
= 15.4% eligible for donation.

The quantity of prepared pre-consumer food donated by Pomona College supports the validity of this estimate. In the 2012 academic year, Food Recovery Network volunteers at Pomona College in Claremont, California were able to pick up 526 full trays and 712 half trays of leftover food from campus dining halls.[8] The volunteers only pick up prepared leftovers from dinner; the Salvation Army collects prepared lunch foods separately.[9] As for Wellesley, we assume that approximately the same quantity of food is served for lunch and dinner each day, and that half as much perishable food is prepared for breakfast compared to lunch or dinner.[10] Assuming that both colleges' academic years comprise a similar number of days, and that food waste scales linearly with student population, Wellesley College is likely to produce 27,000 kilograms (27 metric tons) of prepared, uneaten food per academic year, or 127 kilograms per day, that is available for donation.

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[4] Washington State Department of Health. *Charity Food Donations.* Accessed May 2013. http://www.doh.wa.gov/CommunityandEnvironment/Food/FoodWorkerandIndustry/CharityFoodDonations.aspx.
[5] Audrey Mutschlecner, student dining hall worker. Interviewed by Carly Gayle. February 2013.
[6] Browne Foodservice. "Stainless Harmony Pan." Accessed 28 Feb. 2013. Amazon, http://www.amazon.com/Browne-Foodservice-575175-1-Stainless-Harmony/dp/B002VWKFSC. 9 quart pan, equivalent to 8.516 liters.
[7] Assuming the density of food is equal to the density of water, at 1 kg per liter.
[8] Tiffany, Laura. "Nick Murphy '13 is working to expand food rescue programs." Pomona College. Accessed May 2013. http://www.pomona.edu/news/2012/06/21-food-recovery-network.aspx.
[9] Tiffany, Laura. "Nick Murphy '13 is working to expand food rescue programs." Pomona College. Accessed May 2013. http://www.pomona.edu/news/2012/06/21-food-recovery-network.aspx.
[10] Scaled down because of the popularity of ready-to-eat foods such as cereal and whole fruit, and the tendency for many students to skip breakfast.

526 full trays + 712 half trays
= 882 full tray equivalents from dinner.
882 trays (dinner) + 882 trays (lunch) + 441trays (breakfast)
= 2205 full trays per year.
882 full trays * 9 quarts / tray * 8.516 liters / quart * 1 kg / liter
= 18,800 kg per year at Pomona.
10,800 kg per year at Pomona * (2300 Wellesley students / 1600 Pomona students)
= 27,000 kg per year at Wellesley.
27,000 kg per year / 212 days per academic year,
= 127 kg per day at Wellesley.

This number is slightly lower than the estimate from the dining hall worker. A small quantity of other pre-consumer food, such as lightly bruised fruit and bread, may be available for donation. Our original estimate of 160 kilograms per day accounts for these other sources of food.

Pickup by an intermediary food recovery organization is one route that Wellesley could take to bring its excess food to the hungry. One such organization in the Boston area is Lovin' Spoonfuls, which picks up perishable food in refrigerated cargo vans and delivers it to shelters the same day. Lovin' Spoonfuls delivers much of the recovered food to Pine Street Inn in Boston, 26 kilometers from Wellesley College. The shelter stores food in a walk-in refrigerator and does any necessary preparation and cooking before serving it.[11] We choose donation to Lovin' Spoonfuls as our sample scenario because the organization has the ability to handle perishable food and pick up food daily with no cost to the institution donating the food.[12] Food for Free and direct donation to a shelter, such as Metro West Harvest,[13] are other potential options.

5.2.2 Technology/Equipment

Preparing the food for donation would require refrigeration using Wellesley's existing walk-in refrigerators, as well as the purchase of disposable aluminum pans or other disposable boxes to transport the food. As Lovin' Spoonfuls delivers food to shelters the same day as it picks up, it has no warehouse facilities. Food is transported to shelters in Boston in a refrigerated cargo van. Once at the shelter, the food would be stored in an existing walk-in refrigerator. We assume it would then be reheated in an oven for approximately ten minutes before being served.

5.2.3 Inputs

Energy
The total estimated energy consumption is 97 kWh of electricity and two gallons of gasoline, from the refrigerators, oven for reheating food, and transportation (Table 5-1).

[11] Emma McCarthy, Lovin' Spoonfuls Operations Manager. Interviewed by Carly Gayle. November 5, 2012.
[12] Lovin' Spoonfuls."Food Donation Guidelines." 2013. PDF obtained from Emma McCarthy, Lovin' Spoonfuls Operations Manager, through email correspondence. March 25, 2013.
[13] Mark Roche, General Manager of the College Club. Interviewed by Audrey Mutschlecner. March 14, 2013. The Wellesley College Club currently donates to Metro West Harvest.

Table 5-1: Components of energy impacts, donation to people

Component	Electricity (kWh)	Gasoline (gallons)
Refrigeration (Wellesley)	18	--
Transportation (Wellesley to shelter)	--	2
Refrigeration (shelter)	18	--
Reheating in oven (shelter)	61	--

Cooling one metric ton of food at Wellesley is responsible for approximately18 kWh of electricity consumption, assumed to come exclusively from the cogeneration plant on campus.[14] A commercial walk-in refrigerator at Wellesley is modeled as 10 cubic meters, able to hold a maximum of about 600 liters, or 0.6 metric tons, of food.[15] A refrigerator of this size consumes 660 kWh of electricity per month,[16] or 21.7 kWh per day. Assuming a morning pick-up, energy would be spent refrigerating the donated food for an average of 12 hours at the College.[17] The energy required to keep one metric ton of food cool for 12 hours is assumed to be equal to that needed to keep 0.5 metric ton of food cool for 24 hours.[18]

21.7 kWh / day / 0.6 metric tons = 18 kWh / 0.5 day / 1 metric ton

The pick-up van has a combined fuel economy of 14 mpg, meaning that each round trip from Wellesley to Boston consumes just over two gallons of gasoline.[19] We estimate that a full van carries up to one metric ton of food to the shelter;[20] 1 metric ton of food from Wellesley donations is therefore responsible for two gallons of gasoline burned. We assume that the van picks up food at each dining hall individually, and that no other campus vehicle is used to take the food to a central location.

Refrigeration is required immediately upon arrival at the shelter. We assume that the food would arrive in the afternoon, and that half would be served at dinner and half would be served at lunch the following day, also resulting in an average of 12 hours of refrigeration time.[21] Following the same process and assumptions of the calculations for Wellesley's refrigeration energy,

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[14] Patrick Willoughby, Director of Sustainability at Wellesley College. Class discussion. March 6, 2013.

[15] Assuming a three-foot wide walkway in the center, a maximum of 2/3 of the volume of the refrigerator could be packed with food.

[16] U.S. Cooler Company. "Operating costs for walk-in coolers and freezers." Accessed May 2013. http://blog.uscooler.com/operating-cost-walkin-cooler-freezer/#more-666.

[17] Assuming approximately 3/8 of food served throughout the day is from lunch, is cleaned up at 2 p.m., and must be refrigerated for 19 hours; 3/8 is from dinner, is cleaned up at 9 p.m., and must be refrigerated for 13 hours; and 1/4 is from breakfast and does not need to be refrigerated before pickup. These assumptions lead to an average of 12 hours refrigeration time for the food.

[18] Cooling hot food to refrigerator temperatures takes more energy than maintaining a cold temperature, so the relationship is not truly linear. For the purposes of this approximation, linearity is a reasonable assumption.

[19] U.S. Department of Energy, Energy Efficiency and Renewable Energy Program. "Compare Side by Side: 2012 Ford E150 FFV." Accessed February 20, 2013. http://fueleconomy.gov/feg/Find.do?action=sbs&id=31886.

[20] AOL Autos. "2012 Ford E150." Accessed February 2013. http://autos.aol.com/cars-Ford-E_150-2012/specs/ The payload of the van is 1450 kg; assuming it is not packed completely full, 1000 kg of recovered food per van load is a reasonable estimate.

[21] Assuming the food served for dinner is refrigerated for four hours and the food served for lunch the following day is refrigerated for 20 hours.

refrigerating food donations from Wellesley leads to another 18 kWh per metric ton of food, assumed to come from the municipal electricity grid.

Lastly, the food would be reheated before being served, which we estimate will require 61 kWh of electricity per metric ton of food. We assume that each aluminum foil tray of food would be reheated for ten minutes, and that the oven can hold 4 trays of food at once. The oven must therefore be running for 30.5 hours in order to heat one metric ton (733 trays) of food from Wellesley.

4 trays of food / 10 minutes = 733 trays of food / 30.5 hours

The average electric oven running at 350° F for one hour consumes two kWh of energy.[22] One metric ton of Wellesley's food is therefore responsible for 61 kWh of electricity use from the municipal electricity grid.

Materials

This study accounts for the materials in the refrigerator and oven, scaled down to reflect the contribution of one metric ton of stored food, as well as the aluminum trays used to transport the food. Table 5-2 lists the mass of each material component of the refrigerator and the pans.

Table 5-2: Summary of material impacts, donation to people

Material	Mass (kg) per 1 metric ton food
Steel	0.244
Polyurethane insulation	0.0364
Aluminum-zinc alloy coating	0.0048
R-134 refrigerant liquid	0.00092
Copper	0.0036
Control unit (largely printed circuit board)	0.0025
ABS plastic	0.00052
Aluminum	30.4
Cardboard	1.6
Glass	0.0009

Disposable aluminum foil trays will likely be used to transport the food from Wellesley to the shelter.[23] For this analysis, we selected a foil tray with a foil-backed cardboard lid that holds three pounds of food.[24] One metric ton of food will require 733 trays. We assume that the trays are filled completely and are comprised of 95% aluminum and 5% cardboard by mass.[25]

[22] Macavinta, Courtney. "Range Buying Guide: How Much Energy Does the Average Range / Oven Use?" CNET, managed by CBS Interactive, Inc. Accessed March 24, 2013. http://reviews.cnet.com/4520-17895_7-6882870-6.html.
[23] Food Recovery Network, University of Maryland Chapter. "Organizing Tools: Sample Protocol for a Pick-Up." Accessed March 24, 2013. http://www.foodrecoverynetwork.org/resources/organizing-tools/.
[24] PacToGo. "3 lb. Oblong Entrée Take-Out Foil Pan w/Board Lid Combo Pack 250/CS." Accessed March 24, 2013. http://www.pactogo.com/3-lb-oblong-foil-pan-with-board-lid-combo-pack-250-cs.html.
[25] PacToGo. "3 lb. Oblong Entrée Take-Out Foil Pan w/Board Lid Combo Pack 250/CS." Accessed March 24, 2013. http://www.pactogo.com/3-lb-oblong-foil-pan-with-board-lid-combo-pack-250-cs.html. A pack of 250 trays weighs

Walk-in refrigerators have a life span of approximately ten years.[26] One metric ton of food waste cooled for 12 hours was shown to occupy the equivalent of 83% of one refrigerator's capacity for one day. One metric ton of food waste is therefore responsible for 0.02% of the material impact of one refrigerator. As refrigerators in two locations are utilized, the material impact attributed to refrigeration is the equivalent of 0.04% of the material impact of one refrigerator over its lifetime.[27] The materials inventory for the refrigerator was based on a refrigerator from the Kolpak company,[28] adapted from a Life Cycle Assessment completed by a Wellesley student in December, 2012.[29]

The representative oven selected weighs a total of 68 kilograms.[30] This is modeled as 66 kilograms of stainless steel, one kilogram of glass, and one kilogram of control unit, consisting largely of printed circuit board. The life expectancy of a wall oven is about 15 years.[31] We assume that in a shelter, the oven would be running an average of two hours prior to every meal, equivalent to 32,850 hours over the oven's lifetime. One metric ton of food from Wellesley is responsible for 0.09% of the oven's lifetime use, so the overall material impact of an oven is scaled by that amount.

6 hours / day * 365 days / year * 15 years = 32850 hours / lifetime
30.5 hours / 1 metric ton Wellesley food = 0.09% of material impact of 1 oven.

The food recovery organization may need to hire another driver and buy a new cargo van to add any more pick-ups to their schedule, but it is very unlikely that adding Wellesley College alone would warrant the purchase of a new vehicle.[32]

5.2.4 Outputs

Taking the food to a shelter may offset the need for shelters to purchase food, or may simply allow the shelter to feed more people. The ratio of purchase offset to hunger reduction will vary daily based on the number of clients, the volume of other donations, and the shelter's available

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24 lbs, or 10.9 kg, so 733 trays have a mass of 32 kg. The assumption of foil weight vs. cardboard weight was made qualitatively by looking at the photo on the website.

[26] Southern California Edison Utilities, Heschong Mahone Group. "Preliminary CASE Report: Analysis of Standards Options for Walk-In Refrigeration." Accessed May 2013. http://www.energy.ca.gov/appliances/2008rulemaking/documents/2008-02-01_documents/CASE_studies/Preliminary_Analysis_for_Walk-in_Refrigerated_Storage.pdf.

[27] 1 / [10 years * 365 days / year] * 83% capacity * 2 refrigerators = 0.04% of material impact of 1 refrigerator.

[28] Food Service Warehouse. "Kolpak (PX7-068-CT) - 5'10" Prefab Cooler (floorless) - Polar-Pak." Accessed October 30, 2012. http://www.foodservicewarehouse.com/kolpak/px7-068-ct/p347959.aspx.

[29] Gayle, Carly. "Environmental Impact Assessment of the Medway Passive Refrigerator." Presented at the Engineering Sustainability 2013 Conference. April 8, 2013, Pittsburgh, PA. Unpublished as of May 2013.

[30] Sears. "Kenmore 27" Electric Self-Clean Single Wall Oven." Accessed March 24, 2013. http://www.sears.com/kenmore-27inch-electric-self-clean-single-wall-oven/p-02248783000P?prdNo=5&blockNo=5&blockType=G5.

[31] House Logic. "Appliance Guide: Wall Ovens." Accessed May 2013. http://www.houselogic.com/home-advice/appliances/guides-wall-ovens/.

[32] Emma McCarthy, Lovin' Spoonfuls Operations Manager. Interviewed by Carly Gayle. November 5, 2012.

funds. We assume that half of donations will result in a purchasing offset and half will address hunger without a purchasing offset.

5.3 Environmental Impacts of Donation to People

5.3.1 Collection and Preparation of Food Waste

Table 5-3 shows the energy used for refrigeration at Wellesley, and Table 5-4 shows the materials inventory of the equipment manufacturing and aluminum pans.

Energy

Table 5-3: Energy from collection and preparation: refrigeration at Wellesley

Energy source	Energy per 1 metric ton food (kWh)
Cooling energy, natural gas, at cogen unit with absorption chiller 100 kW/CH S	18

Energy for on campus refrigeration is responsible for 3.67 kg CO_2 equivalent, 0.01 kg benzene equivalent, and 4.55 kg 2,4-D equivalent (Table 5-9).

Materials

Table 5-4: Material impact from collection and preparation: aluminum trays and refrigeration at Wellesley

Category	Material or process	Mass (kg) per one metric ton food
Equip. mfg.	Hot rolled sheet, steel, at plant/RNA	0.092
Equip. mfg.	Polyurethane, flexible foam, at plant/RER S	0.0182
Equip. mfg.	Foaming, expanding/RER S	0.0182
Equip. mfg.	Zinc, sheet/GLO	0.0024
Equip. mfg.	Refrigerant R134a, at plant/RER S	0.00046
Equip. mfg.	Copper tube, technology mix, consumption mix, at plant, diameter 15 mm, 1 mm thickness EU-15 S	0.0018
Equip. mfg.	Aluminium sheet, primary prod., prod. mix, aluminium semi-finished sheet product RER S	0.0001
Equip. mfg.	Sheet rolling, aluminium/RER S	0.0001
Equip. mfg.	Electronics for control units/RER S	0.0008
Equip. mfg.	Acrylonitrile-butadiene-styrene copolymer, ABS, at plant/RER S	0.00026
Collection	Aluminium, secondary, from new scrap, at plant/RER S	30.4
Collection	Sheet rolling, aluminium/RER S	30.4
Collection	Corrugated board, mixed fibre, single wall, at plant/RER S	1.6

Note that material impacts of refrigeration are analyzed under the "equipment manufacture" category in section 5.3.5, while the aluminum trays are analyzed under "collection containers." Material inputs for refrigeration are responsible for 0.39 kg CO2 equivalent, 0.01 kg benzene equivalent, and 0.60 kg 2,4-D equivalent (Table 5-9).

Transportation of Food Waste

We assume no transportation by Wellesley vehicles on campus; food would be picked up from each dining hall rather than taken to a central pickup location.[33] Note that the earlier calculation of two gallons of gasoline required to transport one metric ton of food to the shelter is not explicitly included in the Life Cycle Assessment calculations. Instead, we chose a van that approximates the Ford van's size and gas mileage. The impact is calculated based on the number of metric ton kilometers of travel by this van. One metric ton of food is responsible for 52 kilometers round-trip of travel, for a total of 52 ton-kilometers (Table 5-5).

Table 5-5: Transportation to an off campus facility

Vehicle	Metric ton kilometers (tkm) per one metric ton food
Operation, van < 3,5t CH/S	52

The transportation of waste is responsible 99.35 kg CO2 equivalent, 0.32 kg benzene equivalent, and 147.08 kg 2,4-D equivalent (Table 5-9).

5.3.2 Process

Table 5-6 and Table 5-7 show the materials and energy use of the oven and refrigerator at the shelter that can be attributed to one metric ton of food.

Materials

Table 5-6: Material impact from donation to people: shelter's refrigerator and oven

Material or process	Mass (kg) per one metric ton food
Hot rolled sheet, steel, at plant/RNA	0.092
Polyurethane, flexible foam, at plant/RER S	0.0182
Foaming, expanding/RER S	0.0182
Zinc, sheet/GLO	0.0024
Refrigerant R134a, at plant/RER S	0.00046
Copper tube, technology mix, consumption mix, at plant, diameter 15 mm, 1 mm thickness EU-15 S	0.0018
Aluminium sheet, recycled scrap, aluminium semi-finished sheet product RER S	0.0001
Sheet rolling, aluminium/RER S	0.0001
Electronics for control units/RER S	0.0008
Acrylonitrile-butadiene-styrene copolymer, ABS, at plant/RER S	0.00026
Hot rolled sheet, steel, at plant/RNA	0.061
Flat glass, uncoated, at plant/RER S	0.0009
Electronics for control units/RER S	0.0009

[33] Patrick Willoughby, Director of Sustainability at Wellesley College. Class discussion. March 6, 2013.

Note that all of these materials are analyzed together under the "equipment manufacture" category in section 5.3.5, along with the refrigerator at Wellesley.

The materials inputs for the refrigerator and oven at the shelter are responsible for 0.56 kg CO2 equivalent, 0.01 kg benzene equivalent, and 1.12 kg 2,4-D equivalent (Table 5-9).

Energy

Table 5-7: Energy for donation to people: refrigeration and oven use at the shelter

Component	Energy source	Energy (kWh) per 1 metric ton food
Refrigerator	Electricity, at grid, Eastern US/US	18
Oven	Electricity, at grid, Eastern US/US	61

The energy required for refrigerating and heating the food at the shelter is responsible for 64.23 kg CO2 equivalent, 0.05 kg benzene equivalent, and 2.10 kg 2,4-D equivalent (Table 5-9).

5.3.3 Avoided Impacts

We assumed that half of the food donated to shelters would offset food purchases that would otherwise have been purchased by the shelter. With food donations, the offset food would not be cooked at the shelter and the energy inputs associated with cooking could be subtracted from the total environmental impacts.

We modeled the 500 kg of offset food as 166 kg each of bread, chicken, and tomatoes (Table 5-8). We assumed that the frozen chicken would be cooked for one hour in the oven. The tomatoes are modeled as being cooked for an average of half an hour in the oven, as they are sometimes served fresh and sometimes cooked as sauce. It is assumed that the capacity of an oven is about six kilograms of food,[34] so the oven would run for 41.5 hours to cook the chicken and tomatoes. As with the estimate for reheating food, the oven consumes two kWh of electricity per hour of run-time.[35] The food donation therefore offsets 83 kWh of electricity.

Table 5-8: Avoided impacts of donation to people

Material or process	Avoided mass (kg) per 1 metric ton food	Avoided energy (kWh) per 1 metric ton food
Chicken, frozen, whole sale	166	--
Tomato, standard	166	--
Bread, wheat, fresh, whole sale	166	--
Electricity, at grid, Eastern US/US	--	83

Offsetting food purchases by the shelter is responsible for avoided impacts of 1310 kg CO2 equivalent, 0.26 kg benzene equivalent, and 41.90 kg 2,4-D equivalent (Table 5-9).

[34] Earlier, we estimated that an oven would hold four aluminum trays, equivalent to about six kg of food.
[35] Macavinta, Courtney. "Range Buying Guide: How Much Energy Does the Average Range / Oven Use?" CNET, managed by CBS Interactive, Inc. Accessed March 24, 2013. http://reviews.cnet.com/4520-17895_7-6882870-6.html.

5.3.4 Water Use

No water use is associated with donation to people. The aluminum trays used to transport food are disposable, and do not require washing.

5.3.5 Summary: Life Cycle Impacts and Assessment of Donation to People

Table 5-9: Environmental impact by process stage, donation to people

Impact category	Unit	Collection	Energy on campus	Transport	Energy off campus	Equipment	Avoided	**Total**
Climate change	kg CO2 eq.	116.28	3.67	14.90	64.23	0.95	-1310.6	**-1194.40**
Human toxicity	kg benzene eq.	6.58	0.01	0.00	0.05	0.01	-0.26	**0.55**
Ecosystem toxicity	kg 2,4-D eq.	489.70	4.55	2.95	2.10	1.72	-41.90	**599.09**

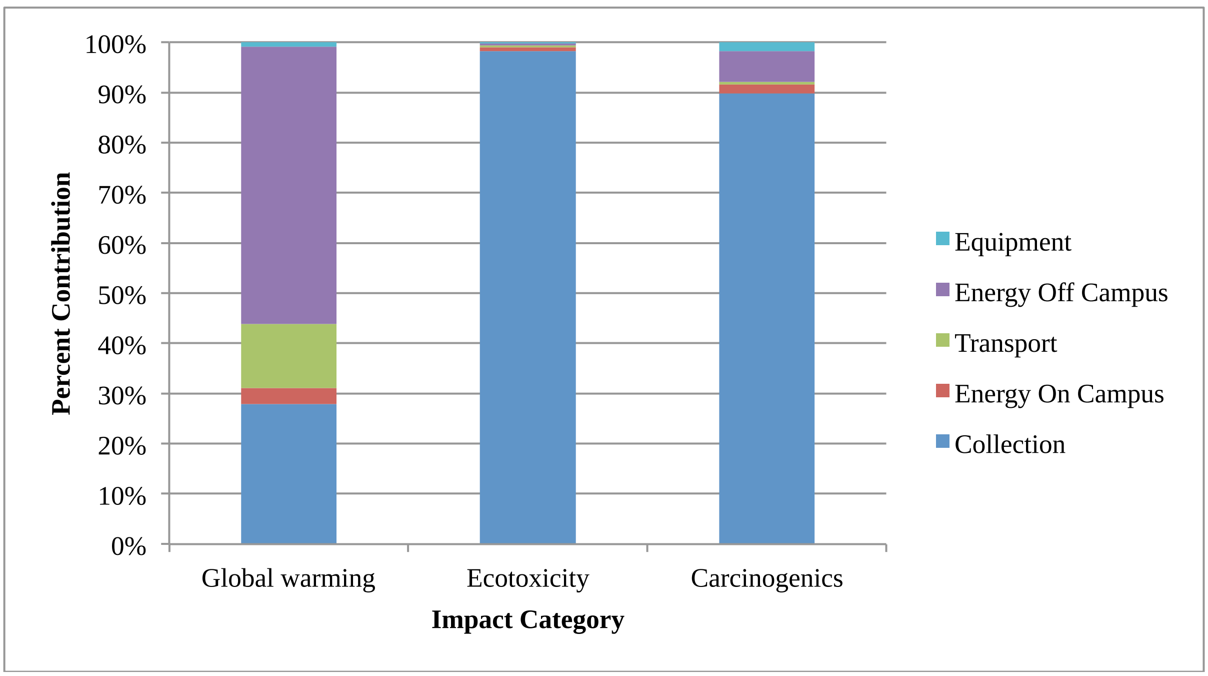

Figure 5-1: Percent contribution of process stages to each impact category, donation to people

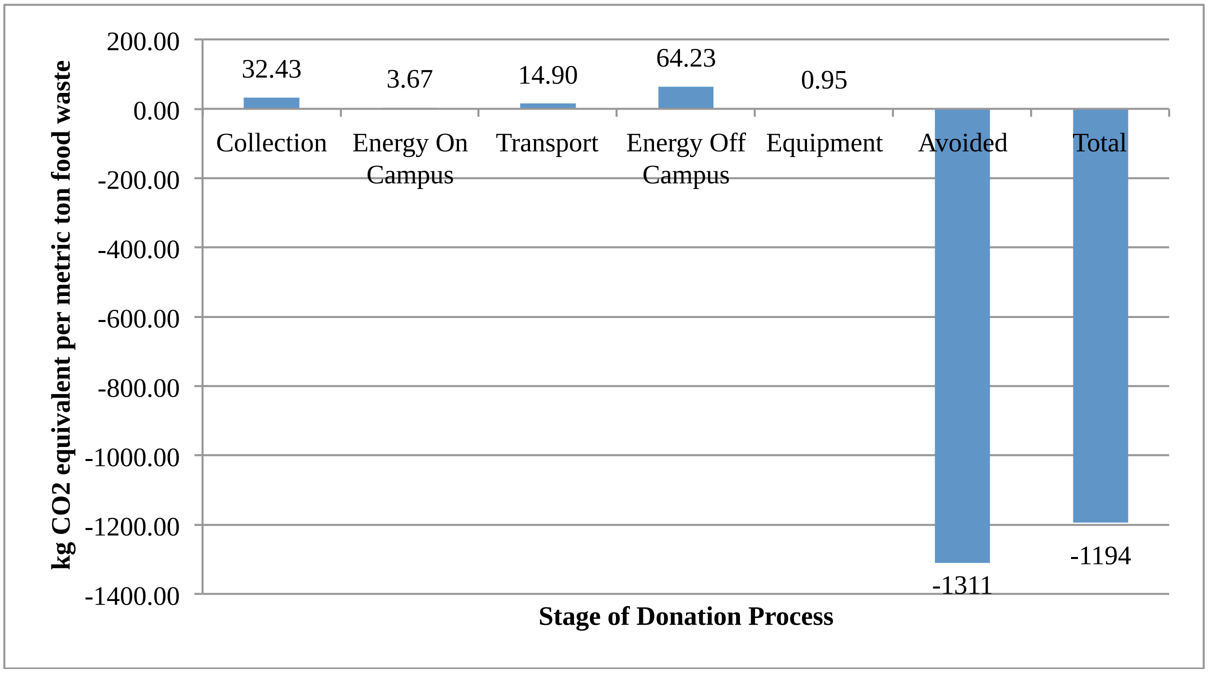

Figure 5-2: Climate change impact of each process stage, donation to people

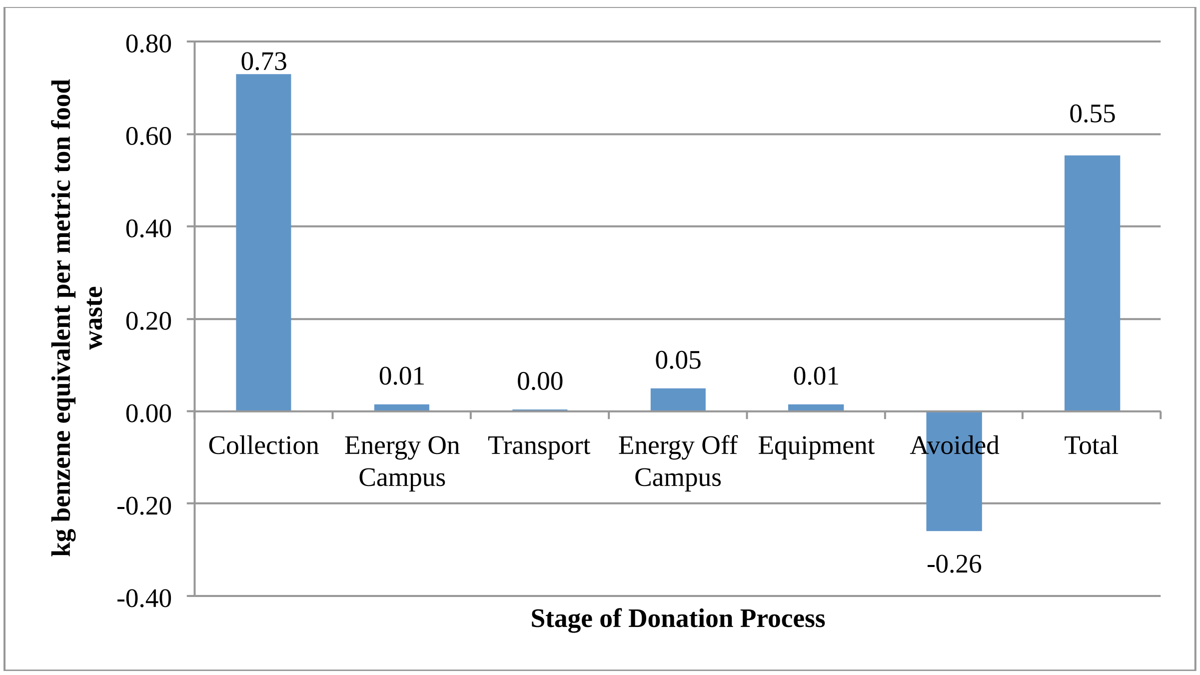

Figure 5-3: Human toxicity impact of each process stage, donation to people

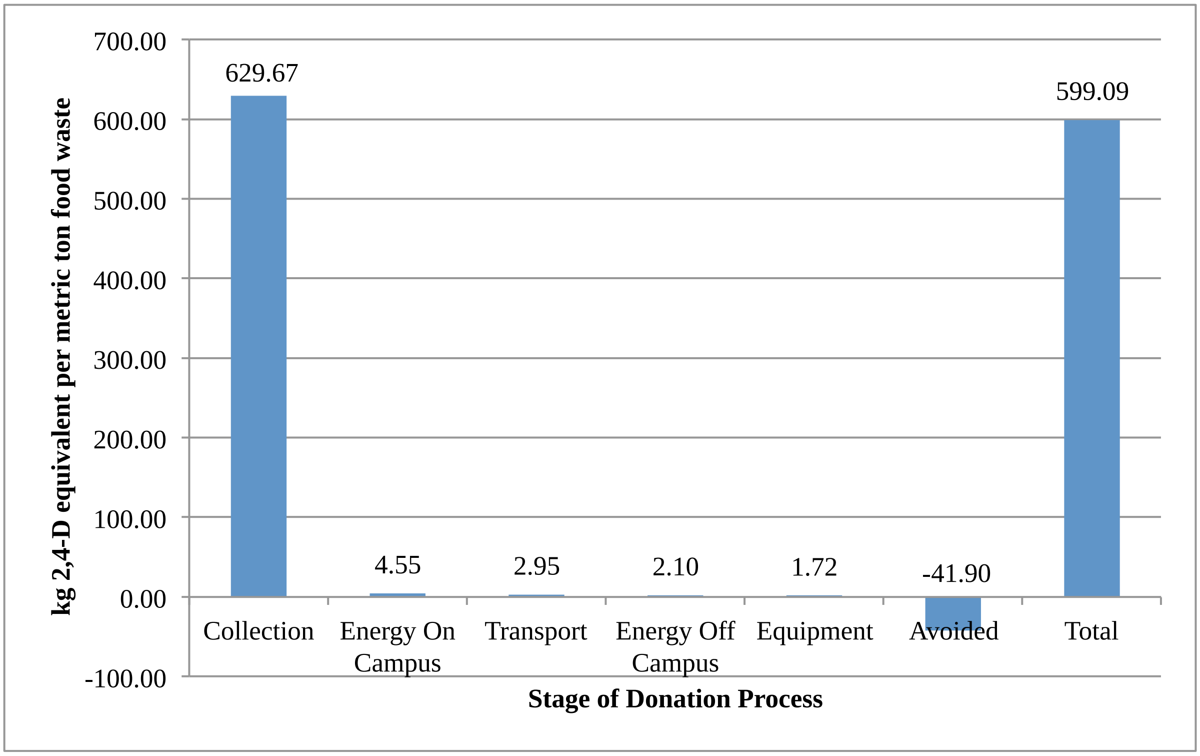

Figure 5-4: Ecosystem toxicity impact of each process stage, donation to people

Figure 5-1 and Table 5-9 show the contribution of each process stage to the total impact of donation to people. Most of the contribution to climate change is attributed to the energy used by the refrigerator and oven at the shelter, though these impacts are dwarfed by the avoided impact of food bought by the shelter (Figure 5-2). Conventionally produced food is energy intensive; the 4.4 metric tons of CO_2 avoided through donating food for one academic year is equivalent to the CO_2 produced by burning 485 gallons of gasoline.[36]

This positive environmental impact in terms of climate change, though, is outweighed by high levels of ecotoxicity and carcinogens. The vast majority of each impact comes from the aluminum trays used to store and transport food to the shelter (Figure 5-3, Figure 5-4), specifically the sheet rolling process used to create the trays. An investment in heavier-duty reusable containers, brought to the shelter and returned to Wellesley when empty, has the potential to greatly reduce this impact long-term. Although they would require washing, which consumes hot water, soap and employee time, reusable containers would likely be the more environmentally sound choice. Lovin' Spoonfuls does not accept donations in reusable trays,[37] so if the relatively high ecosystem toxicity and human toxicity are barriers to implementation, the College can investigate other food recovery organizations and shelters. Metro West Harvest, for instance, takes reusable coolers of food from the College Club and replaces them with empty coolers;[38] it is unclear whether this method would still be feasible if scaled to the whole College.

[36] Assuming 20 pounds CO2 produced per gallon of gasoline burned. Statistic from U.S. Energy Information Administration, "Frequently asked questions: how much carbon dioxide is produced by burning gasoline and diesel fuel?" (accessed 24 March 2013).
[37] "Food Donation Guidelines," 2013.
[38] Roche, 2013.

5.4 Costs of Donation to People

5.4.1 Direct Cost

Tipping Fees
Donating food to people in the Greater Boston Area would not have any associated tipping fees since the College would not be paying an organization or facility to take the food waste. We would be working with an organization such as Lovin' Spoonfuls where pick-up of food donations is free of charge.

Trucking Fees
There is also no transportation cost associated with donation to people, as food donations would be picked up for no cost.

5.4.2 Operational Cost

Transportation Cost
A partnership with Lovin' Spoonfuls or a similar organization would entail no transportation costs, as the organization would pick up the food from all five dining halls.

Labor costs
Dining hall staff at the College would only need to place excess food into containers and place the containers in the refrigerator. These steps would not require significantly more time than the time it takes to put this food in the trash or disposal. No additional employees would be necessary.

Energy costs
Donating food to people will require extra refrigeration. Although the refrigerators used for storage may already be in use for other supplies, the food donated would increase the energy used by the refrigerators. Each metric ton of food would require 18 kWh of energy on campus and each kWh of electrical energy costs the College $0.11. Thus, each metric ton of food donated would cost the College $1.98 in electricity.

5.4.3 Equipment

Food donation would require the purchase of disposable aluminum trays for storing and transporting the food. Based on the volume that each tray holds, we found that for every metric ton of food, we would need to purchase approximately 733 trays. [39] At a cost of $0.48 per tray (wholesale), this would total $351.84 per metric ton of food.[40]

5.4.4 Offset Cost

[39] See estimate in section 2.3.2.
[40] PacToGo. "3 lb. Oblong Entrée Take-Out Foil Pan w/Board Lid Combo Pack 250/CS." Accessed March 24, 2013. http://www.pactogo.com/3-lb-oblong-foil-pan-with-board-lid-combo-pack-250-cs.html.

If 15% of food waste could be donated to people, then Wellesley College would not have to pay for this waste to be composted by another method.

5.4.5 Summary: Cost of Donation to People

Assuming that the food recovery organization can pick the food up from each of the five dining halls, there would be no costs aside from operating the refrigerator and buying the disposable trays.

Table 5-10: Cost of donation to people per metric ton of food waste

Cost Category		**Amount ($ / metric ton)**
Direct:		
	Facilities	$0.00
	Transportation	$0.00
Operational:		
	Transportation	$0.00
	Labor	$0.00
	Other (Energy)	$1.98
Equipment		$351.48
Offset costs		$0.00
Total Cost		$353.82

Purchasing the aluminum trays would be the largest direct financial cost involved in donating food to people. The College could reduce this cost by utilizing reusable containers instead of disposable aluminum ones, but would have to find a different food recovery organization, as Lovin' Spoonfuls cannot return containers.[41] We think that aluminum trays would be preferable for their convenience and relatively low cost, but the College can investigate alternatives such as plastic trays to determine the lowest-cost option.

[41] "Food Donation Guidelines, 2013."

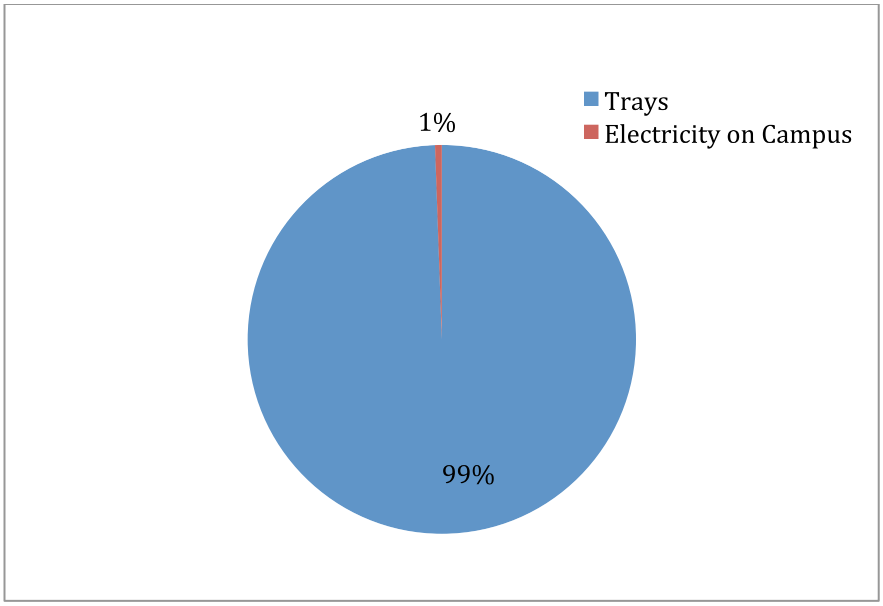

Figure 5-5: Cost of donation to people

5.5 Social Impacts of Donation to People

5.5.1 Campus Experience - Neutral

Donating excess food from Wellesley College to hungry people in the Greater Boston Area would not greatly enhance the overall experience of students and staff on campus. That said, the College's positive engagement with an organization that serves disadvantaged people is something everyone on campus could be proud of. Campus-wide publicity of the food donation program would raise awareness on campus and reflect the generosity of the College.

5.5.2 Educational Benefit - Neutral

While the College's participation in a food donation program would be publicized on campus, students would not be directly engaged in the donation process. Therefore, this method would lack educational opportunities. While we have not explored the possibilities of engaging the student body in the process, it is possible that the donation program could be the subject of various student reports and projects and could give students an opportunity to research public health and social justice efforts on campus and in the Greater Boston Area.

5.5.3 Implementation Difficulty

Separation - High
Donating food to people would require dining hall staff to separate and package pre-consumer food that is healthy and safe to eat. It will likely take time for dining hall staff to learn to intuitively identify food that is fit for donation.

Permitting and Regulations - Low

Donation to people would not require any permits as the food is simply taken off campus to be distributed. No campus facilities, aside from the refrigerator, would be used to prepare or use the food in any additional way.

Time until Implementation - Low
Partnering with a food recovery organization such as Lovin' Spoonfuls would allow for donation to begin almost immediately after approval from the administration.

Risk - Medium
Donating food to people would be mildly risky. There is a low probability that food would be contaminated, given proper training of dining hall staff to recognize good food to donate. The food that is donated would be expected to be up to the same standard as it would be when served to Wellesley students. Despite the best precautions, there is always a small chance that contaminated food from Wellesley could reach a shelter off campus. While the College would be protected by the Bill Emerson Act, the College could receive negative publicity and may be forced to abandon the program if illness resulted from a donation from Wellesley.

5.5.4 Social Justice - Positive

Donating Wellesley's excess food to people in the Greater Boston Area is one way Wellesley College can advocate for social justice in our community. Hunger and poverty are not absent in this area and by helping to distribute our food resources to those in need, we would be creating a more equitable and just society.

5.5.5 Summary: Social Impacts of Donation to People

Table 5-11: Social impacts of donation to people

Social Impact		Score
Campus experience		Neutral
Educational benefit		Neutral
Difficulty:		
	Separation	High
	Permitting and regulations	Low
	Time until implementation	Low
	Risk	Medium
Social justice		Positive

The lack of educational opportunities and the risk associated with donating food to people off-campus are the biggest downsides to this method. Educational opportunities could be increased if the program were to include student participation, but given the identified organization we would be working with there is not much room for student involvement. However, increasing transparency and publicity of the program may inspire students to write about or conduct research on the donation partnership and process. The risk of donating contaminated food is minimal, with adequate staff training and inspection of food items that are donated. Ensuring that the College is abiding by food safety measures throughout the preparation process would also be necessary.

The positive contribution of food donation to social justice would make this method desirable. Hunger is an issue in the Greater Boston Area and distributing thousands of pounds of good food to those in need is the morally right use of food that is still perfectly edible.

5.6 Conclusions

Sending as much edible, healthy, pre-consumer food as possible to a food recovery organization such as Lovin' Spoonfuls would have a number of advantages. Food donation would improve food security in the Greater Boston Area and possibly offset the purchase of foods with a higher environmental impact, also resulting in economic savings for the shelters. If the College would choose to work with a food organization that accepted the use of reusable food containers, the cost and environmental impact would both drop significantly, making donation to people an attractive choice from environmental, financial, and social justice angles.

The only major difficulty with this method of waste diversion would be in training dining hall staff to recognize which foods are suitable for donation and how to package them properly. Once this action becomes ingrained in the dining hall culture, a successful donation program could be a blessing for both the people receiving food and for the College's waste diversion goals.

We recognize that donating food to people would not be able to divert enough food on its own to meet the requirements of the Organic Waste Ban, but would complement another, more comprehensive composting method. With a team of well-trained, motivated dining hall staff, donating food to people would be a win-win method for diverting food waste at Wellesley.

6.0 Donation to Pigs

6.1 Introduction to Donation to Pigs

Donating food waste to local pig farms provides a nutritious source of food for animals. This method will benefit local businesses, while diminishing Wellesley College's food waste output. The creation of a campus-wide donation system would positively affect students' perception of the potential of food waste. Productive use can be made of much of the excess food that we discard, starting with feeding the hungry. Food donation to animals can be thought of as the second step in the food waste hierarchy; feed people first, then animals, and finally compost.[1]

The Wellesley College Club already donates some of its leftover food to a pig owned by a local community resident.[2] Wellesley College explored the option of donating food waste to a pig farm during the composting pilot project in Bates dining hall, but experienced difficulty when a load of waste was rejected from a pig farm due to a higher-than-acceptable level of compostable dishware, which the pigs cannot digest.[3]

Donating food to a pig farm requires collecting the food, filtering out coffee grounds and excessively salty foods, and then boiling – if meat products are present – to prevent the transmission of diseases to the pigs.[4] It is then transported to a pig farm, and fed to the pigs. Alternatively, food waste can be transported without treatment to the pig farm, which will process (boil) the food waste on site before feeding it to the pigs. Transportation costs would need to be considered, but tipping fees should be negligible, as most pig farms accept food donations at no cost.[5]

6.2 Implementing Donation to Pigs at Wellesley College

6.2.1 Overview of Implementation at Wellesley

We estimate that donation to pigs would be able to divert 100% of Wellesley College's food waste. The preferred dietary sodium requirement of a juvenile swine is 0.25% of the daily feed weight; as they grow to maturity, their need falls to 0.10%.[6] Based on the nutritional data provided by AVI Fresh (which is provided solely for the heated and prepared food), 47% of prepared foods contain 0.20% sodium (out of the total mass) or less; 53% contains 0.21% or more.[7] 0.20% was chosen as a marker that falls between the tolerance of adult and juvenile swine. The average sodium content of all the prepared foods is 0.27%; however, when prepared

[1] EPA. "Food Reduction Hierarchy." Accessed March 1, 2013. http://www.epa.gov/smm/foodrecovery/.
[2] Mark Roche, General Manager of the College Club. Interviewed by Audrey Mutschlecner. March 14, 2013.
[3] Patrick Willoughby, Wellesley College Director of Sustainability. Class Interview by ES 300. March 6, 2013.
[4] EPA. "Feed Animals." Accessed January 8, 2013. http://www.epa.gov/foodrecovery/fd-animals.htm.
[5] MassDEP. "Reducing Food Waste." Accessed March 26, 2013. http://www.mass.gov/dep/recycle/reduce/reducefw.pdf.
[6] Merck Veterinary Manual. "Nutritional Requirement of Pigs." Accessed March 1, 2013. http://www.merckmanuals.com/vet/management_and_nutrition/nutrition_pigs/nutritional_requirements_of_pigs.html.
[7] AVI Fresh. "Nutritional Guide" Available in print in all dining facilities.

foods are combined with scraps and vegetables, the average sodium content decreases. A representative selection of vegetables has a sodium content of 0.02% of the total mass. When the prepared food is combined with the unprepared food, the average sodium content is reduced to 0.21% of the total food waste mass. Not only is this figure within the ideal range of sodium content, it is an order of magnitude less than the oral lethal dose of sodium for swine, which is 2.2% of sodium per total mass.[8]

If implemented at Wellesley, food waste would be collected at each dining hall daily. The waste would be collected in standard five-gallon buckets, which would be stored in the dining hall's walk-in refrigerator. After collection, food waste would be transported to a nearby pig farm. Many nearby pig farms treat the food waste on site, eliminating Wellesley's need to do so prior to transportation.[9]

There are several pig farms in close proximity that could be used. Brambly Farms in Norfolk, MA, is twelve miles from campus; the farm raises and sells heritage pigs, as well as a small variety of other animals.[10] Drumlin Farm in Lincoln, MA is only eleven miles away and is notable because it also offers several community education programs.[11] Starretts Farm, in Mendon, MA, is twenty miles away and is known to regularly receive food donations from larger institutions.[12] Additional possibilities include Krochmal Farms (Tewksbury, MA, 32 miles from the College),[13] Martin Brothers Farm (Auburn, MA, 35 miles),[14] and Blash's Pig Farm (34 miles).[15] Meat products may have to be separated, depending on how the facility pre-treats the food before using it as feed. As many options seem to be at least a half-hour drive from campus, transportation time and fuel cost would be important considerations. Starretts Farm will be used as the representative farm in the calculations for pig donations, because it is listed by the MassDEP as a licensed food waste accepter, and is located close to the College.

There are at least two options regarding transportation. The College could hire a private transportation company, or use vehicles and personnel already employed by the College. The convenience and ease of hiring a private trucking company may in fact be preferable. Wellesley could use EOMS, a trucking company that we already work with, for the cost of $45 per metric ton.[16] Given Wellesley College's pre-existing relationship with EOMS, we will use this option in our calculations.

6.2.2 Technology/Equipment

[8] Merck Veterinary Manual. "Overview of Salt Toxicity." Accessed March 1, 2013. http://www.merckmanuals.com/vet/toxicology/salt_toxicity/overview_of_salt_toxicity.html.
[9] MassDEP. "Reducing Food Waste." Accessed March 26, 2013. http://www.mass.gov/dep/recycle/reduce/reducefw.pdf.
[10] "Brambly Farms." Accessed March 1, 2013. http://www.bramblyfarms.com/.
[11] MassAudubon. "Drumlin Farm Wildlife Sactuary." Accessed March, 1, 2013. http://www.massaudubon.org/Nature_Connection/Sanctuaries/Drumlin_Farm/index.php.
[12] MassDEP. "Reducing Food Waste." Accessed March 26, 2013. http://www.mass.gov/dep/recycle/reduce/reducefw.pdf.
[13] "Krochmal Farms." Accessed March 1, 2013. http://www.krochmalfarms.com/.
[14] "Martin Brothers Farm." Accessed March 1, 2013. http://www.manta.com/c/mm2m09s/martin-brothers-farm.
[15] "Blash's Pig Far." Accessed March 1, 2013. http://www.manta.com/c/mtv230b/blash-s-pig-farm.
[16] Patrick Willoughby, Wellesley College Director of Sustainability. Class Interview by ES 300. March 6, 2013.

We assume that the pig farm would employ a machine or fire-pit system to boil the food waste prior to feeding it to the pigs. As the boiling process takes place off campus, the College would have no need to purchase technology or equipment.

6.2.3 Inputs

Energy
The energy inputs required for this method stem from on-campus refrigeration prior to transportation, and off-campus boiling of food waste prior to its consumption by the pigs.

Cooling one metric ton of food at Wellesley would be responsible for approximately 18 kWh of electricity consumption, assumed to come exclusively from the cogeneration plant on campus.[17] A commercial walk-in refrigerator at Wellesley is modeled as 10 cubic meters, able to hold a maximum of about 600 liters, therefore 0.6 metric tons, of food.[18] A refrigerator of this size consumes 660 kWh of electricity per month,[19] the equivalent of 21.7 kWh per day. Assuming a morning pick-up, energy would be spent refrigerating the donated food for an average of 12 hours at the College.[20] The energy to keep one metric ton of food cool for 12 hours is assumed to be equal to that needed to keep 0.5 metric ton of food cool for 24 hours.[21]

According to examples from existing pig farms, we assume that the food is boiled in a cast iron pot, heated by burning wood.[22] Bringing one kilogram of water to boiling requires roughly one kilogram of wood, and sustaining that boiling for one hour requires another kg of wood.[23] Three metric tons of wood would be required to provide the energy to boil one metric ton of food, mixed with 0.5 metric tons of water, for one hour.

Materials
Our analysis accounts for the materials in the on-campus refrigerator and off-campus boiler, scaled down to reflect the contribution of one metric ton of food. Five-gallon polyethylene buckets would be another material needed, but were not included in the SimaPro calculation due to their classification as assumed bins.

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[17] Class decision after discussion with Patrick Willoughby, 6 March 2013.
[18] Assuming a three foot wide walkway in the center, a maximum of 2/3 of the refrigerator could be full.
[19] U.S. Cooler Company. "Operating costs for walk-in coolers and freezers." Accessed March 1, 2013. http://blog.uscooler.com/operating-cost-walkin-cooler-freezer/#more-666.
[20] Assuming approximately 3/8 of food served throughout the day is from lunch, is cleaned up at 2 p.m., and must be refrigerated for 19 hours; 3/8 is from dinner, is cleaned up at 9 p.m., and must be refrigerated for 13 hours; and 1/4 is from breakfast and does not need to be refrigerated before pickup. These assumptions lead to an average of 12 hours refrigeration time for the food.
[21] Cooling hot food to refrigerator temperatures takes more energy than maintaining a cold temperature, so the relationship is not truly linear. For the purposes of this approximation, linearity is a reasonable assumption. 21.7 kWh / day / 0.6 metric tons = 18 kWh / 0.5 day / 1 metric ton.
[22] Winona Farm. "Food Waste Recycling." Accessed March 26, 2013. http://www.thefarm.winona-mn.us/foodwaste.htm.
[23] World Health Organization. "Water Sanitation Health." Accessed March 26, 2013. http://www.who.int/water_sanitation_health/dwq/wsh0207/en/index4.html.

Walk-in refrigerators have a life span of approximately ten years.[24] One metric ton of food waste cooled for 12 hours was shown to occupy the equivalent of 83% of one refrigerator's capacity for one day. One metric ton of food waste is therefore responsible for 0.02% of the material impact of one refrigerator. As refrigerators in two locations are utilized, the material impact attributed to refrigeration is the equivalent of 0.04% of the material impact of one refrigerator over its lifetime.[25] The materials inventory for the refrigerator was based on a refrigerator from the Kolpak company,[26] adapted from a Life Cycle Assessment completed by a Wellesley student in December 2012.[27]

In order to calculate the percent of the boiling equipment materials that can be attributed to the preparation of one metric ton of Wellesley's food waste, we assume that the cast iron pot and outer fire container weighed a total of 320 kg[28] and had a lifetime of 100 years.[29] Assuming that pigs eat approximately two kg of food per day,[30] and that a representative pig farm might have 100 pigs, then 0.014% of the cast iron materials can be attributed to the preparation of one metric ton of Wellesley's food waste.[31]

6.2.4 Outputs

In order to account for offsets in animal feed, we assume that the animal feed being replaced by the food waste is 33% water, so one metric ton of food waste replaces 666 metric tons of dry animal feed.

6.3 Environmental Impacts of Donation to Pigs

6.3.1 Collection and Preparation of Food Waste

The following tables represent the inputs into SimaPro software for each stage of the process and its associated impacts.

Energy

Energy for on-campus refrigeration is responsible for 3.67 kg CO2 equivalent, 0.01 kg benzene equivalent, and 4.55 kg 2,4-D equivalent (Table 6-1).

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[24] "Preliminary CASE Report: Analysis of Standards Options for Walk-In Refrigeration." Southern California Edison Utilities Company. January 31, 2008.
[25] 1 / [10 years * 365 days / year] * 83% capacity * 2 refrigerators = 0.04% of material impact of 1 refrigerator.
[26] Food Service Warehouse. "Kolpak (PX7-068-CT) - 5'10" Prefab Cooler (floorless) - Polar-Pak." Accessed October 30, 2012. http://www.foodservicewarehouse.com/kolpak/px7-068-ct/p347959.aspx.
[27] Carly Gayle. "Environmental Impact Assessment of the Medway Passive Refrigerator." Presented at the Engineering Sustainability 2013 Conference. April 8, 2013, Pittsburgh, PA. Unpublished as of May 2013.
[28] "Cast Iron." Accessed March 26, 2013. http://www.asianexports.cn/Cast-Iron-Cooking-Cauldrons/Jambalaya-Pot-Large/prod_282.html.
[29] "Cast Iron Pans." Accessed 26 March 2013. http://whatscookingamerica.net/Information/CastIronPans.htm
[30] "How much does a pig eat?" Accessed March 1, 2013. http://books.google.com/books?id=pDCzSe0TBIUC&pg=PA34&lpg=PA34&dq=how+much+does+a+pig+eat+per+day&source=bl&ots=eqYEVyZm5X&sig=cG-9LKgkQMJgFWfmCgiA2JgR55w&hl=en&sa=X&ei=uA5RUaixCKnl0gGitoDYAQ&ved=0CGgQ6AEwBg#v=onepage&q=how%20much%20does%20a%20pig%20eat%20per%20day&f=false.
[31] 200 kg per day * 365 days per year * 100 years = 7,300,000 kg of food boiled over the lifetime of the pot. 1000 kg / 7,300,000 kg = 0.00014.

Table 6-1: Energy from collection and preparation, donation to pigs

Energy source	Energy per one metric ton food (kWh)
Cooling energy, natural gas, at cogeneration unit with absorption chiller 100 kW/CH S	18

Materials
Material inputs for the refrigerator are responsible for 0.39 kg CO2 equivalent, 0.01 kg benzene equivalent, and 0.60 kg 2,4-D equivalent (Table 6-2).

Table 6-2: Material impact from collection and preparation, donation to pigs

Category	Material or process	Mass (kg) per one metric ton food
Equip. mfg.	Hot rolled sheet, steel, at plant/RNA	0.092
Equip. mfg.	Polyurethane, flexible foam, at plant/RER S	0.0182
Equip. mfg.	Foaming, expanding/RER S	0.0182
Equip. mfg.	Zinc, sheet/GLO	0.0024
Equip. mfg.	Refrigerant R134a, at plant/RER S	0.00046
Equip. mfg.	Copper tube, technology mix, consumption mix, at plant, diameter 15 mm, 1 mm thickness EU-15 S	0.0018
Equip. mfg.	Aluminum sheet, primary prod. mix, aluminum semi-finished sheet product RER S	0.0001
Equip. mfg.	Sheet rolling, aluminum/RER S	0.0001
Equip. mfg.	Electronics for control units/RER S	0.0008
Equip. mfg.	Acrylonitrile-butadiene-styrene copolymer, ABS, at plant/RER S	0.00026

Transportation of Food Waste
We assume that the trucking company would pick up from each dining hall, so no on-campus transportation would be required.[32] The off-campus transportation of food waste would be

[32] Patrick Willoughby, Wellesley College Director of Sustainability. Class Interview by ES 300. March 6, 2013.

responsible for 9.55 kg CO_2 equivalent, 0.01 kg benzene equivalent, and 0.04 kg 2,4-D equivalent (Table 6-3).

Table 6-3: Transportation to an off-campus facility, donation to pigs

Vehicle	Metric ton kilometers (tkm) per one metric ton food
Small lorry transport, 7,5 t total weight 3,3 t max payload RER S	70

6.3.2 Process

Materials
The material inputs for the boiler at the farm are responsible for 0.07 kg CO_2 equivalent, 0.01 kg benzene equivalent, and 0.24 kg 2,4-D equivalent (Table 6-4).

Table 6-4: Material impact from the composting process: food boiler at the pig farm

Boiler	Mass (kg) attributed to 1 metric ton food
Cast iron, at plant/RER S - 0.044 kg	0.045

Energy
The energy required for boiling the compost at the farm is responsible for 13.41 kg CO_2 equivalent, 1.70 kg benzene equivalent, and 3.53 kg 2,4-D equivalent (Table 6-5).

Table 6-5: Energy from composting process: boiling at the farm

Component	Energy source	Mass (kg) per 1 metric ton food
Boiler	Wood waste, unspecified, combusted in industrial boiler/US	3000

6.3.3 Avoided Impacts

We assume that one metric ton of food donated to the pig farm would offset the purchase of 666 kg (dry weight) of standard animal feed (Table 6-6). Offsetting the purchase of one metric ton of pig feed is responsible for avoided impacts of 1145 kg CO_2 equivalent, 0 kg benzene equivalent, and 0.1 kg 2,4-D equivalent.

Table 6-6: Avoided impacts of pig feed purchases

Component	Avoided mass (kg) per one metric ton food
25 Animal feeds, EU27	666

6.3.4 Water Use

The water usage of the donation to pigs method is estimated to be a half-liter per kilogram of food waste, a total of 500 liters per metric ton. Its use is solely for the purpose of boiling food waste prior to its consumption by the pigs.

6.3.5 Summary: Life Cycle Impacts and Assessment of Donation to Pigs

Table 6-7: Environmental impact by process stage per metric ton of food waste. Total includes avoided impacts.

Impact category	Unit	Energy on campus	Transport	Energy off campus	Equipment	Avoided	**Total**
Climate change	kg CO2 eq.	3.67	9.55	13.41	0.46	-1145	**-1117**
Human toxicity	kg benzene eq.	0.01	0.01	1.70	0.02	0	**1.74**
Ecosystem toxicity	kg 2,4-D eq.	4.55	0.04	3.53	0.84	-0.1	**8.86**

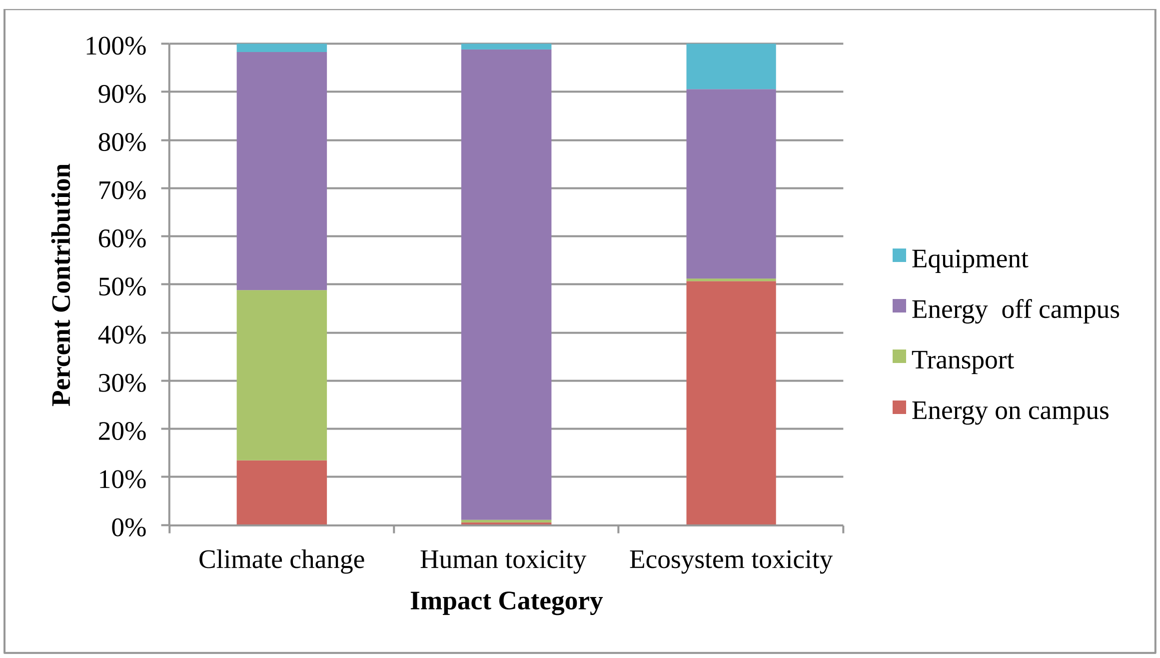

Figure 6-1: Percent contribution of process stages to each impact category, donation to pigs

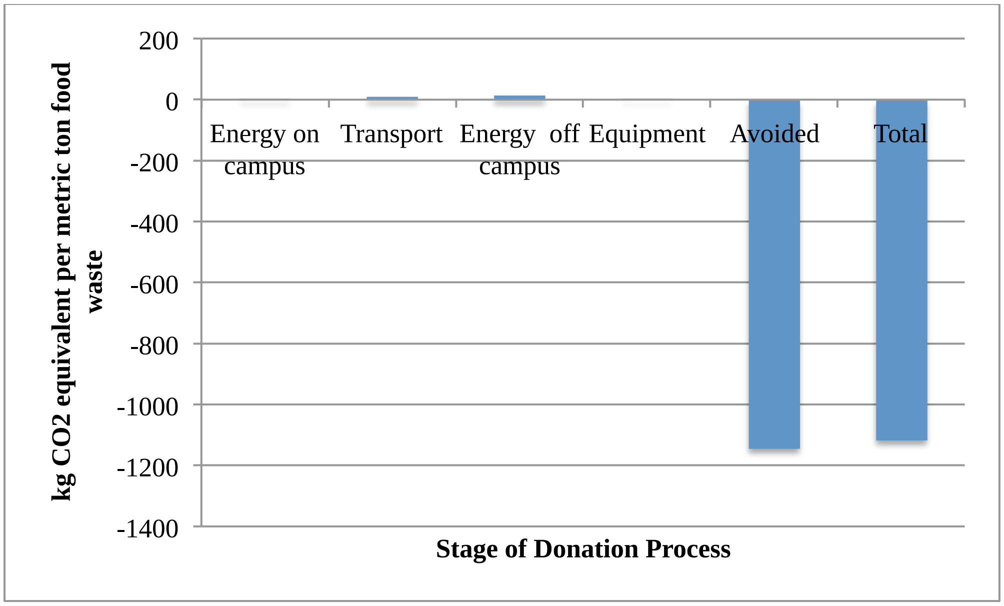

Figure 6-2: Climate change impact of each process stage, donation to pigs

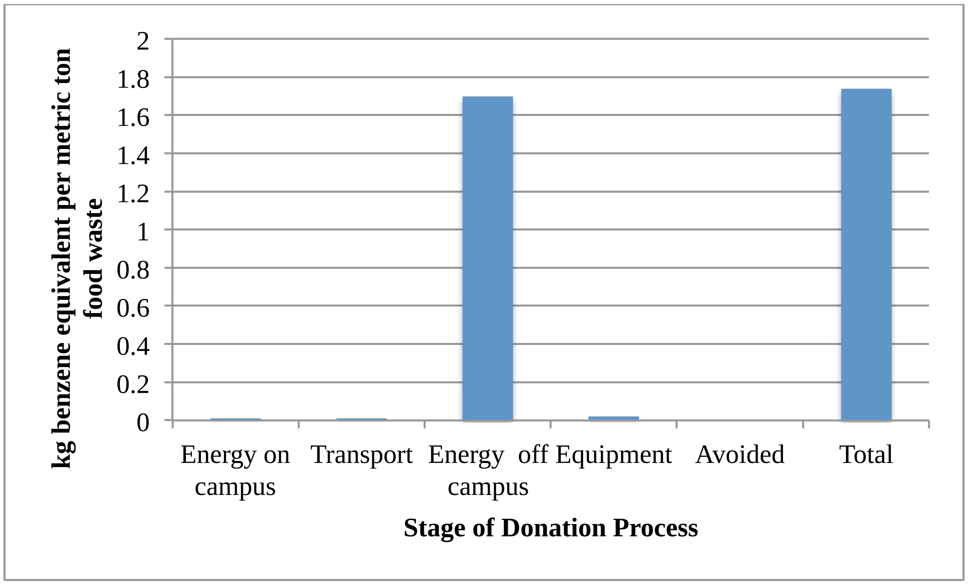

Figure 6-3: Human toxicity impact of each process stage, donation to pigs

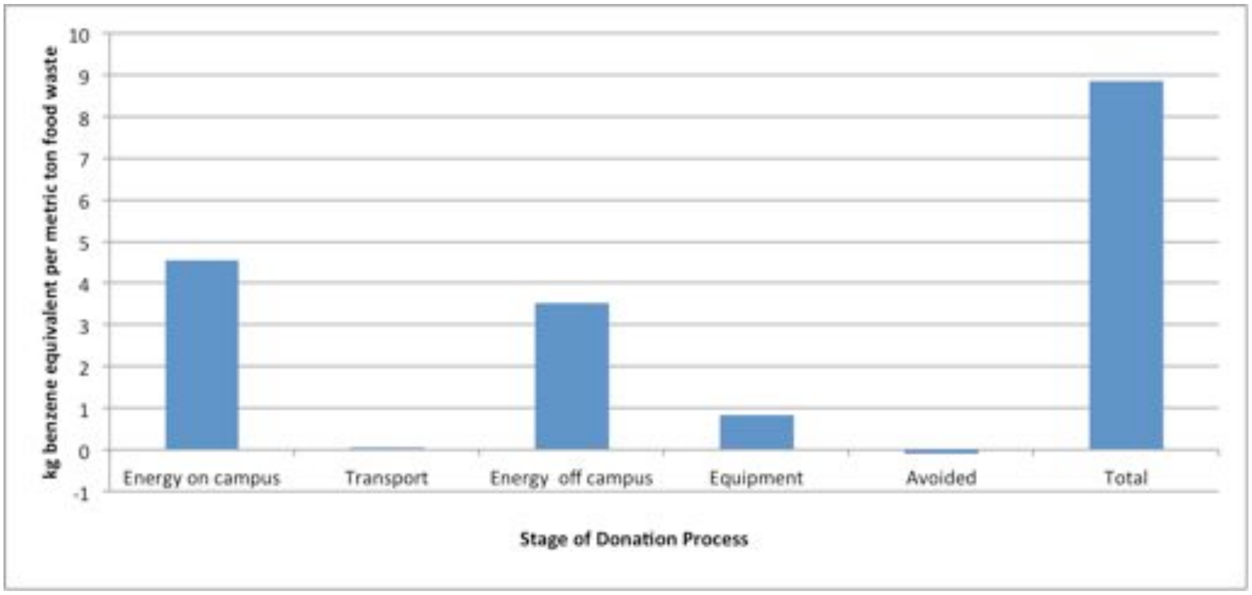

Figure 6-4: Ecosystem toxicity impact of each process stage, donation to pigs.

The avoided impact of buying commercially-produced animal feed means that donating food to people creates a substantial carbon offset (Table 6-7). Over the life cycle of this method, the majority of carcinogens (human health impact) are released from burning wood during the boiling of food waste. These impacts may be reduced depending on the fuel source used by the farm. Most of the ecosystem toxicity comes from powering the on-campus refrigerator to store food before it is picked up, though a significant percentage also comes from the emissions from burning wood to boil the food waste off campus.

6.4 Costs of Donation to Pigs

6.4.1 Direct Cost

Tipping Fees
For the representative pig farm chosen, Wellesley College would not need to pay to donate food waste.[33]

Trucking Fees
Transportation costs would be incurred when moving the food waste from the College to the pig farm. The cost to pay the off-campus hauler is estimated to be $45 per ton.[34]

6.4.2 Operational Cost

Transportation Cost

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[33] MassDEP. "Reducing Food Waste." Accessed March 26, 2013.
http://www.mass.gov/dep/recycle/reduce/reducefw.pdf.
[34] Patrick Willoughby, Wellesley College Director of Sustainability. Class Interview by ES 300. March 6, 2013.

We make the assumption that the contracted truck would pick up at each dining hall, so there would be no need to transport the waste to a central campus location.

Labor Cost
No additional labor costs are incurred, as putting excess food waste into the five-gallon buckets should not be substantially different from disposing of it otherwise. The buckets would be placed in the walk-in cooler until pickup.

Energy Cost
Although the refrigerators used for storing the food waste before donation may already be in use for other supplies, the food donated would increase the energy used by the refrigerators. Each metric ton of food would require 18 kWh of energy on campus and each kWh of electrical energy costs the College $0.11.[35] Thus, each metric ton of food donated would cost the College $1.98 in electricity.

Other Operational Costs (Water)
There are no operational water costs, as the water used for boiling would occur at the pig farm.

6.4.3 Equipment
Food waste would be transported in standard five-gallon buckets, which cost $2.34 each.[36] One metric ton of food waste would require approximately 55 buckets, totaling $129.[37]

6.4.4 Offset Cost
If 100% of food waste could be donated to pigs, then Wellesley College would not have to pay for this waste to be composted by another method.

6.4.5 Summary: Cost of Donation to Pigs
The total cost for the method of donating food waste to pigs would be $176 per metric ton of food waste (Table 6-8). The cost incurred through the use of off-campus trucking could only be reduced through negotiations with the trucking company. The five-gallon buckets are reusable, so this cost would only be incurred once.

[35] Patrick Willoughby, Wellesley College Director of Sustainability. Class Interview by ES 300. March 6, 2013.
[36] "Home Depot 5-Gal Bucket." Accessed March 26, 2013. www.homedepot.com
[37] If 1 cup of food weighs approximately one-half pound, then one five-gallon bucket can hold 40 pounds (18.14 kg) of food.

Table 6-8: Cost of donation to pigs

Cost Category		**Amount ($/metric ton)**
Direct:		
	Facilities	$0.00
	Transportation	$45.00
Operational:		
	Transportation	$0.00
	Labor	$0.00
	Energy	$1.98
	Other (water)	$0.00
Equipment		$129
Offset costs		$0.00
Total Cost		**$175.98**

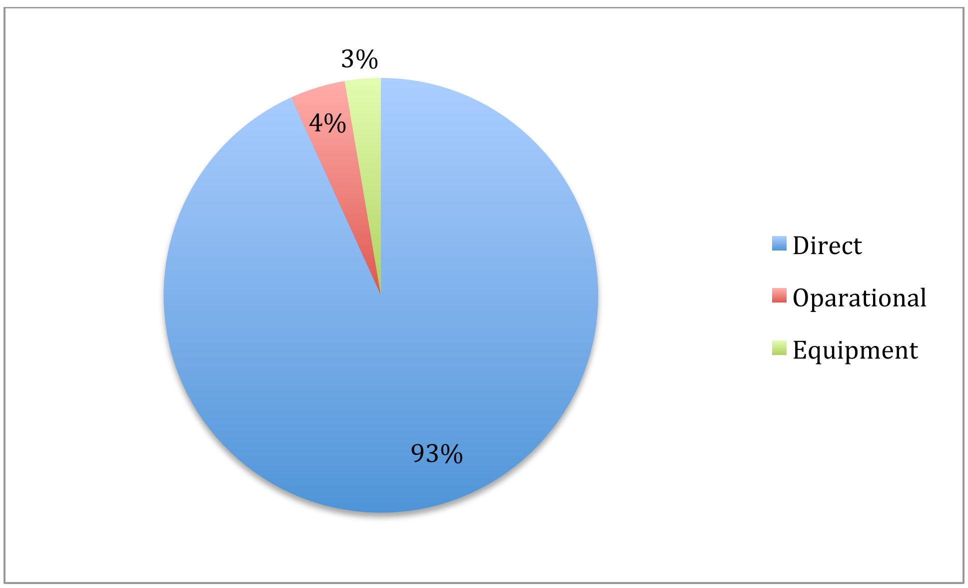

Figure 6-5: Cost of donation to pigs

6.5 Social Impacts of Donation to Pigs

6.5.1 Campus Experience – Neutral

Donating excess food to pigs would not change the way students interact with food waste or be at all visible to students, so this method would not change the campus experience.

6.5.2 Educational Benefit – Negative

Students would not be directly engaged in the donation process or in the logistics of the pig farm, so there would be a lack of educational opportunities.

6.5.3 Implementation Difficulty

Separation - Medium
Donating food waste to pigs would require a medium amount of separation on the part of Wellesley dining hall staff. Coffee grounds and compostable dishware cannot be accepted. Pig farms have a low tolerance for contamination, so separation must be done vigilantly – but as coffee grounds in dining halls are always handled by staff, and compostable dishware is easy to spot and separate from food waste, we do not foresee separation being a large hassle.

Permitting and Regulations - Low
Donation to pigs requires no permits and would begin almost immediately after approval from the administration.

Time until Implementation - Low
The administration would only need to work out the specifics of the arrangement with whichever pig farm is chosen. As there is no infrastructure that would need to be built, implementation would be achieved quickly.

Risk - Medium
Donation to pigs is associated with a low risk of safety concerns, but a medium risk of contamination. Compostable dishware must be excluded from this waste stream. It may be difficult for staff to sort out highly salty foods on the spot, even with a guide highlighting foods with a sodium content above the acceptable level. Contamination with non-food items may result in a rejection of the load from the pig farm. As a violation of Organic Waste Ban, this may lead to extra financial cost and communication to determine the final destination of the waste.[38] During the pilot testing in Bates dining hall, the College attempted to send waste to a pig farm, but the load was rejected due to the presence of compostable dishware.[39]

6.5.4 Social Justice – Neutral

Assuming that pigs and all of the externalities of commercial swine production would be present regardless of the pigs' source of food, feeding food waste to pigs has a neutral social justice impact. Donation of food waste to pig farms may increase the financial capital of small farmers,

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[38] MassDEP, "Organics Sub-Committee Meeting Summary," 10 Dec. 2012, www.mass.gov/dep/public/committee/osc1210.pdf (Accessed 11 Mar. 2013).
[39] Patrick Willoughby, Director of Sustainability at Wellesley College. Class discussion. March 6, 2013.

but without a full analysis of the impact of Starretts Farm on the surrounding community, this benefit is not enough to merit a positive social justice score.

6.5.5 Summary: Social Impacts of Donation to Pigs

The greatest social impact is associated with the separation of food waste. Although the need for separation cannot be reduced, brief employee training can ensure that the process goes smoothly (Table 6-9).

Table 6-9: Social impacts of donation to pigs

Social Impact		Score
Campus experience		Neutral
Educational benefit		Negative
Difficulty:		
	Separation	Medium
	Permitting and regulations	Low
	Time until implementation	Low
	Risk	Medium
Social justice		Neutral

6.6 Conclusions

Sending food waste to a pig farm is a reasonably low-cost option for food waste diversion, though the environmental impacts are high. The offsetting of purchases of commercial pig feed leads to a net positive impact on climate change, but the high ecosystem toxicity and carcinogen impacts lead to a high overall environmental impact. Theoretically, this method would dispose of 100% of Wellesley College's food waste.

The primary drawback of this method is the low tolerance for non-food items, such as napkins or compostable cups. Brief training may be needed to help employees recognize which waste is acceptable for donation and which is not. Because of the stringent contamination rules, this method comes with a risk of having loads rejected from the pig farm. As a violation of the Organic Waste Ban, this may lead to extra financial cost and communication to determine the final destination of the waste.[40] Since this has already happened once during the composting pilot test in Bates,[41] the College may be understandably wary of pursuing this method.

[40] MassDEP, "Organics Sub-Committee Meeting Summary," December 10, 2012. Accessed March 11, 2013. www.mass.gov/dep/public/committee/osc1210.pdf.
[41] Patrick Willoughby, Director of Sustainability at Wellesley College. Class discussion. March 6, 2013.

7.0 Aerated Static Piles Off Campus

Figure 7-1: Aerated static piles.[1]

7.1 Introduction to Aerated Static Piles Off Campus

Aerated static pile composting (hereon referred to as 'pile composting') is a method of composting in which food waste and bulking materials (i.e. wood chips, newspaper) are layered to form piles that decompose through contact with air.[2] These piles tend to generate mature compost within three to six months, depending on the method of aeration.[3] The compost created with this method can be used for applications such as agricultural or landscaping purposes.[4]

The piles of food waste and bulking materials range from 1.5-2.5 meters in height and 3-4.9 meters in width.[5] Ventilation of aerated static piles will increase decomposition; often this airflow is achieved using a variation of blowers, pipes, sensors, and fans, which deliver and

[1] National Geographic. "How Much Can a Compost Pile Heat?" Green Living. Accessed May 2013 http://greenliving.nationalgeographic.com/much-can-compost-pile-heat-3025.html.
[2] EPA. "Types of Composting." Wastes-Resource Conservation. Accessed May 2013 http://www.epa.gov/compost/types.htm.
[3] EPA. "Types of Composting." Wastes-Resource Conservation. http://www.epa.gov/compost/types.htm Accessed May 2013.
[4] EPA. "Types of Composting." Wastes-Resource Conservation. Accessed May 2013 http://www.epa.gov/compost/types.htm.
[5] FAO Natural Resources Management and Environment Department. "3. Large-scale composting." On-Farm Composting Methods. Accessed May 2013. http://www.fao.org/docrep/007/y5104e/y5104e07.htm.

channel air from the bottom of the pile to the top of the pile. Ventilation allows for the creation of larger piles, which increases the total waste processing capacity per acre of land used.[6]

Pile composting cannot handle animal byproducts or oily foods. As a result, any oily or animal-based foods must be separated from the waste stream in dining facilities and diverted using another method. Pile moisture levels and aeration capacity must be maintained to ensure successful decomposition of organic matter, which can be difficult to regulate outdoors in temperate climates. Thus, pile composting has seasonal limitations. During the summer, high temperatures cause evaporation of water in piles, and during the winter, cold temperatures limit aeration, due to reliance on passive airflow. If the piles are not properly monitored for moisture content or aeration, bad odors can be emitted from the piles.[7]

7.2 Implementing Aerated Static Piles at Wellesley

7.2.1 Overview of Implementation at Wellesley

Implementation at Wellesley would require our food waste to be collected and then sent either to a nearby farm or a nearby commercial composting facility. For the purposes of this analysis, we assume that we would use the composting facility operated by Casella Organics in Bridgewater, Massachusetts, 34.7 miles (55.8 km) from Wellesley. This facility utilizes aerated static piles to produce high-quality compost, which is sold on the market for agricultural use and use on turf fields.

The Natural Resource Defense Council (NRDC) estimates that 18% of total food waste in the United States sourced from retail, food service, and households is meat, poultry, and fish waste.[8] This would imply that Casella Organics would only be able to accept 82% of the College's food waste. However, a study by Buzby *et al* has shown that women are less likely to consume less meat products than men. [9] Since Wellesley is an all-women's college with a vegetarian dining hall (Pomeroy) it is quite likely that Wellesley is different from the average American household.[10] Thus, we can assume that Wellesley's food waste is made up of less animal waste than was found in the average American household. Based on these studies and without an experiment to measure the College's food waste composition, we assume that Casella Organics (in Bridgewater, Massachusetts) would accept 90% of total food waste generated by Wellesley College.

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[6] Covered Aerated Static Pile Composting. Harvest Power. Accessed May 2013. http://www.harvestpower.com/wp-content/uploads/2012/05/Harvest-CASP-brochure-v.2012.04.26.pdf.

[7] EPA. "Types of Composting." Wastes-Resource Conservation. Accessed May 2013.http://www.epa.gov/compost/types.htm.

[8] Gunders, Dana. "Wasted: How America Is Losing Up to 40% of Its Food from Farm to Fork to Landfill." *NRDC Issue Paper,* August (2012): 13.

[9] J.C. Buzby et al., "The Value of Retail- and Consumer-Level Fruit and Vegetable Losses in the United States." *The Journal of Consumer Affairs*, Fall (2011): 492-515.

[10] Faith, Myles S., Julia M. Hormes, Paul Rozin, and Brian Wansink. "Is Meat Male? A Quantitative Multimethod Framework to Establish Metaphoric Relationships." *The Journal of Consumer Research*, October (2012): Vol. 39.

7.2.2 Technology/Equipment

Pile composting would require the use of bins in each residence hall and food service location. Animal products and oils would need to be separated from food waste sent to the Bridgewater facility. It would also be possible to separate the waste by using a sifter, although we would not recommend purchasing one due to its cost and energy use.

7.2.3 Inputs

Energy
Transportation would be the largest energy input for composting piles off campus, though the composting facility would be responsible for providing this service. Using the energy efficiency estimate for the 70-yard trailer truck by the 2012 ES 300 report, the transportation to and from the composting facility in Bridgewater would require twelve gallons of fuel per trip.[11]

Materials
Material inputs would include a front loader, aeration equipment, textile used to cover each pile, and a sifter, though the College would not be responsible for acquiring such materials.

7.2.4 Outputs

Sending our food waste to an off-campus facility would produce the byproduct of compost. This output would not replace Wellesley College's future purchases of conventional soil and fertilizer.

Piles produce outputs that can contribute to atmospheric greenhouse gas pollution, including carbon dioxide, methane, nitrous oxides, and sulfur oxides.[12]

7.3 Environmental Impacts of Aerated Static Pile Composting

7.3.1 Collection and Preparation of Food Waste

Energy
There would be no additional energy inputs required for the collection and preparation of food waste for pile composting.

Materials
No additional material inputs for collection and preparation of food waste would be required for pile composting, since this method would only requires the use of collection bins.

Transportation of Food Waste
This method of composting would require transportation of the College's food waste to the Bridgewater facility. According to the 2012 ES 300 report, the College currently contracts

[11] Efficiency of 5.5 to 6 miles per gallon.
[12] Greenhouse Gas Emissions from Composting of Agricultural Wastes. Accessed May 2013. http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/cl9706/$File/GHGBulletinNo6Composting.pdf.

Wellesley Trucking to transport waste in a 70-yard trailer truck to an incineration site.[13] Although Casella Organics would pick up our waste, we assume in our analysis that the truck model would be similar to the one that Wellesley currently uses to transport waste. We assume that food waste sent to the Casella Organics site in Bridgewater would be transported in a large, diesel-powered combination truck from the U.S. that travels 112 km along its round trip route from Wellesley College to the site and back.

7.3.2 Process

Materials
We assume that the piles are formed using a front loader that is equivalent to general agricultural production machinery (CH/I U) and weighs approximately 1.1 metric tons.[14] In addition, we assume that the aeration system (which consists of an electric blower and aeration pipes) is made primarily of 0.06 metric tons of steel as well as .13 metric tons of PVC piping.[15] For materials, we assume that the bulking material of the compost piles, which usually makes up ⅔ of the piles by mass, does not impact our analysis. It is not being manufactured for pile composting, but is recovered using residential leaf and yard waste. Additionally, we assume that the piles are covered with basic cotton textile to control odors and emissions.

7.3.3 Avoided Impacts

This method would have no avoided impacts. Compost created via pile composting would not be used as fertilizer at Wellesley College.

7.3.4 Water Use

Due to our location in a temperate climate, aerobic static pile composting would require no water.[16]

7.3.5 Summary: Life Cycle Impacts and Assessment of Aerated Static Piles

Table 7-1: Environmental impact by process stage, piles

Impact Category	Unit	Total	Method	Transportation
Climate Change	kg CO2 eq	0.013988014	0.003546014	0.010442
Human Toxicity	kg toluen eq	0.253425892	0.18170661	0.071719282
Ecosystem Toxicity	kg 2,4-D eq	0.007140541	0.00514887	0.001991671

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[13] Environmental Studies 300, Spring 2012. *Waste Not, Want Not: An Environmental Impact Assessment of the Wellesley College Waste Stream and Steps for a More Sustainable Future.* Wellesley, MA: Wellesley College, 2012. Assuming that the truck is 4m high and 3m wide.
[14] Wheel Loaders. CAT. Accessed May 2013 http://www.cat.com/equipment/wheel-loaders
[15] Power Blower Ventilation. Industrial Contractors' Supply Inc. Accessed May 2013 http://www.icscompany.net/Ind_Power_Blowers.pdf.
[16] Kuter, Geoff. Interviewed by Ellen Bechtel. Phone Interview. March 4th, 2013.

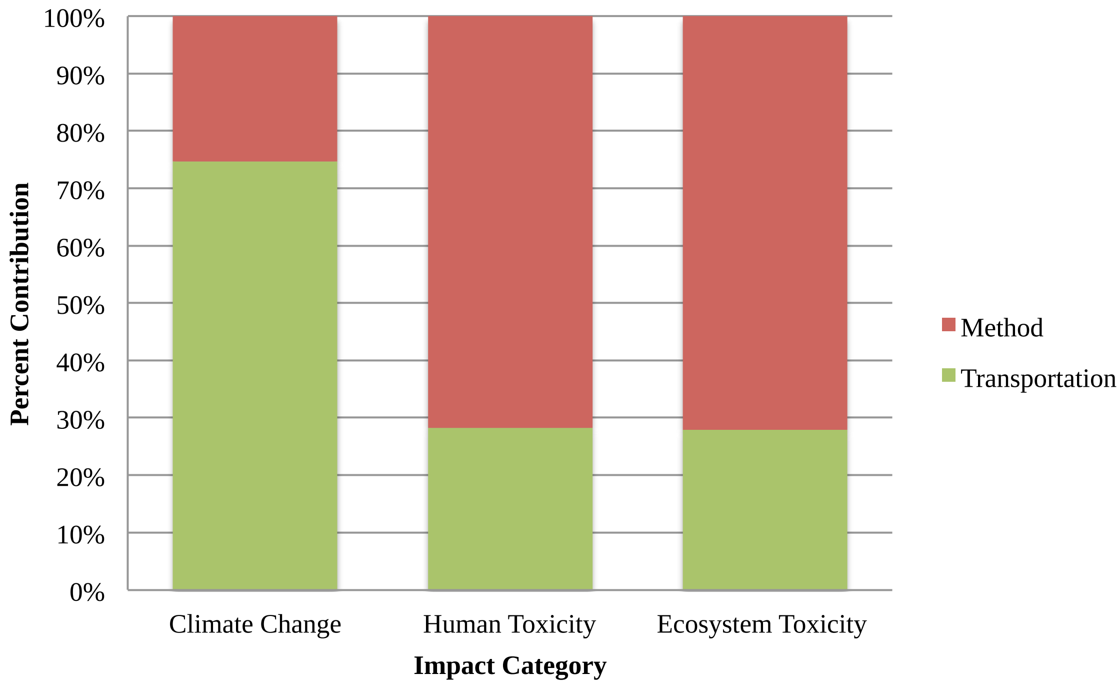

Figure 7-2: Percent contribution of process stages to each impact category, piles

Table 7-1 shows the breakdown of environmental impacts in each stage of the life cycle and Figure 7-2 shows the percent contribution of each life cycle stage to the three impact categories.

Climate Change

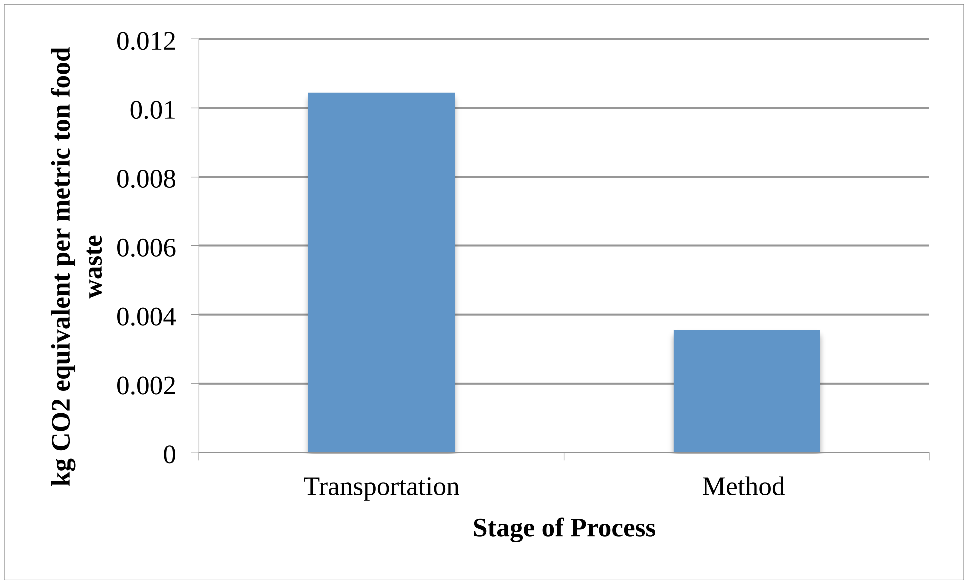

Figure 7-3: Climate change impact of each process stage for aerated static piles

Climate change impacts would have the largest total impacts of all categories. The proxy for climate change would be 0.0134 kilograms of carbon dioxide per metric ton of food waste. Pile composting would have the largest impact on climate change of environmental effects included in this assessment and within the climate change category, transportation would have a larger impact than the method itself (see Figure 7-3).

Human Toxicity

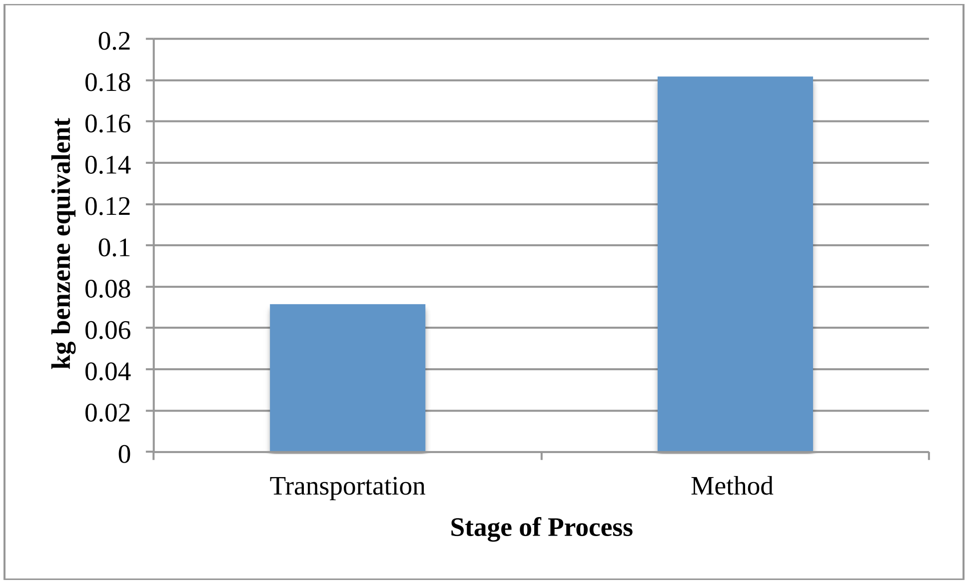

Figure 7-4: Human toxicity impact of each process stage, piles

The human toxicity impact of aerated static pile composting would amount to 0.2534 kilograms of benzene per metric ton of food waste. Human toxicity would be the highest of all the environmental effects for this pile composting as shown in Table 7-1. The significant contributor to human toxicity would be the composting method, as seen in Figure 7-4.

Ecosystem Toxicity

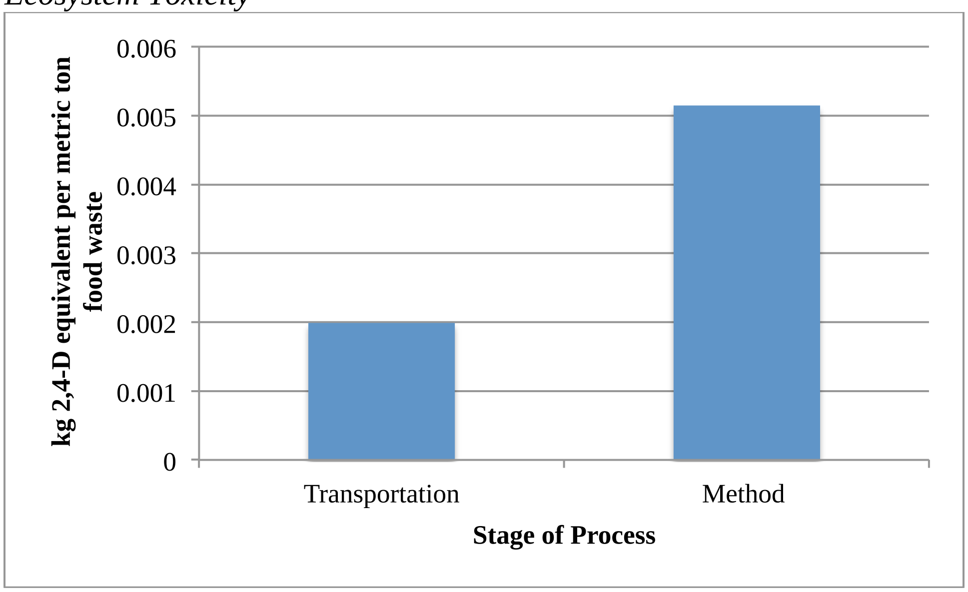

Figure 7-5: Ecosystem toxicity impact of each process stage, piles

Ecosystem toxicity would equate to 0.00714 kilograms of 2,4-Dichlorophenoxyacetic acid per metric ton of food waste. Breakdown of ecosystem toxicity by life cycle processes can be seen in Figure 7-2. The significant contributor to ecosystem toxicity would be the composting method, as seen in Figure 7-5.

Since this analysis is not looking at a created product, it does not include a manufacturing stage. The environmental impacts of manufacturing the individual material components and processes described in the Transportation and Method section, are nevertheless included as part of the SimaPro analysis (i.e. the manufacturing costs associated with the creation of a front loader.)

In our analysis, transportation would be the greatest influence on climate change impacts. Wellesley's food waste would be sent to the Casella facility in Bridgewater in a large diesel-powered combination truck. The truck's fuel economy and associated 112 km travel distance would be the responsible factors for these high greenhouse gas emissions.

The aerated static pile composting method would be the more influential process in both human and ecosystem toxicity categories, due to the PVC piping and electric blower that form the aeration system.

Pile composting would create quality compost but this end product would not replace conventional fertilizer due to its low nitrogen and phosphorus concentrations.[17] Thus, we do not calculate environmental effects for offsets.

7.4 Cost of Method Aerated Static Piles Off Campus

7.4.1 Direct Cost

Tipping Fees

We assume that the tipping fees for Casella Organics would be equivalent to those used for Windrows Off Campus (see Chapter 8). This cost would include $25 per pick-up site, a monthly service charge of $5.00 for using 65-gallon pickup toters, and a tip fee of $4.50 for each toter that is picked up. The fees are based on the assumption that a full toter would not exceed 200 lbs, or 90.7 kg when filled, and the fees will be adjusted if we find that toters weigh more than this amount on average.[18]

Total cost of tipping fees ($/metric ton)
= service charge/toter + "tip fee"/toter + $25 pick-up fee
= [(5.00 $/toter) + (4.50 $/toter) + $25 pick-up fee)]/(90.7 kg waste)
= 0.38 $/kg of waste
= (0.38 $/kg of waste) * (1000kg/1 metric ton)
= 380 $/metric ton of waste

[17] Kuter, Geoff. Interviewed by Ellen Bechtel. Phone Interview. March 4th, 2013.
[18] Kuter, Geoff. Interviewed by Ellen Bechtel. Phone Interview. March 4th, 2013.

The total facilities cost would be $380 per kg of food waste.

Trucking Fees
The cost of transporting Wellesley's food waste is included in the facilities cost noted above.

7.4.2 Operational Cost

Transportation Cost
Wellesley would not require operational transportation because Casella Organics would pick up the College's food waste from each dining hall.

Labor costs
The work required of dining hall workers to sort and dispose of food waste would be comparable to the amount of work currently required to dispose of dining hall waste. The method would require no additional labor costs.

Energy costs
This method would not require additional energy costs.

Other operational costs
There are no other operational costs.

7.4.3 Equipment

Pile composting would require no equipment costs because the College would not process the food waste, but would hire a company to transport and process the waste.

7.4.4 Offset Cost

The compost produced at the Casella Organics compost site would not be given back to the College; thus, there would be no offset cost associated with the final product.

7.4.5 Summary: Cost of Aerated Static Piles Off Campus

Table 7-2: Cost of aerated static pile composting per metric ton of food waste

Cost Category		**Amount ($/metric ton)**
Direct:		
	Facilities	$380
	Transportation	$0.00
Operational:		
	Transportation	$0.00
	Labor	$0.00
	Other (water)	$0.00
Equipment		$0.00
Offset costs		$0.00
Total Cost		$380

Table 7-2 show the total costs of pile composting as $380 per metric ton of food waste diverted. This would be completely attributed to facility cost.

It would be possible to decrease the direct cost if the College uses one central location for pick-up, which would directly lower tipping fees. If pickups were decreased, Wellesley College would incur additional diesel fuel and labor costs. Depending on the amount of waste diverted each week, this alternative scenario involving fewer pickups could be cost-effective. The additional fuel and labor would amount to one 6.76 km[19] loop from facilities center around campus, totaling one hour of driving time. This labor cost (at $24.16 per hour)[20] and fuel cost of the truck ($3.50 per gallon, average of seven miles per gallon,[21] $2.10 in fuel per loop) would total $26.26 per transport. Assuming that each pick-up site would hold one toter, this would amount to an additional $60 per kg of food waste diverted.

Cost of transporting all waste to one pickup site ($/metric ton)
= [(cost per transport $)/(number of toters/transport)]/(metric tons/toter)
= [(26.26 $/transport) / (5 toters / transport)]/ (0.0907 metric tons / toter)
= 60 $/metric ton of food waste

[19] Drawn from Google Maps. March 11, 2013.
[20] Personal Communication. Willoughby, Patrick. Question Responses. March 8, 2013.
[21] Willoughby, Patrick. ES 300 class. March 6, 2013.

This approach would decrease the overall cost of the method because the pickup fee would only be $25 for the one pickup site. Thus, if we had a total of five toters per pickup, the direct cost would be only $160 per metric ton of food waste diverted.

Total cost of diverting all waste to one pickup site ($/metric ton)
= [number of toters * (service charge/toter + tipping fee/toter) + $25 pickup fee]/[metric tons/toter * number of toters]
= [5 toters * (5.00 $/toter + 4.50 $/ toter) + $25 pickup fee]/ [(0.0907 metric tons/toter) * (5 toters)]
= 160 $/metric ton of food waste

Thus, with a central pickup location on campus, the cost per metric ton of food waste with pile composting would decrease to $220 per metric ton of food waste.

7.5 Social Impacts of Aerated Static Piles Off Campus

7.5.1 Campus Experience - Neutral

This method takes place off campus, and therefore would have a minimal impact on campus aesthetics, aside from bins put in place for waste collection. This method would incur little or no effect on the campus experience.

7.5.2 Educational Benefit - Negative

Because the Casella facility is a large company and is located 45 minutes away, it seems unlikely that Wellesley students would establish any connection to the composting site. Due to its distance from campus, the facility would not be visible in the daily lives of students or provide educational opportunities.

7.5.3 Implementation Difficulty

Separation – Medium
This method would require sorting food scraps to separate animal products and oils from food waste produced at dining halls.

Permitting and Regulations - *Low*
This method is off campus and thus would not require Wellesley to acquire permits or follow regulations.

Time until Implementation - *Low*
This method can be implemented immediately, since Casella Organics would be ready to take out food waste at any time.

Risk - *Low*
This method is off campus and thus poses no risk to the Wellesley College community.

7.5.4 Social Justice - Neutral

Pile composting would result in no positive or negative effects on social justice concerns.

7.5.5 Summary: Social Impacts of Aerated Static Piles Off Campus

Table 7-3: Social impacts of aerated static pile composting

Social Impact		Score
Campus experience		Neutral
Educational benefit		Negative
Difficulty:		
	Separation	Medium
	Permitting and regulations	Low
	Time until implementation	Low
	Risk	Low
Social justice		
	Off campus	Neutral

Overall, this method would have few social costs (Table 7-3). Because it is located far from campus it would not impose on campus life in areas other than collection and separation of food waste in campus dining facilities. However, the location of this facility would also inhibit the promotion of this method for educational purposes and other social benefits such as visibility and student participation.

7.6 Conclusions

This method could be implemented quickly, with relatively low cost, and with little change to how the College currently operates. The primary benefits are the low cost and low responsibility of Wellesley College; the College simply would need to pay a fee to a facility, separate out animal products from other food waste, and assure that food waste is accessible for transportation. The only difficulty associated with this method could be the potential sorting of food waste to separate out animal products. After training and cultural change, sorting would be a minor issue.

Implementation of this process using an off-campus facility would be quick, and would not require large infrastructural changes on campus. This seemingly easy and inexpensive transition is likely to attract the attention of the College administration.

Although it would be possible to implement this method on campus, we do not evaluate on-campus implementation, which would require extensive changes to current on-campus yard waste composting and would likely have a high social impact. On-campus implementation would not be as immediately advantageous as moving the College's food waste to an outside facility, but it would not require transportation to a facility and would provide the College with high quality compost that could substitute in a one-to-one ratio for peat.[22] If the administration is interested in implementing this method on campus, a full analysis should be performed.

[22] Geoff Kuter. Interviewed by Ellen Bechtel. March 4th, 2013.

8. Windrow Composting Off Campus

Figure 8-1: Windrow composting off campus

8.1 Introduction to Windrow Composting Off Campus

Windrow composting (hereon referred to as “windrowing”) is a form of aerobic composting in which food waste is mixed with carbon-rich bulking materials (i.e. woodchips, leaves, newspaper) and then set into long piles that are turned periodically for aeration.[1] Windrowing is recommended by the EPA for high-volume composting, and, if carefully managed, can compost substances such as grease and animal byproducts. Windrows can also be used in cold or rainy climates.

The drawbacks of windrowing include the potential contamination of local groundwater and surfacewater by the leachate byproduct (a nutrient rich water-based liquid). Thus, large-scale windrow compost and leachate should regularly be tested for heavy metals before distribution.[2]

A large area is required to host the piles, which are typically 1.5 m high, 3 m at the base, and up to 100 m long.[3] The size, shape, and spacing of windrows must be carefully managed in order to

[1] Joint Service Pollution Prevention and Sustainability Library. “Windrow Composting.” Accessed March 2013. http://www.p2sustainabilitylibrary.mil/p2_opportunity_handbook/7_II_A_2.html.
[2] EPA. "Types of Composting." Wastes-Resource Conservation. Accessed February 23, 2013. http://www.epa.gov/compost/types.htm.
[3] Joint Service Pollution Prevention and Sustainability Libary. “Windrow Composting.” Accessed March 2013. http://www.p2sustainabilitylibrary.mil/p2_opportunity_handbook/7_II_A_2.html.

achieve an adequate air flow and an internal temperature of approximately 60° C (140° F). If a windrow is too large, then the center becomes too warm and it may become partially anaerobic, which will cause the windrow to emit foul odors and will decrease the quality of the end-product compost.[4] If the windrow is too small, it may not maintain the proper temperatures to evaporate water and kill pathogens and weed seeds. Windrows are aerated passively or mechanically. For passive aeration, perforated pipes run through the piles and provide airflow throughout the pile, similar to those used in pile composting (see Chapter 7). For mechanized aeration, front-end loaders or bucket loaders turn the heaps approximately two to four times before the compost matures over the course of three to four months.[5] After the piles have matured, the compost is sifted and large undecomposed pieces of waste are returned to the windrows for further decomposition.

8.2 Implementing Windrow Composting Off Campus at Wellesley College

8.2.1 Overview of Implementation at Wellesley

Wellesley College would implement windrow composting by collecting its food waste and transporting it to a windrowing site off campus. For the purpose of this analysis, we assume that the College will send its food waste to the Needham Recycling and Transfer Center (henceforth to be referred to as the 'Needham facility') managed by Agresource Inc. The site is located 5.5 km (3.4 miles) away at 1421 Central Avenue in Needham, MA.[6] The site can accept all vegetative and animal-based food waste, as well as all compostable (not necessarily all biodegradable) utensils. Pick-up and transportation of the food waste is provided through Agresource's services, and therefore Wellesley College would not be responsible for hiring an additional hauler or for hauling food waste by Wellesley College employees. This method would be able to divert up to 100% of the College's food waste.

8.2.2 Technology/Equipment

Wellesley College would have no responsibility for technological investment because Agresource Inc. provides collection bins.

A truck from the Agresource Inc. route would make an approximately 11km round-trip from the Needham site to Wellesley College and back. It would pick-up at the College twice per week.[7] We assume that the truck used to haul Wellesley's waste to Needham would be approximately equivalent to the 70-yard diesel trailer truck of 5.5-6 miles per gallon used in the 2012 ES 300

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[4] Natural Resources Management and Environment Department "Large-scale composting; Wind-row composting" Wastes-Resource Conservation. Accessed February 24, 2013. http://www.fao.org/docrep/007/y5104e/y5104e07.htm.
[5] Geoff Kuter, Agresource Inc. Interviewed by Ellen Bechtel. March 4, 2013.
[6] City of Needham. "Recycling & Waste Management Program." Accessed March 20, 2013. http://www.needhamma.gov/index.aspx?NID=262.
[7] Although in reality the truck would add additional pick-uppick-up locations at other food waste sites along its route, we assumed for this analysis that the truck would make a specific trip from the Needham site to the College because of lack of other data. (Geoff Kuter, Agresource Inc. Interview by Ellen Bechtel. March 4, 2013.)

report, which transports 70 cubic yards of waste.[8] This is more than enough to hold the four tons per week produced by the College.

Weekly food waste on campus (metric tons/week)
= (Wellesley's annual food metric tons/year) / (52 weeks/year)
= (220 metric tons per year) / (52 weeks per year)
= 4.2 metric tons food waste/week

For analysis in SimaPro7, we assume that this truck is equivalent to a large, diesel-powered combination truck from the US. We assume a truck lifespan of 10 years.

The windrowing process at the Needham site would require investments in a front-end loader and industrial compost sifter. Both pieces of equipment would cost from $12,000-16,000 respectively, but the College is not responsible for this machinery.[9]

8.2.3 Inputs

Energy
There would be no energy used on campus if the food waste is stored in the bins, as refrigeration is not necessary under Agresouce Inc.'s policy. The large diesel combination truck used for pick-up has a fuel efficiency of approximately six miles per gallon (2.5 km/L). Machinery used at the Agresource Inc. site, including the front-end loader, run on diesel fuel and do not use electricity from the grid. The front loader has an average efficiency of three gallons per hour (11.3 L/hr).[10] The sifter has an average efficiency of 1.5 gallons per hour (5 L/hr).[11]

Materials
Because the method would take place off campus, Wellesley College's responsibility in the windrowing process would extend only as far as the food waste the College generates. It would not be responsible for the additional carbon inputs to the windrowing process or the fuel used to operate the transportation truck, front-end loader, and industrial sifter. Wellesley College would not be responsible for the impacts of the materials required by this method, including Agresource's collection toters,[12] a diesel truck, a front-end loader, a sifter (all three with a lifespan of 10 years), and a steady supply of bulking materials.

8.2.4 Outputs

Windrowing takes place off campus, so Wellesley College would only be responsible for the

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[8] Environmental Studies 300, Spring 2012. *Waste Not, Want Not: An Environmental Impact Assessment of the Wellesley College Waste Stream and Steps for a More Sustainable Future.* Wellesley, MA: Wellesley College, 2012.
[9]Geoff Kuter, Agresource Inc. Interview by Ellen Bechtel. March 4, 2013.
[10] John Deere. "Specifications." Accessed March 20, 2013.
http://www.deere.com/en_US/docs/construction/non_current_products/wheel_loaders/544G%2B624G%2B644G.pdf.
[11]"REMU: Screening Buckets & Screening Plants" COR Equipment Sales. Accessed March 20, 2013.
http://www.cor-equip.com/REMU_screening_buckets_and_plants.pdf.
[12] Toters were not included in analysis because they are necessary and constant among the various compost options investigated.

output generated from its food waste. Mature compost from the Needham facility is sold to a network of facilities throughout the northeast and is marketed as the highest quality compost.[13] Windrowing has the potential for a small output of leachate, which may have a eutrophying effect. Such an output falls outside of the boundaries of this report.

8.3 Environmental Impacts of Windrowing

8.3.1 Collection and Preparation of Food Waste

Energy
Agresource Inc. requires no waste preparation process. Health code requirements may mandate that the waste be refrigerated, in which case sealed waste toters would be stored in walk-in refrigerators that already exist in the dining halls. Since no new refrigerators would need to be purchased, no significant change in energy use would be required. Therefore, there are no environmental impacts from this step in the windrowing method.

Materials
Windrowing would require no sorting or processing of food waste, so no materials are included in our analysis. We assume that the bulking material of the compost piles (leaf and yard waste, which usually makes up two-thirds of the windrows by weight) does not impact our analysis: the Town of Needham already collects and composts yard waste.

Transportation of Food Waste
We assume that this truck is equivalent to a large, diesel-powered combination truck from the US that travels approximately 11km in a round-trip route from the Needham site to Wellesley College and back, and picks up waste at Wellesley College two times per week.[14] We assume a truck lifespan of 10 years.

8.3.2 Composting Process

Materials
We assume that the piles are formed and turned using a front-loader that is equivalent to SimaPro7's general agricultural production machinery (CH/I U) and weighs 11 metric tons.[15] We assume that the sifter used on the finished piles is equivalent to the same agricultural machinery and weighs one metric ton.[16] These SimaPro equivalents automatically include all components (metal, glass, etc) of the machinery in the Life Cycle Assessment.

Energy

[13]Agresource Inc. "Quality Compost Products." Accessed March 20, 2013. http://www.agresourceinc.com/compost.htm.
[14] Although in reality the truck would add additional pick-uppick-up locations at other food waste sites along its route, we assumed for this analysis that the truck would make a specific trip from the Needham site to the College because of lack of other data. (Geoff Kuter, Agresource Inc. Interview by Ellen Bechtel. March 4, 2013.)
[15] Geoff Kuter, Agresource Inc. Interview by Ellen Bechtel. March 4, 2013.
[16] Argus Industrial Company. "EZ-Screen 550." Argus Industrial Company. Accessed March 3, 2013. http://ez-screen.com/wp-content/uploads/2012/02/brochure-ez-550.pdf.

There would be no energy inputs required for windrowing.

8.3.3 Avoided Impacts

Off-campus windrowing would result in no avoided impacts because the College would not use the end compost product on campus.

8.3.4 Water Use

Precipitation and porous draining of the piles naturally regulate the moisture content of the windrows, requiring no additional water in the windrowing process. Therefore, there would be no environmental impact from water usage for windrowing at the Needham facility. [17]

8.3.5 Summary: Life Cycle Impacts and Assessment of Windrow Composting Off Campus

Table 8-1: Environmental impact by process stage, windrow composting off campus

Impact Category	Unit	Transportation	Method	Total
Climate Change	kg CO2 eq	0.006567	0.00377	0.002797
Human Toxicity	kg benzene eq	0.1617	0.1424	0.01921
Ecosystem Toxicity	kg 2,4-D eq	0.0111	0.000533	0.01061

The Life Cycle Assessment indicates that the environmental impacts of windrowing would be low. The most significant impacts would be from the process of windrowing itself; transportation impacts would be significantly lower (Table 8-1). The proximity of the Needham site would lessen the overall environmental impact of this process, making it a favorable method.

[17] Geoff Kuter, Agresource Inc. Interview by Ellen Bechtel. March 4, 2013.

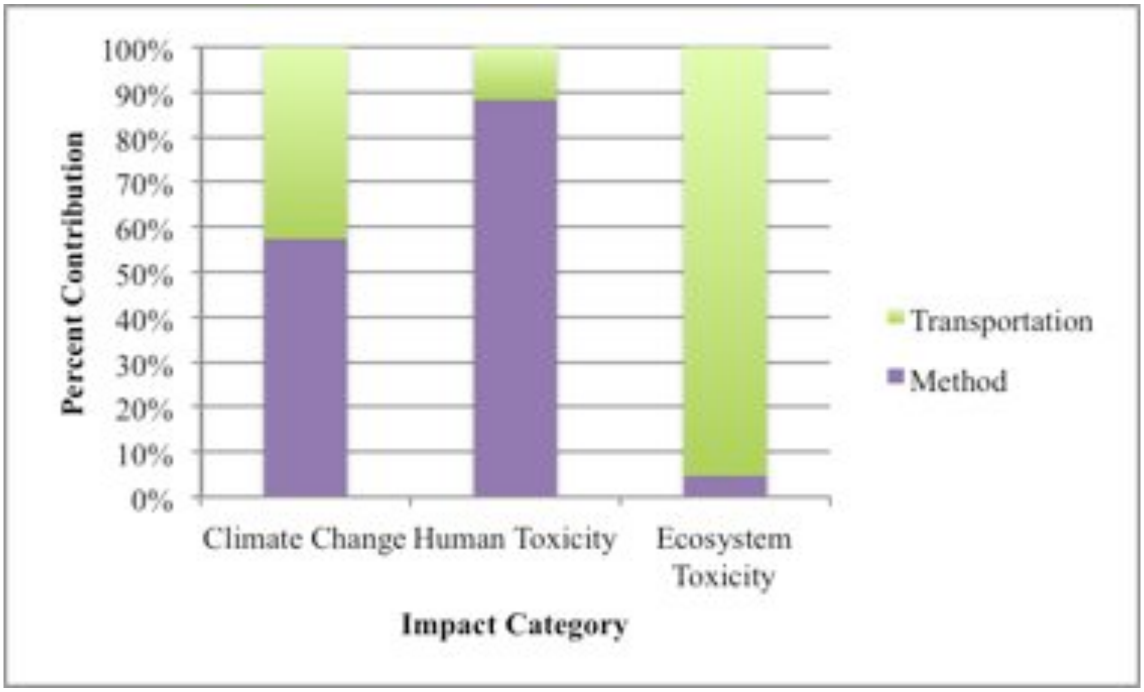

Figure 8-2: Percent contribution of process stages to each impact category, windrows

Climate Change

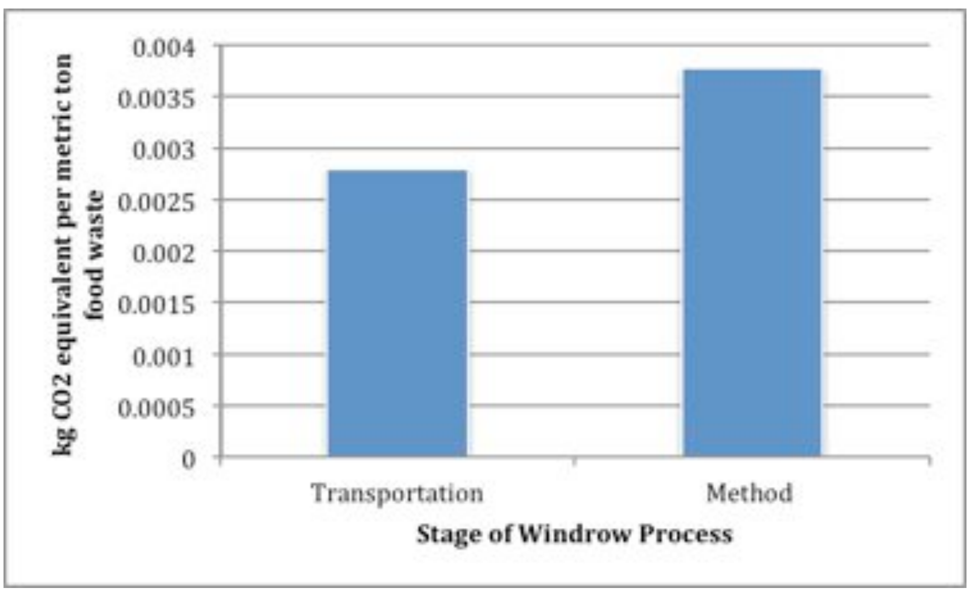

Figure 8-3: Climate change impact of each process stage, windrows

Climate change impacts would have the second largest total impact of all categories assessed using SimaPro7. The proxy for climate change, or global warming as calculated in the program, would be .013134 kilograms of carbon dioxide per metric ton of food waste, as seen as in Table 8-1 and Figure 8-2. As seen in Figure 8-3 the largest contributor to climate change would be the composting method, though transportation would not be far behind.

Human Toxicity

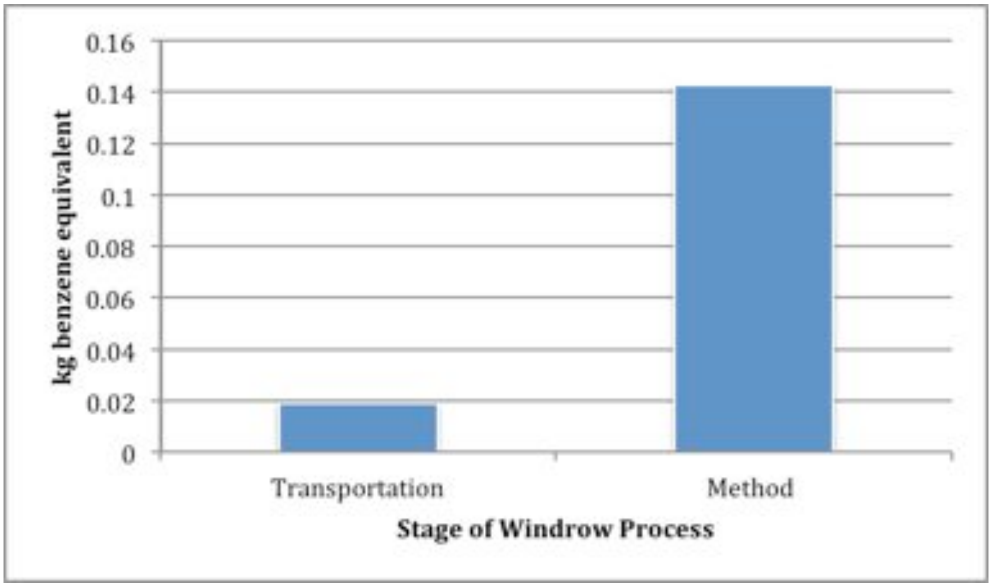

Figure 8-4: Human toxicity impact of each process stage, windrows

For windrow composting, human toxicity would amount to 0.32331 kilograms of benzene per metric ton of food waste, as shown in Table 8-1. Human toxicity would be the lowest of all the environmental effects for this method, as visible in Figure 8-2. As seen in Figure 8-4, the largest contributor to human toxicity would be the composting method, not transportation.

Ecosystem Toxicity

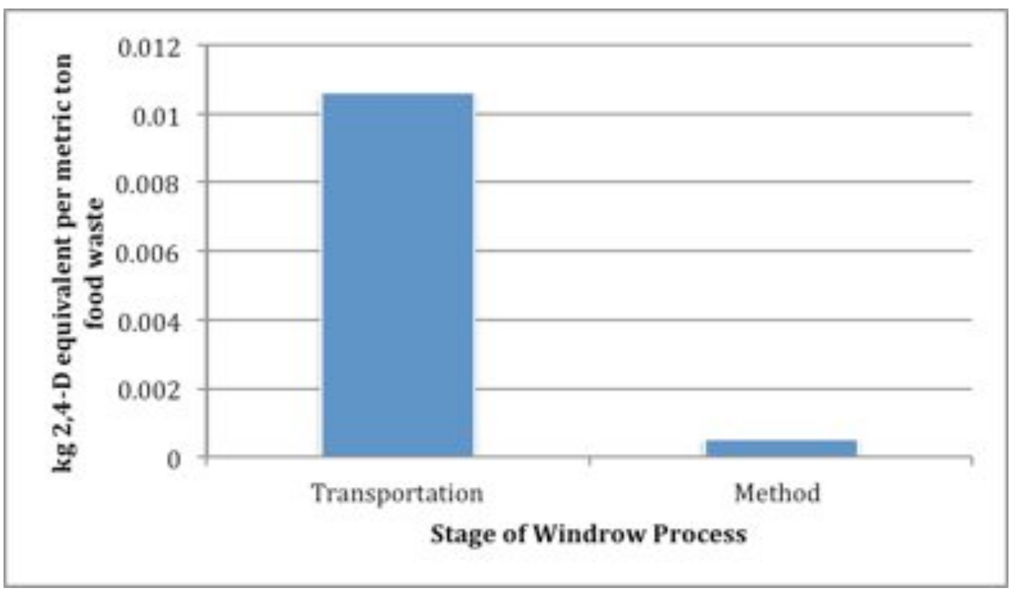

Figure 8-5: Ecosystem toxicity impact of each process stage, windrows

SimaPro 7 uses 2,4-Dichlorophenoxyacetic acid, an herbicide, as a proxy for ecosystem toxicity. In this calculation, ecosystem toxicity would be 0.02224 kilograms of 2,4-Dichlorophenoxyacetic acid per metric ton of food waste. Of the three impact categories assessed in SimaPro, the impacts of windrow composting would have the greatest implications for ecotoxicity, as shown in Table 8-1 and Figure 8-2. As seen in Figure 8-5, the largest contributor to ecosystem toxicity would be transportation.

8.4 Costs of Windrow Composting

8.4.1 Direct Cost

Tipping Fees
Sending Wellesley College's food waste to the Needham Recycling and Transfer Station through Agresource Inc. would cost $25 per site per pick-up. Thus, if the Agresource truck stops at five locations around campus each week, the College would need to pay for five pick-up sites. Furthermore, the College would pay a monthly service charge of $5.00 and a "tip fee" of $4.50 for each 65 gallon Agresource Inc. toter that would be picked up. The fees are based on the assumption that a full toter would not exceed 200 lbs (90.7 kg) when filled, and the fees would be adjusted if we find that toters weigh on average in excess of this amount.[18]

Total cost of tipping fees ($/metric ton)
= service charge/toter + tipping fee/toter + $25 pick-up fee
= [(5.00 $/toter) + (4.50 $/toter) + $25 pick-up fee)]/(90.7 kg waste)
= 0.38 $/kg of waste
= (0.38 $/kg of waste) * (1,000kg/1 metric ton)
= 380 $/metric ton of waste

Thus, the total facilities cost would be $380 per metric ton of food waste diverted from Wellesley's current waste stream.[19]

Trucking Fees
The fees for transportation are paid to the Needham facility through pick-up fees.

8.4.2 Operational Cost

The total operational cost for Wellesley College is zero.[20]

Transportation Cost
Wellesley College is not responsible for funding the transportation of food waste. The costs of transportation of the food waste are completely included in the trucking (pick-up) fee.

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[18] Geoff Kuter, Agresource Inc. Interview by Ellen Bechtel. March 4, 2013.
[19] ($5.00 service charge/toter + $4.50 tipping fee/toter + $25 pick-up fee) / 90.7 kg waste =$0.38 per kg of waste diverted
[20] All operational costs are entailed by Agresource, Inc. Wellesley College covers its portion of the operational costs in the trucking (pick-up) fee.

Labor costs
No additional labor is needed.

Energy costs
There are no energy costs to be considered for this process. It should be noted that if regulations require the food to be refrigerated before pick-up, it is possible that this process may require refrigerating the waste in existing walk-in refrigerators, which will require energy.

Other Operational Cost
There are no other operational costs for this method.

8.4.3 Equipment

Wellesley College is not responsible for acquiring any equipment to implement this method: Agresource Inc. will provides toters.

8.4.4 Offset Cost

The Needham Recycling and Transfer station will not sell compost to Wellesley College, so there is no offset cost.

8.4.5 Summary: Cost of Windrow Composting Off Campus

The total cost to Wellesley College of hiring Agresource Inc. to haul our waste to its windrow composting site in Needham would be $380 per metric ton of food waste diverted. This cost is broken down into categories in Table 8-2.

The pick-up fee would represent the largest cost of this method. This cost would be reduced by centralizing a pick-up location for the College. It would be possible to decrease the direct cost if we let food waste accumulate for longer amounts of time and have fewer pick-ups but additional toters. Furthermore, the dining halls would also use one central location for pick-up, which would directly lower the fees to the College. In this scenario, the College would need to pay for diesel fuel and additional labor. The additional fuel and labor would amount to one 6.7 km[21] loop from facilities center around campus, totaling 1 hour. This labor cost (at $24.16 per hour)[22] and fuel cost of the truck ($3.50 per gallon,[23] average of 7 miles per gallon,[24] $2.10 in fuel per loop) totals $26.26 per transport. Assuming that each pick-up site would hold one toter, this would amount to an additional $60 per metric ton of food waste diverted.

Cost of transporting all waste to one pick-up site ($/metric ton)
= [(cost per transport $) / (number of toters/transport)] / (metric tons/toter)
= [(26.26 $/transport) / (5 toters / transport)] / (0.0907 metric tons / toter)
= 60 $/metric ton of food waste

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[21] "Wellesley, Massachusetts." Map. *Google Maps.* March 11, 2013.
[22] Patrick Willoughby, Director of Sustainability at Wellesley College. Interview by Elli Blaine. March 8, 2013.
[23] Assumption of ES 300 class. March 6, 2013.
[24] Patrick Willoughby, Director of Sustainability at Wellesley College. Interview by Elli Blaine. March 6, 2013.

This centralization would decrease the overall cost of the method because the pick-up fee would only be $25 for one pick-up site. Thus, if we had a total of five toters per pick-up, the cost would be only $160 per metric ton of food waste diverted.

Total cost of diverting all waste to one pick-up site ($/metric ton)
= [number of toters * (service charge/toter + tipping fee/toter) + $25 pick-up fee] / [metric tons/toter * number of toters]
= [5 toters * (5.00 $/toter + 4.50 $/ toter) + $25 pick-up fee] / [(0.0907 metric tons/toter) * (5 toters)]
= 160 $/metric ton of food waste

Thus, if pick-up sites were reduced to one central location on campus, the College would pay only $220 per metric ton of food waste.

Table 8-2: Cost of windrow composting off campus per metric ton of food waste

Cost Category		**Amount ($/metric ton)**
Direct:		
	Facilities	$380.00
	Transportation	$0.00
Operational:		
	Transportation	$0.00
	Labor	$0.00
	Energy	$0.00
	Other	$0.00
Equipment		$0.00
Offset costs		-$0.00
Total Cost		**$380**

8.5 Social Impacts of Windrowing

8.5.1 Campus Experience – Neutral

This method would take place off campus, and therefore would have no impact on campus aesthetics. The compost collection bins would be equivalent to the waste collection bins already on campus. The waste would be picked up once or twice per week, depending on holding capacity of the toters and the total amount of food waste produced, so it is unlikely that there would be any issues associated with holding the waste on campus.

8.5.2 Educational Benefit - Neutral

Because Agresource is a large company, it seems unlikely that Wellesley students would establish any notable connection to the composting site. However, the facility was made available for a student tour during the Spring 2013 semester, and thus it may be worthwhile to pursue a deeper relationship with the company.

8.5.3 Implementation Difficulty

Separation - *Low*
No separation of food waste would be required for windrowing.

Permitting and Regulations - *Low*
Wellesley College would not need to obtain permits or comply with regulations to implement windrowing.

Time until Implementation - *Low*
This method would be implemented as soon as Wellesley establishes a working partnership with Agresource Inc., which has the capacity to accommodate 100% of Wellesley's food waste.

Risk - *Low*
This method would present no risk to the Wellesley College community since it would occur off campus. Additionally, Agresource has no recorded issues with odor.[25]

8.5.4 Social Justice - Neutral

There would be insignificant social justice factors associated with off-campus windrowing.

8.5.5 Summary: Social Impacts of Windrow Composting Off Campus

Windrowing would have no clear negative social costs, and the ease of implementation indicates that the method would be beneficial. It seems that there would be some effort needed to increase the educational opportunities provided by this method of composting. The Needham site has been made available for student tours, and it is quite possible that if composting was included in curriculum, students may be able to tour a facility that composts Wellesley's food waste. None of the other categories have any significant potential for change.

[25] Geoff Kuter, Agresource Inc. Interview by Ellen Bechtel. March 4, 2013.

Table 8-3: Social impacts of windrow composting

Social Impact		**Score**
Campus experience		Positive
Educational benefit		Neutral
Difficulty:		
	Separation	Low
	Permitting and regulations	Low
	Time until implementation	Low
	Risk	Low
Social justice		Neutral

8.6 Conclusions

Windrowing can handle all of Wellesley's food waste because it is well suited for composting large volumes of waste, including difficult materials such as animal products and grease. The best approach for Wellesley would be to implement windrow composting via the Needham Recycling and Transfer Station run by Agresource Inc. due to its close proximity to campus and high capacity for food waste. This proximity would lessen the environmental impact associated with transportation and would result in low transportation costs, compared to methods that are farther away from campus. Another benefit of this method is that Agresource would be responsible for all aspects of the process post-collection. Agresource's responsibility would mean that Wellesley would be assured that the waste leaving campus would be properly cared for, without taking financial responsibility for any problems encountered after the waste leaves campus. Because the Needham facility is already operating under-capacity, windrowing would be implemented in a short time-frame with relatively low difficulty.

9.0 Rotary In-Vessel Composting On Campus

Figure 9-1: Large scale rotary in-vessel composter with grinding hopper[1]

9.1 Introduction to On-Campus Rotary In-Vessel Composting

Rotary in-vessel composting is a rapid composting process that involves the mixing of materials by tumbling in a rotating cylinder. The rotation initiates fast bacterial decomposition by aerating and mixing the carbon- and nitrogen-rich materials. Ideally, temperatures within the drum reach over 71°C and produce compost after three to fourteen days. Additional curing (explained in the next paragraph) takes two to four weeks.[2] Processing food waste in tumblers requires the addition of bulking material such as wood chips, manure, or yard waste to ensure adequate aeration and a proper carbon to nitrogen (C:N) ratio. The tumbling machinery would provide protection against wildlife and odors, operate in all types of weather, and process a myriad of materials including meat, oils, vegetables, bones, yard waste, and soiled paper waste.[3]

A rotary in-vessel operation includes the following procedures: food waste is collected, coupled with additional inputs such as yard waste, and then processed through a grinder.[4] The ground material is then transferred into the rotating cylinder until the machine reaches its maximum capacity. Loading food waste can either take place all at once or incrementally over a few days.

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[1] TMA Organics. "Photo Gallery." Accessed May 1, 2013. http://tmaorganics.com/gallery.html.
[2] Jean, Bonhotal. "In-Vessel Composting For Medium-Scale Food Waste Generators." *BioCycle 52(3)*, 2011. http://cwmi.css.cornell.edu/invesselcomposting.pdf. Accessed February 25, 2013.
[3] EPA. "Backyard or On-site Composting." Last modified 1/8/2013. Accessed February 25, 2013. http://www.epa.gov/epawaste/conserve/composting/types.htm.
[4] Levy, Morgan. South Dade Soil & Water Conservation District, "In-Vessel Aerobic Composting of Organic Waste On Site And Re-use On Site For Environmental and Economic Advantage." Accessed February 25, 2013. http://www.southdadeswcd.org/wp-content/uploads/2010/10/White-Paper-on-In-Vessel-Composting-05-10-10.pdf.

A timer initiates rotation of the vessel for two-twelve hour increments within a four-day cycle.[5] During rotation, temperatures within the drum can exceed 54°C.[6] After this cycle, the resulting compost is taken out of the vessel and to a curing area. Compost is then cured, or left in standing piles to finish decomposition, until the temperature of the compost falls below 32°C.[7] Samples are then tested in a lab for pathogens, heavy metals, proper ratios, etc. to ensure the safety and quality of the compost. Finally, the resulting compost is used for a variety of purposes, such as for enriching soil on campus.

Case Studies

Several other college campuses have been successful in implementing in-vessel systems to divert organic waste and create useful compost material. Two such examples are listed below.

Warren Wilson College | Asheville, NC

Warren Wilson College, a private four-year liberal arts college located in Asheville, North Carolina, uses a BW Organics Greendrum to divert 136 to 227 kilograms of food waste per day. Food is inserted into the tumbler, where it is mixed with bulking material (achieving a ratio of 1:1:1, food : wood chips : sawdust) and added to the drum. A fan blowing into the drum maintains oxygen in the system, keeping it aerobic and heated. The resulting product is put in curing piles, where it is turned, fluffed, and left to sit until it finishes composting. This method allows for the composting of meat, dairy, vegetable, and any other food product without attracting unwanted pests. Students can control the humidity, temperature, and other factors to foster an ideal environment for composting. This in-vessel composting system thus converts most of Warren Wilson's waste into high-quality compost that is used for the campuses gardens and landscaping.[1]

University of Alberta - Augustana | Camrose, Alberta, Canada

The University of Alberta at Augustana has 1000 students, half of whom participate in the school's meal plan. In addition to pre- and post-consumer waste reduction initiatives, the University installed a rotating in-vessel composter, called the The Biovator, for their leftover food waste. The Biovator by Nioex Systems Inc. digests 350 kilograms (771.6 pounds) of food waste per day.[2] Through the Biovator, the Augustana campus is now able to divert roughly 52% of its total waste and turn it into usable compost.

[1] Warren Wilson College. "Composting at WWC." Accessed February 24, 2013. http://www.warren-wilson.edu/~recycle/compost.php.
[2] Nioex Systems Inc. "Biovator Case Study - Augustana Campus." Accessed February 24, 2013. http://nioex.com/files/5187-NIO CaseStudy_WEB2.pdf.

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[5] Levy, In-vessel Aerobic, p4.
[6] Richard, Tom. Department of Agricultural and Biological Engineering Cornell University, "Municipal Solid Waste Composting: Biological Processing." Accessed February 25, 2013. http://compost.css.cornell.edu/MSWFactSheets/msw.fs2.html.
[7] Levy, In-vessel Aerobic, p4.

9.2 Implementing On-Campus Rotary In-Vessel Composting at Wellesley College

9.2.1 Overview of Implementation at Wellesley

At Wellesley, food waste would be separated and collected in the dining halls in 60-gallon toters. The College's Freightliner swap loader dump truck would be used twice per day to take food from the dining halls to the composting site. This truck would travel a total of three miles to collect waste from each dining hall and travel to and from the composting site. At the site, food would be dumped into a grinding hopper, which would shred the food. Once shredded, the food would be transferred into the tumbler using a conveyor belt. A backhoe would add wood chips to the tumbler from a nearby yard waste pile, resulting in a mixture of three parts wood chips to one part food waste.

The tumbler would be set to rotate for two hours and rest for ten hours, then repeat.[8] In order to ensure that the contents of the tumbler remain above 55°C, the temperature would be checked whenever food waste is added.[9] Over the course of five days, material in the tumbler would decompose into compost and slowly makes its way toward the output end. Completed compost spills out the end of the tumbler into a concrete bin where it can be scooped up by the backhoe and placed in a nearby pile. At this stage, the composting process is 75% done. (The thermophilic bacteria have done their work, but the mesophilic bacteria are needed to finish the process.) Each curing pile sits statically for about two weeks until the internal temperature drops below 32°C.[10] At this point, samples would be collected and analyzed for pathogens, weed seeds, or other harmful substances. Wellesley would have to check the quality and safety of the compost by performing tests at a third-party certified soil lab. This would yield unbiased results and ensure high quality compost. Additional tests for educational purposes could be done at the College's labs. If deemed satisfactory, the compost would be ready to be screened (to take out any large chunks) and then stored for later use.

A tumbler, about twelve meters long and three meters wide, would be able to process 100% of Wellesley's organic waste, which amounts to one metric ton per day during the academic year. The tumbler would require a space that is equivalent to two standard parking spaces end-to-end and has a solid flat surface. Additional space outside of the tumbler would be needed to accommodate curing piles, completed compost piles, and feedstock material. Together, these piles would take up an area equivalent to three or four parking spaces. The site would also require electrical power and, depending on the type of motor, may require an industrial three-

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[8] Noiex Systems, "Biovator Manual." Accessed February 25, 2013. http://nioex.com/files/biovator_manual.pdf.
[9] Levy, Morgan. South Dade Soil & Water Conservation District, "In-Vessel Aerobic Composting of Organic Waste On Site And Re-use On Site For Environmental and Economic Advantage." Accessed February 25, 2013. http://www.southdadeswcd.org/wp-content/uploads/2010/10/White-Paper-on-In-Vessel-Composting-05-10-10.pdf.
[10] Levy, Morgan. South Dade Soil & Water Conservation District, "In-Vessel Aerobic Composting of Organic Waste On Site And Re-use On Site For Environmental and Economic Advantage." Accessed February 25, 2013. http://www.southdadeswcd.org/wp-content/uploads/2010/10/White-Paper-on-In-Vessel-Composting-05-10-10.pdf.

phase connection. People located near the site would be subjected to some noise from machinery and potential odor in the event of malfunction.

When choosing a location for tumblers on campus, we considered four areas: 1) the distribution center (DC lot) area, 2) south of the power plant, 3) North 40 near the community gardens, and 4) the yard waste site by the golf course (Figure 9-2). The first two options are not ideal due to space constraints and proximity to people's living and working spaces. In order to make room for tumblers near the North 40, trees would have to be cut down on the College's land, which we would want to avoid. We recommend the fourth option as the best location for an in-vessel compost tumbler because of the open space and distance from people's homes. To accommodate the tumbling method, concrete may need to be poured and electricity lines would need to be installed.

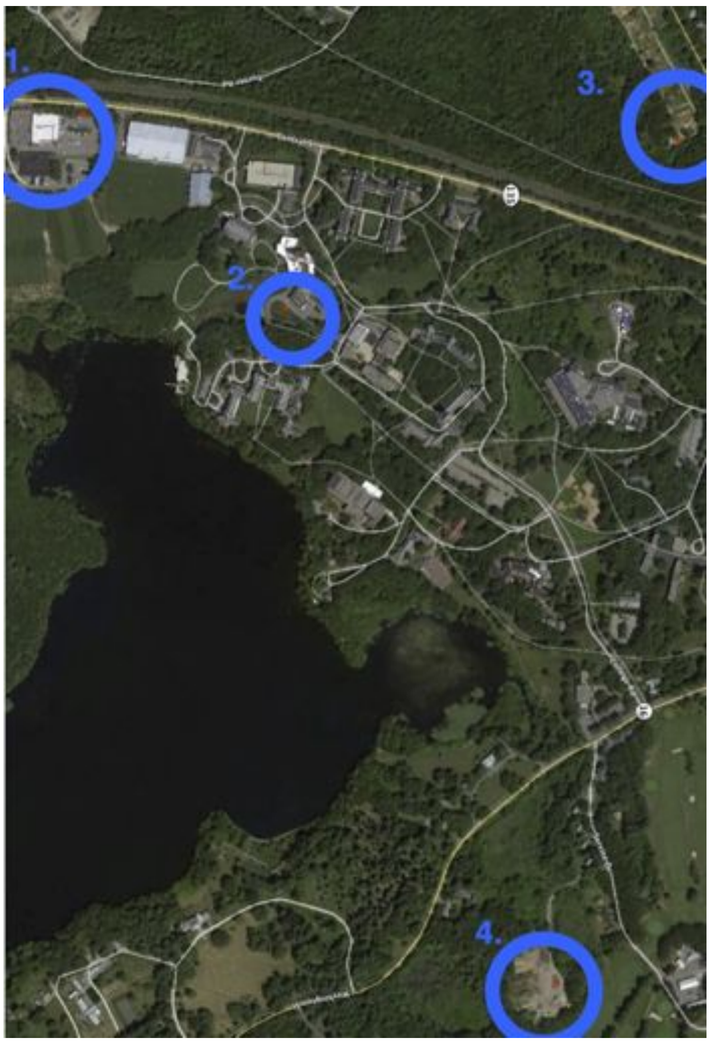

Figure 9-2: Potential locations for in-vessel composters on campus.

9.2.2 Technology/Equipment

On-campus implementation would require new equipment, space for the equipment and compost piles, and transportation.

Transportation

Figure 9-3: An example of a truck needed for transportation of food waste for in-vessel composting

To transport food waste across campus to the tumbler site, we recommend using the Freightliner swap loader dump truck (with a capacity of 12 cubic yards, or 9.175 metric tons), which Wellesley currently owns and operates on campus (Figure 9-3). The truck would do 2.5-mile loop two times per day (.004tkm/kg of food). The truck would require a custom-made watertight bed or a detachable dumpster-style container that could be dumped into the hopper of the tumbler. Trucks of this size typically run on diesel and have a fuel economy of about eight mpg with load.

Tumbler

Figure 9-4: In-vessel rotary composter [11]

Wellesley would need a tumbler roughly three meters in diameter and ten to twelve meters long in order to handle the estimated one metric ton in food waste per day during the academic year and the corresponding amount of wood chips for bulking material (Figure 9-4). Tumblers of this size typically use a five horsepower (hp) electric motor, which would run for four hours per day.[12] We recommend a tumbler with an attached hopper, built-in shredder, and input conveyor. The shredder likely uses a 5 hp motor and would be used for about 30 minutes per day. The conveyor would use a 1 hp motor and be used for about 30 minutes per day.

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[11] Picture source: http://tmaorganics.com/gallery.html
[12] Rotary Composters. "Products." Accessed February 25, 2013. http://www.rotarycomposters.com/products.html.

Backhoe

Figure 9-5: Backhoe owned by Wellesley College.

A backhoe would be used to put food waste from the collection truck into the tumbler (Figure 9-5). It would also scoop up finished compost, place it in piles to cure and possibly move the compost once finished. Assuming that the loader is stored at the service garage near the composting site, it would not travel a great distance, but would be operated roughly 30 minutes per day. A typical (100 hp) backhoe uses about 1.5 gallons of diesel per hour.[13]

9.2.3 Inputs

On-campus implementation would require energy and material inputs, in addition to the organic waste, to successfully produce compost.

Energy

On-campus operations would require about 13.7 kWh of energy per metric ton of organic waste.

Materials

[13] Volvo, "FAQs - Fuel Efficiency Guarantee." Accessed February 25, 2013. http://http://www.volvoce.com/constructionequipment/na/en-us/products/fuel-efficiency/Pages/faqs.aspx.

Table 9-1: Materials used for an on-campus in-vessel rotary composter

Component	Quantity	Material	SimaPro Processes
Tumbler Drum	1	Steel, low-alloyed, at plant/RER S	Welding, arc, steel/RER S & Hot rolling, steel/RER U
Tumbler Drum Insulation	1	Polystyrene foam slab, at plant/RER S	Foaming, expanding/RER S
Tumbler Wear Bars	1	Steel, low-alloyed, at plant/RER S	Hot rolling, steel/RER U
Tumbler Drum Motor (2 hp)	1	Electric motor, electric vehicle, at plant/RER S	
Tumbler Supports	2	Steel, low-alloyed, at plant/RER S	Hot rolling, steel/RER U
Concrete Slabs (glass fiber reinforced concrete)	5	Concrete block, at plant/DE S	
Conveyor/Auger	1	Steel, low-alloyed, at plant/RER S	
Auger Motor (1 hp)	1	Electric motor, electric vehicle, at plant/RER S	
Hopper/Grinder	1	Steel, low-alloyed, at plant/RER S	
Grinder Motor (5 hp)	1	Electric motor, electric vehicle, at plant/RER S	

The components of the system, the quantity needed, and the SimaPro listed materials and SimaPro manufacturing processes used for each component are listed in Table 9-1. In addition to the tumbler the system requires five concrete slabs (three for food waste/compost storage aboveground and two for supporting the tumbler), a conveyor to transport food into the tumbler, and a hopper/grinder to shred food deposited into the tumbler. Some components listed in Table 9-1 are subcomponents of the tumbler: the tumbler drum includes sprayed insulation outside the body of the tumbler in order to facilitate high temperatures inside the tumbler, tumbler wear bars prevent sand in compost from wearing away at the tumbler drum, and the tumbler supports act as a base.

Table 9-2: Estimated dimensions (volume and mass) used for an on-campus in-vessel rotary composter

Component	Dimensions (D=diameter, T=thickness)	Volume (each) (m^3)	Mass (each) (kg)	Mass (kg) (total)	Mass per functional unit
Tumbler Drum	40' x 8'D x 1" T	2.59	20,354.81	20,354.81	0.004
Tumbler Drum insulation	3"T	7.62	244.14	244.14	0.00004
Tumbler Wear Bars	.5"T	1.27	9,980.93	9,980.93	0.002
Tumbler Drum Motor (2 HP)			23.18	23.18	0.000004
Tumbler Supports	3" x 8' x 2'	0.11	888.07	1,776.13	0.0003
Concrete Slabs (glass fiver reinforced concrete)	8' x 8' x 6"	0.91	1,721.40	8,607.00	0.002
Conveyor/Auger	10' x .5' x 1'	0.14	1,115.98	1,115.98	0.0002
Auger Motor (1 HP)			17.05	17.05	0.000003
Hopper/ Grinder	8' x 2' bottom x 6' top x .5"T	0.33	2,601.33	2,601.33	0.0005
Grinder Motor (5 HP)			38.18	38.18	0.00001

Table 9-2 presents the estimated dimensions, volume, and mass (for each component, total and per functional unit) for each material needed for an on-campus in-vessel rotary composter. We also estimate that 27.5 meters of weld would be needed, given the weights of the 1 hp motor (17.01 kg), the 5 hp motor (38.10 kg) and the 2 hp motor (23.13 kg).

Method Inputs
Wellesley would need about half as much bulking material as organic waste in the tumbler in order to maintain the correct carbon to nitrogen ratio. This means we need at least 110 metric tons of tree waste for the total 220 metric tons of waste. Wood shavings, sawdust, used animal bedding, and wood chips may be used as bulking material, although existing tree waste on campus would be sufficient to meet the composting process needs. Depending on the water content of the food and the bulking material, water may need to be added in order to maintain moisture levels. Manure may need to be added to ensure the correct ratio of nitrogen, though this has not been added to our analysis because it is not a direct requirement of in-vessel composting. Another institution, Middlebury College buys manure from a local horse farm and stores it in piles at its composting site.

9.2.4 Outputs

While we do not include the avoided impacts of fertilizer in our analysis, it is worth noting that rotary in-vessel tumbling produces humus-rich compost, which can be used as a soil amendment to enhance soil quality. Using Middlebury College as a model, we recommend that the College use this compost as a soil amendment on the College grounds for landscaping projects, the athletic fields, and at the student and faculty garden plots on North 40. [14] If compost is leftover from campus use, we could offer the compost to faculty, staff, students, and anyone associated with the College for personal garden use. Using compost on campus would reduce transportation and labor costs associated with marketing, selling and distributing compost to outside farmers and gardeners, making it a logistically easier option.

9.3 Environmental Impacts of On-Campus Rotary In-Vessel Composting

9.3.1 Collection and Preparation of Organic Waste

Energy
No additional energy would be required for pre-tumbling collection and preparation of organic material.

Materials
No additional energy would be required for pre-tumbling collection and preparation of organic material.

Transportation of Organic Waste

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[14] Middlebury College, Compost Process. Accessed February 24, 2013. http://www.middlebury.edu/offices/business/recycle/compost.

Table 9-3: Use Phase operations for on-campus rotary in-vessel system

Use Phase (Operations)	Process	Mass per functional unit
Transport Food to Site (4 km loop, 0.5 ton, divide by 500 kg)	(We assume always carrying load) Small lorry transport, Euro 0, 1, 2, 3, 4 mix, 7,5 t total weight, 3,3 t max payload RER S	0.004 tkm/kg

A truck would drive a four km loop from the yard waste site, to the dining halls, and back to the yard waste site (Table 9-3). We assume that two trips would be made per day, each hauling .5 metric tons of food per trip. A front loader, at the yard waste site, would load the food waste from the truck into a grinder. An auger would then transport the ground food from the grinder to the tumbler. The tumbler, now filled with food waste, would turn for four hours a day.

9.3.2 Process

Wellesley College would be responsible for all of the environmental impacts associated with the systems processes.

Materials

A tumbler roughly three meters in diameter and ten to twelve meters long would be able to handle the estimated one metric ton of food waste per day and the corresponding amount of wood chips for bulking material. Thus 100% of Wellesley's food waste can be diverted through rotary-in vessel composting on campus. We recommend a tumbler with an attached hopper, built-in shredder, and input conveyor. The components of an in-vessel rotary composter system, including the materials the components are made from, are included in Table 9-4. Table 9-5 shows the estimated dimensions, volume, and mass (for each component, total, and per functional unit) for each material needed for an on-campus in-vessel rotary composter.

Table 9-4: Materials used for an on-campus in-vessel rotary composter

Component	**Quantity**	**Material**	**SimaPro Processes**
Tumbler Drum	1	Steel, low-alloyed, at plant/RER S	Welding, arc, steel/RER S & Hot rolling, steel/RER U
Tumbler Drum insulation	1	Polystyrene foam slab, at plant/RER S	Foaming, expanding/RER S
Tumbler Wear Bars	1	Steel, low-alloyed, at plant/RER S	Hot rolling, steel/RER U
Tumbler Drum Motor (2 hp)	1	Electric motor, electric vehicle, at plant/RER S	
Tumbler Supports	2	Steel, low-alloyed, at plant/RER S	Hot rolling, steel/RER U
Concrete Slabs (glass fiber reinforced concrete)	5	Concrete block, at plant/DE S	
Conveyor/Auger	1	Steel, low-alloyed, at plant/RER S	
Auger Motor (1 hp)	1	Electric motor, electric vehicle, at plant/RER S	
Hopper/Grinder	1	Steel, low-alloyed, at plant/RER S	
Grinder Motor (5 hp)	1	Electric motor, electric vehicle, at plant/RER S	

Table 9-5: Estimated dimensions, volume, and mass used for an on-campus in-vessel rotary composter

Component	**Dimensions (D=diameter, T=thickness)**	**Volume (each) (m^3)**	**Mass (each) (kg)**	**Mass (total) (kg)**	**Mass per functional unit**
Tumbler Drum	40' x 8'D x 1" T	2.59	20,354.81	20,354.81	0.004
Tumbler Drum insulation	3”T	7.62	244.14	244.14	0.00004
Tumbler Wear Bars	.5”T	1.27	9,980.93	9,980.93	0.002
Tumbler Drum Motor (2 HP)			23.18	23.18	0.000004
Tumbler Supports	3" x 8' x 2'	0.11	888.07	1,776.13	0.0003
Concrete Slabs (glass fiver reinforced concrete)	8' x 8' x 6"	0.91	1,721.40	8,607.00	0.002
Conveyor/ Auger	10' x .5' x 1'	0.14	1,115.98	1,115.98	0.0002
Auger Motor (1 HP)			17.05	17.05	0.000003
Hopper/ Grinder	8' x 2' bottom x 6' top x .5"T	0.33	2,601.33	2,601.33	0.0005
Grinder Motor (5 HP)			38.18	38.18	0.00001

Energy

Table 9-6: Use phase estimations for on-campus in-vessel rotary composting.

Use Phase (Operations)	Material	Process	Energy per functional unit
Loading and unloading with Front Loader	N/A	Excavator, technology mix, 100 kW, Construction GLO	4 kWh/metric ton
Running Grinder (5 HP motor, 1 ton/day, running 2 hours/day)	Electricity, natural gas, at power plant/US S	N/A	0.007 kWh/metric ton
Running Auger (loading) (1 HP motor, 1 ton/day, 1 hour/day)	Electricity, natural gas, at power plant/US S	N/A	0.0007 kWh/metric ton
Running Tumbler (2 HP motor, running for 4 hours/day, 1 ton/day)	Electricity, natural gas, at power plant/US S	N/A	0.006 kWh/metric ton

Energy to power the equipment would come from the College’s on-campus cogeneration plant (Table 9-6).

9.3.3 Avoided Impacts

Since this study does not consider compost as an on-campus avoided impact, there are no avoided impacts for tumblers.

9.3.4 Water Use

We predict that this method would use a negligible amount of water. Water use is fairly minimal and would be used to wash-down the bed of the dump truck or other containers. Given that food waste must be packed in compostable plastic garbage bags, water use would be no different than what is currently used for washing the truck. The composting process itself would likely not require any water usage.

9.3.5 Summary: Life Cycle Impacts and Assessment of Rotary In-Vessel On-Campus Composting

Table 9-7: Environmental impacts by process stage, on-campus in-vessel rotary composting

Impact category	Unit	Transportation	Method	Use Phase	Total
Global warming	kg CO2 eq	0.000546	0.013319	0.017620	0.031485
Carcinogenics	kg benzene eq	0.000000	0.000114	0.000012	0.000126
Ecotoxicity	kg 2,4-D eq	0.000002	0.051417	0.001262	0.052681

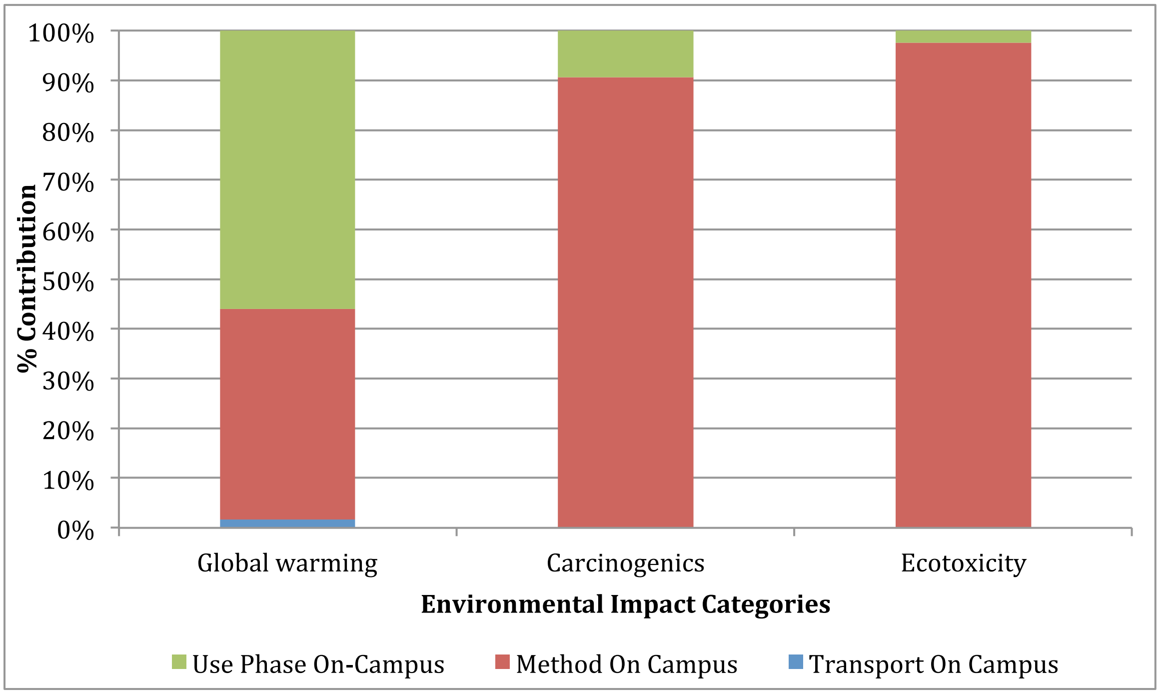

Figure 9-6: Percent contribution of process stages to each impact category, on-campus tumblers

Figure 9-6 shows the relative environmental impacts of each stage of organic waste diversion to an on-campus rotary in-vessel composting system. While all four stages contribute to impacts, the method stage demonstrates the highest impact to carcinogens and eco-toxicity while the use phase contributes most to global warming potential.

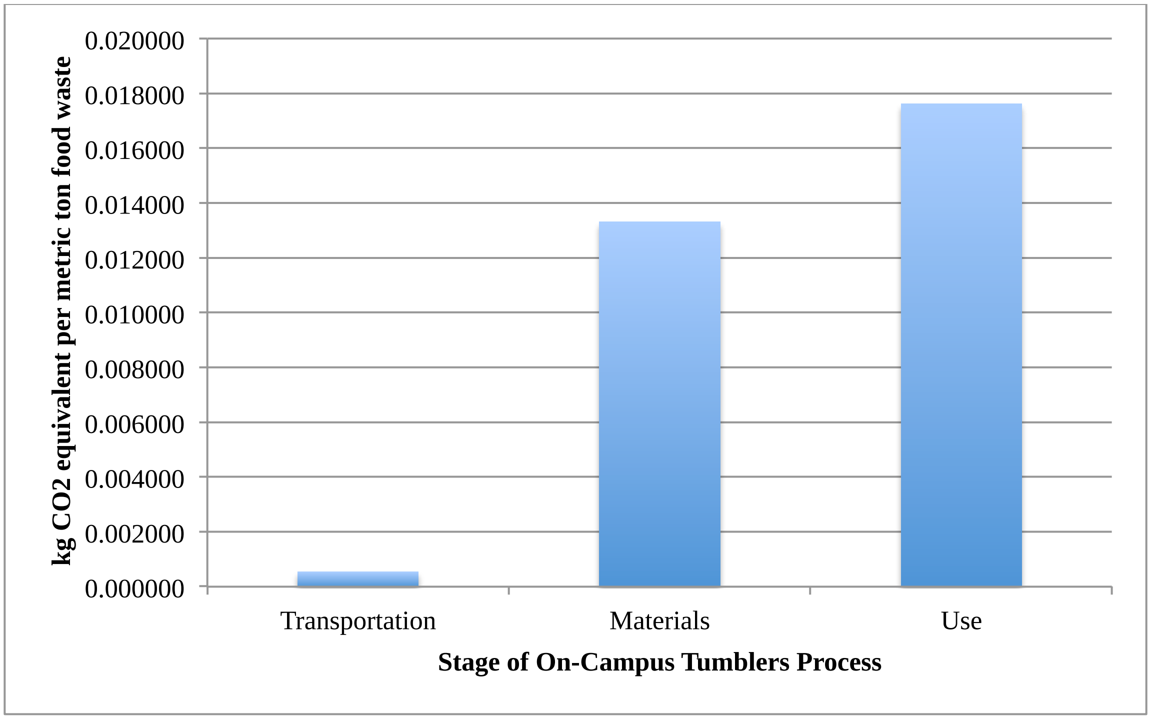

Figure 9-7: Climate change impact of each process stage, on-campus in-vessel rotary composting

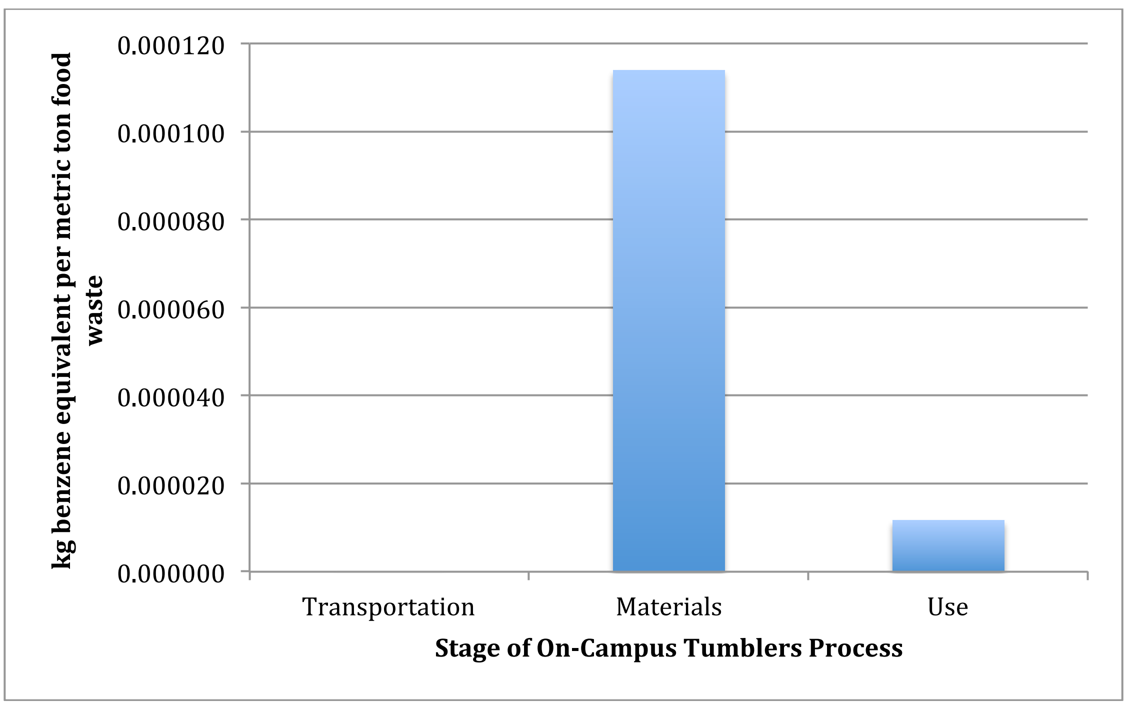

Figure 9-8: Human toxicity impact of each process stage on-campus in-vessel rotary composting

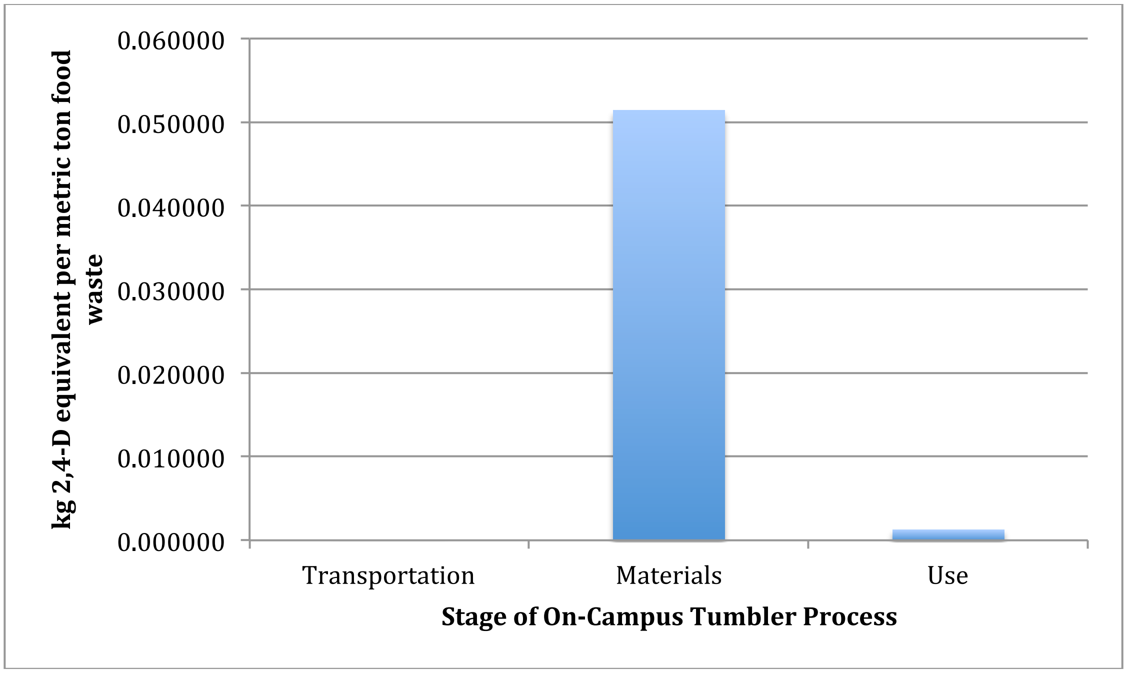

Figure 9-9: Ecosystem toxicity impact of each process stage, on-campus in-vessel rotary composting

The analysis above shows the method stage, which includes the materials and manufacturing processes, to have the greatest environmental impact. By characterizing impact per process, we find that the majority of the ecotoxicity impacts occur through the steelmaking process, which includes steel resource extraction and the hot rolling manufacturing process to create the tumbler. The majority of global warming emissions results stem from the use phase, which includes electricity production at the College's cogeneration plant.

9.4 Costs of Rotary In-Vessel Composting On-Campus

To determine the costs of this method, we envision a system that could process 100% of Wellesley's food waste, estimated at 220 metric tons per year. According to our food waste estimate, Wellesley generates 90% of its food waste during the school year, equaling about 1 metric ton per day.

9.4.1 Direct Cost

There would be no direct costs for this method because we would not be paying any facility to take in our food waste.

9.4.2 Operational Cost

Transportation Cost
Wellesley owns a mid-size Freightliner dump truck, which we recommend using for transporting food to the composting site. It would travel about five miles to transport one metric ton of food

per day. With a fuel efficiency of eight mpg, this transportation would cost $2.50 in diesel per metric ton of food.

Labor Costs
At the composting site, a facility operator would be needed for approximately 2.5 hours per day. The operator would drive the backhoe to the compost site from the service garage at Service Drive and use it to put food waste into the tumbler and add appropriate amounts of bulking material. The operator would also monitor the temperature and conditions of the composting process, attend to equipment issues, and move the compost into curing piles once it comes out of the tumbler. Twice per day, the operator would spend about 15 minutes filling the grinding hopper, 30 minutes running the grinder, and about 30 minutes running the grinder and loading auger. During grinding and loading, the operator should be on site in case of problems, but could use the time to take measurements, conduct maintenance, and move compost into curing piles. We estimated this person's wage at the College's grounds worker rate of $32.97/hour.[15]

In addition, a truck driver would be needed for approximately one hour per day. This person would drive the small dump truck to each of the dining halls and load in food waste from 60-gallon toters into the truck using a hydraulic lift. The driver would dump the food at the composting site where the facility operator would load it into the tumbler with the backhoe. We estimated this person's wage at the College's dining hall deliveries worker rate of $31.41/hour.[16]

A dining hall worker at each of the five dining halls would need to bring the compost out to the loading dock for pickup. Since this labor would not be significantly different than the current process of taking food waste out as trash, it will not contribute to the cost of this composting method.

In total, $113 in labor would be required per metric ton of food waste.

Energy Costs
About 13.7 kWh of electricity would be needed per day to run the composting facility. This electricity goes to running the 2 hp motor on the tumbler four hours per day, the 1 hp motor on the loading auger one hour per day, and the 5 hp motor on the grinder two hours per day. At $0.11 per kWh, electricity would cost $1.51 per day.

Wellesley College owns a backhoe that could be used to for loading food and bulking material into the grinding hopper and moving compost into piles once it comes out of the grinder. We estimate that this task would take one hour per day. A machine of this size typically uses about 1.5 gallons of diesel per hour, costing $6 per day.[17]

In total, energy costs would be approximately $7.51 per metric ton of food waste.

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[15] Patrick Willoughby. Director of Sustainability. Class Communication. March 11, 2013. These wage rates include benefits, which add up to 30% of the original hourly rate.
[16] Patrick Willoughby. Director of Sustainability. Class Communication. March 11, 2013.
[17] Volvo, "FAQs - Fuel Efficiency Guarantee." Accessed February 25, 2013. <http://http://www.volvoce.com/constructionequipment/na/en-us/products/fuel-efficiency/Pages/faqs.aspx>.

Other Operational Cost
A service contract on the composting equipment would cost about $1000 per year[18] and would equal $4.54 per ton of food waste.

This composting method requires bulking material, such as leaves and wood chips, are added to the food waste before processing. The College campus already produces about 110 metric tons of this material per year.[19] We recommend that the process should use the campus-generated material mixed with the food waste in a mass ratio of two parts food waste to one part yard waste. With this ratio, the College will not need to purchase additional bulking material.

We predict that this method would use only a negligible amount of water and, therefore, incur no water cost.

9.4.3 Equipment

Tumblers sized to handle Wellesley's level of waste generally hold about 48 cubic yards (37 cubic meters) in volume and cost $160,000 to $240,000.[20] The expected lifetime of these units is about 20 years.[21] Multiple smaller composters are roughly cost-comparable to a single large composter and could be considered for added redundancy. Add-ons such as the grinding hopper and in-feed auger typically add about $40,000 to the cost. We assumed that these costs included freight charges and installation.

Concrete slabs would need to be poured for the tumbler's foundation. We estimate that we would need four 8'x8' slabs, which would cost $1000 with a lifetime of 20 years.[22]

A power line would need to be run to the tumbler from Service Drive. It would be approximately 500 feet long and we estimate it would cost $1500 with a lifetime of 20 years.

We did not include the cost of buying a backhoe since the College has one already. We also did not include the cost for permits.

The total cost of the equipment, given the lifetime of each piece, would be approximately $46 per metric ton of food waste.

9.4.4 Offset Cost

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[18] Patrick Willoughby. Director of Sustainability. Class Communication. March 11, 2013.
[19] Wellesley College ES300, "Waste Not, Want Not: An Environmental Impact Assessment of the Wellesley College Waste Stream and Steps for a More Sustainable Future." Last modified 2012. Accessed March 25, 2013. http://new.wellesley.edu/sites/default/files/assets/departments/environmentalscience/files/es300-2012-wastenotwantnot.pdf. 197.
[20] Bonhotal, Jean, Mary Schwarz, and Gary Feinland. "In-Vessel Composting Options for Medium-Scale Food Waste Generators." *BioCycle* (2011): 49-53. Web. 11 Mar 2013. <http://cwmi.css.cornell.edu/invesselcomposting.pdf>.
[21] Noiex Systems, "Biovator User Manual." Accessed March 25, 2013. http://nioex.com/files/biovator_brochure.pdf.
[22] "Cost to Install a Concrete Pad." *Homewyse.com*. Homewyse - Smart Home Decisions, Jan. 2013. Web. 9 Mar.

Since this study does not consider compost as an on-campus avoided impact, there are no offset costs for tumblers.

9.4.5 Summary: Cost of Rotary In-Vessel Composting On-Campus

Table 9-8: Cost of on-campus in-vessel rotary composting

Cost Category		Amount ($/Metric Ton)
Direct:		
	Facilities	$0
	Transportation	$0
Operational:		
	Transportation	$2.50
	Labor	$113.00
	Other	$12.05
Equipment		$46.00
Offset costs		$0
Total Cost		**173.55**

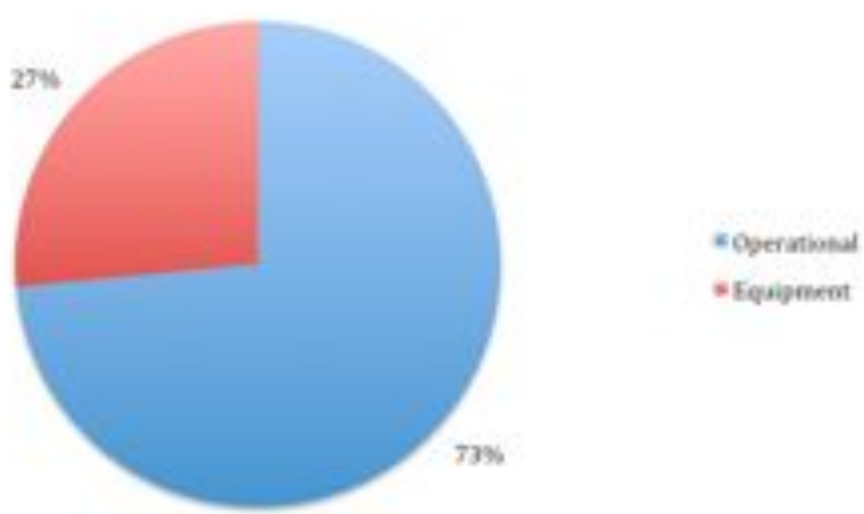

Figure 9-10: Cost of on-campus in-vessel rotary composting

The total cost for tumbling on campus is $173.55 per metric ton of food waste (Table 9-8). Labor accounts for about 64% of the total cost and is the largest cost contributor to this compost operation. To reduce this cost it is possible to create student volunteer or work-study positions for easier tasks such as collecting waste from dining halls or monitoring curing piles. This option would create student employment, while simultaneously allaying costs that may arise from having the College's workers do additional work. Increasing the level of automation involved in the process and reducing the frequency of food pick-ups from dining halls could also reduce the cost. For example, we assumed for safety reasons, a person should be on site for the two hours per day the grinding hopper is running. If it were deemed safe to run the hopper without supervision, then the labor required would be considerably less. Equipment is responsible for about 26% of the cost. Extending the lifetime of the equipment could reduce this contribution. For example, it is possible that building a roof over the tumbler would double its lifetime and thus the unit cost of the equipment would decrease. According to our estimates, the compost created by this method would offset enough fertilizer to cover about 86% of its production cost.

9.5 Social Impacts of Rotary In-Vessel Composting On-Campus

9.5.1 Campus Experience - Positive

We give on-campus rotary in-vessel composting an overall positive score for campus experience for two reasons. This method does not diminish the aesthetic beauty of the campus not does it occupy land near student activities or housing. It would be a source of pride because Wellesley would be seen as an innovative institution; examples of this method at other colleges did not compost 100% of their waste, so implementing this method for 100% of waste diversion at Wellesley would provide a model to other institutions.

9.5.2 Educational Benefit - Neutral

We give this method a neutral overall score for education because it offers high academic opportunities but low visibility. Academic opportunities are high because the composting process and end products are academically interesting for physics, geosciences, and environmental studies classes. Since the tumbler would be located within walking distance of campus it is accessible for laboratory courses and field trips. In terms of visibility, students would not be able to work directly with the method, because it requires knowledge of heavy machinery and may involve liability issues; work would best be done by Wellesley College staff.

9.5.3 Implementation Difficulty

Separation- Low
This method receives a low ranking for the separation required. All types of food can be composted with this method, making the separation process fairly straightforward. Food waste would have to be separated from non-organic waste, but no further separation of food would be required.

Permitting and Regulations - Medium

It is likely that the construction of a rotary in-vessel composter on campus-owned land would require compliance with the Town of Wellesley's Zoning Bylaws. Based on the permitting criteria for construction projects administered by the Town of Wellesley, a rotary in-vessel tumbler would not be categorized as a major construction project or a project with significant impacts, but rather would be categorized as a minor construction project.[23] Such a permitting process involves a design review and a site plan review, but would not require an extensive permitting process.[24]

Time until Implementation - Medium
This method could be implemented on a longer time frame. Implementation would require several processes: equipment purchase, delivery and installation of the tumbler, training of workers and development of standard operating procedures, construction of concrete padding and an electrical extension, and a successful completion of the Town of Wellesley's permitting process. These processes, while not insignificant, would not take more than five years, but would likely take longer than one year.

Risk - Low
This method has low risk, as potential risks associated with composting - including bacteria in food waste, leachate of post-tumbled compost, and odors or gases - are avoided with tumbling. The method of hot composting reaches temperature up to 160 ℉, which kills any bacteria that might have been present in food waste and leads to low risk of bacteria after the composting is complete. Additionally, when in the sealed tumbler, the food waste would not attract pests. Once outside of the tumbler, the end product would be distributed in piles and would likely not produce large amounts of leachate. This end product is 75% fully decomposed. When placed it piles, it would cure outside the tumbler and essentially decompose to fulvic and humic acids and stabilized organic carbon, making the compost less attractive to pests.

Additionally, we do not see leachate being a primary concern with this method: the tumbler would rest on a concrete pad and the consistency of the end product is similar to soil. By lining the curing area with an impermeable material, we would significantly reduce risk of leachate runoff. If problems with leachate arise, a collection method could be implemented in order to avoid runoff into groundwater or surrounding area. The in-vessel method produces gas and odors, but these are contained within the vessel, making this a low-risk method for smells. Risk of combustion in vessel is low.

9.5.4 Social Justice - Neutral

We give this method a neutral score for social justice. If the method is done well, workers are exposed to minimal risk. Additionally, the workers would be only work with the tumbler if they were trained with heavy machinery. Social justice would rank positively if there were a mechanism for employees to offer feedback and be involved in management concerning the

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[23] Town of Wellesley Zoning Bylaws: Section XVIA: Project Approval. Accessed March 9, 2013. http://www.wellesleyma.gov/Pages/WellesleyMA_Planning/ZB/XVIA.pdf.

[24] Town of Wellesley Zoning Bylaws: Section XVIA: Project Approval. Accessed March 9, 2013. http://www.wellesleyma.gov/Pages/WellesleyMA_Planning/ZB/XVIA.pdf.

method. It would be positive if it gave meaningful employment, which depends more on how the College would manage this method and not the method itself.

9.5.5 Summary: Social Impacts of Rotary In-Vessel Composting On-Campus

Table 9-10: Social impacts of on-campus in-vessel rotary composting

Social Impact		Score
Campus Experience		Low
Educational Benefit		Neutral
Difficulty:		
	Separation	Low
	Permitting and Regulations	Medium
	Time Until Implementation	Medium
	Risk	Low
Social justice		Neutral

9.6 Conclusions

On-campus tumblers would help Wellesley College successfully divert its organic waste. This method works in all weather types, could handle 100% of Wellesley's food waste, and would create a quality and consistent product. Additionally, this method would have an institutional benefit, since it would show Wellesley as a leader in sustainable and innovative waste diversion options. With a cost of $178 per metric ton, this method would be considerably more expensive than Wellesley's current incineration-based disposal. The downsides of this option include a large upfront cost and significant efforts by College personnel in order to implement the system. Changes in worker contracts and responsibilities would need to be arranged, and permits would need to be obtained from the Town of Wellesley. The logistics of trucking waste from locations around campus to the waste site would also need to be arranged. While it may be possible for this method to meet the 2014 deadline, it is likely that it will take longer than one year to implement.

10.0 Rotary In-vessel Composting Off Campus

Figure 10-1: Rotary in-vessel composting

10.1 Introduction to Rotary In-Vessel Composting Off-Campus

See section **9.1** for detailed description of tumbling processes.

10.2 Overview of Implementation at Wellesley

10.2.1 Overview of Implementation at Wellesley

Of the 23 food waste composting facilities currently operating in Massachusetts, three utilize rotary in-vessel composting. These three facilities are Rocky Hill Farm in Saugus, MA (27 miles away from Wellesley); Waste Options - Bedminster Nantucket in Nantucket, MA (107 miles away from Wellesley); and WeCare Environmental in Marlborough, MA (16 miles away from Wellesley).[1] If Wellesley chooses to implement off-campus rotary in-vessel composting, we suggest using the WeCare facility in Marlborough, MA because it is the closest geographically to Wellesley and is currently used to divert Wellesley's pre-consumer organic waste from dining halls and the Ruhlman and Tanner Conferences. This facility will be the basis of our analysis.

[1] MassDEP. "Permitted food residuals processors." Accessed February 23, 2013. http://www.mass.gov/dep/recycle/reduce/fcdcmpst.pdf.

The WeCare facility in Marlborough contains two rotary digesters measuring 12.5 feet in diameter and 185 feet in length.[2] Each rotary digester has the ability to process 90 metric tons of organic waste per day, making this facility large enough to accommodate 100% of our food waste. Based on the assumption that Wellesley produces one metric ton of food waste per day during the academic year, the College's food waste would make up 0.005% of WeCare's total capacity.

In order for Wellesley to send 100% of its organic waste to WeCare, the College must first separate its organic waste from the rest of its waste stream, collect it from all dining halls, and store it on campus before it is hauled to WeCare. The College must also contract an organic waste hauler to bring it to the digester site. The number of trips made to WeCare would depend on the amount of waste generated and the volume capacity of trucks used to transport the waste.

See Section **9.2.1** for more specifications on the general in-vessel process.

10.2.2 Technology/Equipment

Wellesley would not have to buy any equipment for off-campus rotary in-vessel. The College would need to hire an external hauling contractor to drive an 8,000-gallon truck from Wellesley to the tumbler site.

10.2.3 Inputs

In order to determine the materials and inputs for WeCare, we scale up the respective impacts from our example on-campus operation analyzed in Chapter 9.0 by 90 times, since similar materials and manufacturing processes are used for industrial tumblers. Based on our one metric ton assumption, Wellesley's food waste at WeCare would make up only 0.005% of WeCare's total capacity and inputs.

Energy
We estimate that processing one metric ton of waste would require about 6 kWh of electricity,[3] but this is difficult to estimate since we have few details of the WeCare facility's equipment.

Materials
Even though we are employing an off-campus rotary in-vessel composting system, we assume responsibility for Wellesley's share of the materials since our waste would contribute to the use of the equipment. In order to determine the materials and inputs for WeCare, we scale up the respective impacts from our example on-campus operation from Chapter 9.0 by 90 times.

10.2.4 Outputs

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[2] Spencer, Robert L. AICP. "Food waste composting in Massachusetts: Rotary drums and in-vessel technologies." Accessed February 24, 2013. http://swanachapters.org/Portals/2/Spencer_InVessel_CompostingSWANA09.pdf
[3] Assumption, estimated from previous analysis in Section 9.0.

Rotary in-vessel composting produces humus-rich compost, which can be used as a soil amendment to enhance soil quality. Compost created by this process would contribute to a decreased demand for chemical fertilizers, which are currently used as soil amendments.

10.3 Environmental Impacts of Rotary In-Vessel Composting Off-Campus

10.3.1 Collection and Preparation of Organic Waste

Energy
No additional energy would be required for pre-tumbling collection and preparation of organic material.

Materials
No additional materials would be required for pre-tumbling collection and preparation of organic material.

Transportation
Our off-campus scenario involves transporting Wellesley's food waste to the WeCare facility in Marlborough, MA. We assume two trips would be made per week in a truck that Wellesley already owns.

10.3.2 Process

Materials
In order to determine the materials and inputs for WeCare, we scale up the respective impacts from our example on-campus operation from Section 9.0 by 90 times.

Energy
At the facility, we account for the electricity used by a drum motor, screener motor, and a front loader (to transport processed waste to a curing area) in order to process the waste created by Wellesley College. To account for the number of times food waste is loaded and unloaded with the front loader, we assume four kg are moved per kg of food waste. Details are found in Table 10-1. In terms of operations, Wellesley's one metric ton of food waste per academic day would make up 1.11% of WeCare's total operations impact. In order to determine the environmental impacts for WeCare, we scale up the respective impacts from our simulated on-campus operation by 90 times, since similar materials and manufacturing processes are used for industrial tumblers, and because WeCare's facility handles 90 times more waste than on-campus.

Table 10-1: Off-campus use-phase estimations for in-vessel rotary composting

Use Phase	Process	Mass per functional unit
Transport Food to We Care (Assume trip 2x week)	(we assume always carrying load) Small lorry transport, Euro 0, 1, 2, 3, 4 mix, 7,5 t total weight, 3,3 t max payload RER S	0.045 tkm
Drum Motor (2 HP)	Electricity, production mix US/US S	0.006 kWh
Screener Motor	Electricity, production mix US/US S	0.0007 kWh
Front Loader for curing	Excavator, technology mix, 100 kW, Construction GLO	4 kg/kg

10.3.3 Avoided Impacts

Each metric ton of food waste composted results in about 0.75 metric tons of compost. We assume that each metric ton of compost offsets 0.25 metric tons of fertilizer. Thus, each metric ton of food waste diverted by Wellesley College corresponds to 0.375 metric tons of fertilizer.

10.3.4 Water Use

We predict that this method would use a negligible amount of water.

10.3.5 Summary: Life Cycle Impacts and Assessment of Rotary In-Vessel Composting Off-Campus

Table 10-2: Environmental impacts by process stage, off-campus in-vessel rotary composting

Impact category	**Unit**	**Total Off Campus**	**Transport Off Campus**	**Method Off Campus**	**Use Phase Off Campus**
Global warming	kg CO2 eq	0.035	0.0061	0.015478	0.034938
Carcinogenics	kg benzene eq	0.0001	4.8698E-07	0.000005	0.000119
Ecotoxicity	kg 2,4-D eq	0.0661	2.73392E-05	0.000223	0.051667

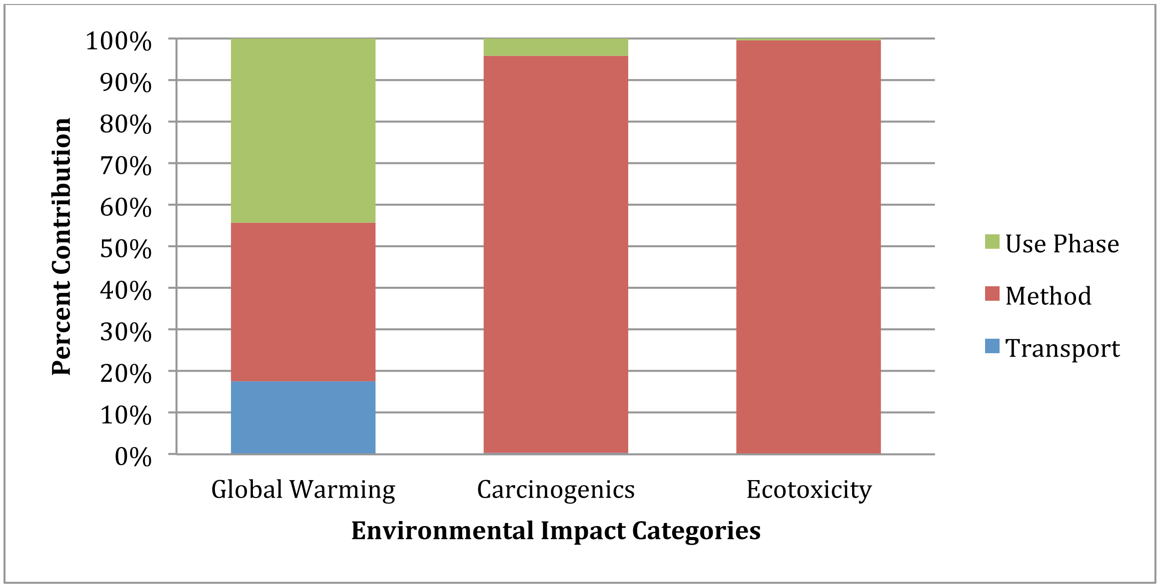

Figure 10-2: Percent contribution of process stages to each impact category, off-campus tumblers.

Figure 10-2 reveals the relative environmental impacts of each stage of organic waste diversion to an off-campus rotary in-vessel composting system. While all four stages contribute to the environmental impacts, the Method phase contributes the highest impact to Carcinogens and Eco-toxicity while the Use Phase contributes most to Global Warming potential.

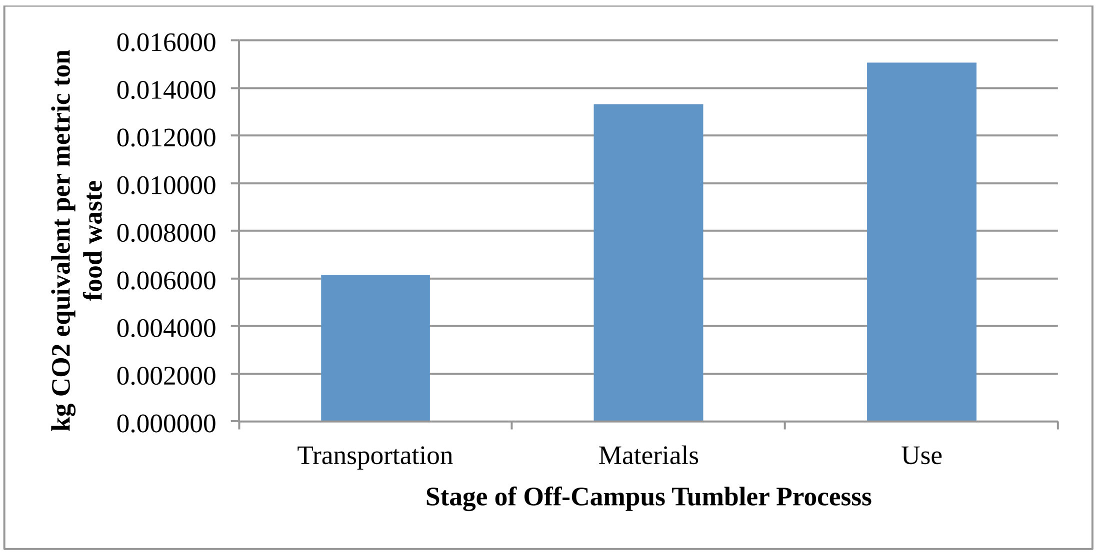

Figure 10-3: Climate change impact of each process stage, off-campus tumblers

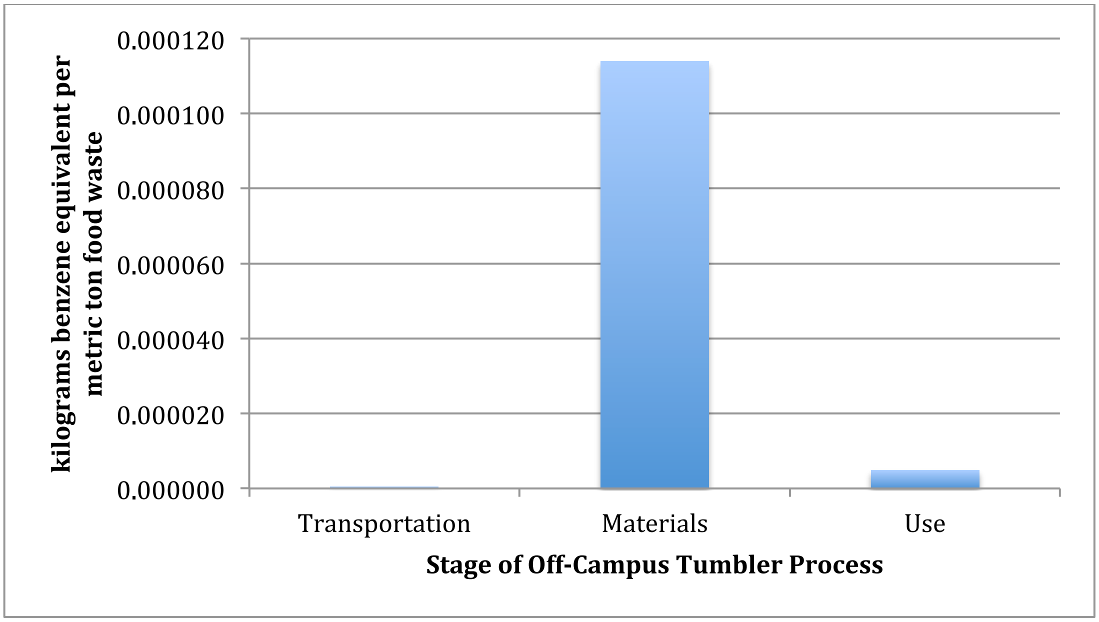

Figure 10-4: Human toxicity impact of each process stage, off-campus tumblers

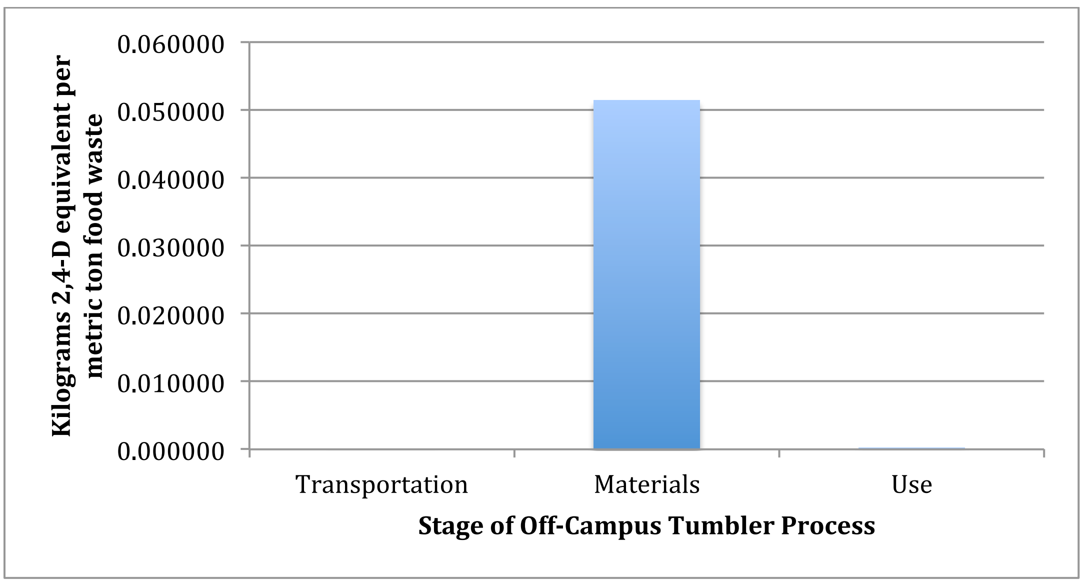

Figure 10-5: Ecosystem toxicity impact of each process stage, off-campus tumblers

The analysis in Table 10-2 and Figure 10-1 shows the Materials stage has the greatest environmental impact. The Materials category includes the materials and manufacturing processes of the system. By characterizing impact per process, we find that the majority of ecotoxicity impact occurs through the steelmaking process, which includes steel resource extraction and the hot rolling manufacturing process to create the tumbler. Thus, in order to reduce Method impacts, we would need to exclude steel processes. This does not seem like a viable possibility, because a majority of rotary in-vessel composters are comprised of this material.

Most emissions that contribute to Global Warming potential occur in the Use phase. These emissions are produced from the front loader in moving finished compost to a curing pile, and from electricity use and diesel. Transportation accounts for a much greater percentage of the climate change impact off campus than on campus (Figure 10-2) because the distance traveled to deliver food waste to WeCare is greater than the distance traveled from dining halls to the yard waste site.

10.4 Costs of Rotary In-Vessel Composting Off-Campus

The costs for this method would be entirely direct costs paid for transportation and disposal.

10.4.1 Direct Cost

Tipping Fees
The WeCare facility has a quoted tipping fee of $65 per short ton[4] ($72 per metric ton). This covers the energy, labor, equipment, and operating costs for the facility.

Trucking Fees
We estimate that a trucking company would charge $61 per metric ton to haul our food waste to Marlborough, MA. This covers all of the company's costs including fuel, labor, equipment, and other operating costs.

10.4.2 Operational Cost

There would be no operational costs for this scenario. The direct costs would cover the costs for transportation, labor, and energy costs. The energy and labor required on campus would not be significantly different from the amount currently required to dispose of food waste as trash.

10.4.3 Equipment

This method would not pose any equipment costs for Wellesley because WeCare and the trucking company would own all of the equipment required. Any necessary on-campus equipment and infrastructure would be the same as what is currently used for disposing of food waste as trash.

10.4.4 Offset Cost

The compost created at WeCare would not offset any costs for the College.

10.4.5 Summary: Cost of Rotary In-Vessel Composting Off-Campus

The total cost for tumbling off campus would be $117 per metric ton of food waste. WeCare's tipping fee accounts for 61% of the cost and the rest is for trucking. Currently, the College uses a

[4] Employee at WeCare. Interview by Mische Kang. March 3, 2013.

trucking company called EOMS trucking to take food waste to WeCare. The company charges the College $55 per short ton ($61 per metric ton), which includes the cost of transportation and the facility tipping fee. It is unclear why the company can operate for so much less than our general estimate of $117 per metric ton, but it is possible that there is an additional source of profit or income, or that the company is taking a current loss to set a good impression and hopes to make money from the College's business in the future.

Table 10-3: Cost of Rotary In-Vessel Composting Off-Campus

Cost Category		**Amount ($/Metric Ton)**
Direct:		
	Facilities	$72
	Transportation	$61
Operational:		
	Transportation	$0
	Labor	$0
	Other	$0
Equipment		$0
Offset costs		$0
Total Cost		$117

10.5 Social Impacts of Rotary In-Vessel Composting Off-Campus

Check **Table 10-4** for reference for our Social Costs of our method.

10.5.1 Campus Experience - Neutral

We give this method a neutral ranking for campus experience. The method does not affect the physical appearance or function on campus. Waste would simply be transported to a different location.

10.5.2 Educational Benefit - Negative

There is a lack of educational opportunities for this method because of its low visibility. Even now, as we plan for composting our organic waste, we are unable to contact WeCare or visit the facility. It is doubtful that this lack of communication would change in the near future. Visibility is relatively low because the method would be off campus.

10.5.3 Implementation Difficulty

Separation - *Low*
This method receives a low ranking for separation required. All types of food can be composted with this method, making the separation process fairly straightforward. Food waste would have to be separated from non-organic waste, but no further separation of food would be required.

Permitting and Regulations - *Low*
This method receives a low ranking for permitting and regulations. The pre-consumer food waste pilot project in the dining halls has already acquired a permit for rubbish haulers with the Wellesley Department of Health to transport waste from Wellesley College to the WeCare facility in Marlborough, MA. We would simply need to expand the scope of the project to include post-consumer food waste from all the dining halls. Besides this, there are no other permits required by Wellesley College.

Time until Implementation - *Low*
This method would be implemented immediately, giving it a low ranking for time until implementation. Since this method is already occurring on campus through small-scale pilot programs, we would need to expand the program and the logistics of this process. There would be no building requirements or permits to apply for. This method would potentially start in a few weeks.

Risk - *Low*
In terms of risk, this method receives a ranking of low. Our waste is easy to collect and we do not need to account for possible contamination within WeCare's facility. The cleanliness of the bins and safe storage of the waste before being trucked to WeCare are the only factors that would increase risk. As long as materials are kept clean and are well-maintained, there would be low risk.

10.5.4 Social Justice - Neutral

We give this method a neutral ranking for social justice. Unless WeCare treats its workers unfairly, the facility and the process do not pose any risk to employees.

10.5.5 Summary: Social Impacts of Rotary In-Vessel Composting Off-Campus

Table 10-4: Social Costs of off-campus rotary in-vessel composting.

Social Impact		**Score**
Campus experience		Neutral
Educational benefit		High
Difficulty:		
	Separation	Low
	Permitting and regulations	Low
	Time until implementation	Low
	Risk	Low
Social justice		Neutral

10.6 Conclusions

This method is easy to implement because it would only require an expansion of the current pre-consumer food waste pilot project in the dining halls. The implementation of off-campus rotary in-vessel composting would cost $117 per metric ton. One important aspect to consider with this method is maintaining a working relationship with WeCare. This method does not provide academic opportunities for the students and would not show the same level of innovation and leadership as an on-campus tumbler. Rather, this method would be a “business-as-usual” solution (Wellesley already hauls waste off campus), meaning that Wellesley would not stand out as a sustainable innovator. The ease of implementation may compel Wellesley College to consider this method as a first step in organic waste diversion: Wellesley would easily implement this method before the Organic Waste Ban while it considers other long-term or on-campus options that would not be ready for implementation by 2014.

11.0 Anaerobic Digestion On Campus

11.1 Introduction to Anaerobic Digestion

Anaerobic digestion is a biological process in which microorganisms break down organic material in the absence of oxygen.[1] Almost any biomass can be decomposed using anaerobic digestion, including any residuals, fats, oils and grease. An anaerobic digester is therefore capable of processing food waste, crop residue, manure, municipal water solids, and industrial wastewater.[2] Only materials containing lignin, a polymer found in the cell wall of rigid plants or trees, cannot be broken down by microorganisms.[3]

The anaerobic digestion process has two byproducts: digestate and biogas. Digestate is a nutrient-rich effluent that consists of water, dead microorganisms, minerals, and approximately half of the carbon concentration of the inputs.[4] For every ton of waste processed, anaerobic digestion will yield 2.3 to 4.2 kilograms of nitrogen, .2 to 1.5 kilograms of phosphorus, and 1.3 to 5.2 kilograms of potassium. Because of the thigh level of nutrients, digestate can be used as a fertilizer and soil conditioner.[5]

Biogas, the second byproduct, consists of roughly 60% methane and 40% carbon dioxide.[6] The ratio of methane to carbon and the traces of other contaminant gases formed will depend on the feedstock digested.[7] Biogas is combusted to generate electricity and heat. It can also be processed into natural gas and transportation fuels.[8] Energy from the biogas produced via anaerobic digestion is often used to power the digestion system itself.

Temperature plays a crucial role in the system size and processing ability of the anaerobic digester. There are three main temperature ranges for anaerobic digestion systems: thermophyllic, mesophylic, psychrophylic. Thermophyllic systems operate at the highest temperature, roughly 50 to 60 degrees Celsius. Because of the high heat, microorganisms rapidly break down organic matter.[9] Mesophylic systems operate between a temperature of 25 to 40

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[1] Ontario Ministry of Agriculture and Food. “Anaerobic Digestion Basics: Fact Sheet.” Accessed February 24, 2013. http://www.omafra.gov.on.ca/english/engineer/facts/07-057.htm#1

[2] American Biogas Council. “What is Anaerobic Digestion?” Accessed February 24, 2013. http://www.americanbiogascouncil.org/biogas_what.asp

[3] NNFCC: The Biochemical Consultants. “What is Anaerobic Digestion?” in The Official Information Portal on Anaerobic Digestion. Accessed February 23, 2013. http://www.biogas-info.co.uk/index.php/ad-basics

[4] NNFCC: The Biochemical Consultants. “What is Anaerobic Digestion?”

[5] NNFCC: The Biochemical Consultants. “What is Digestate?” in The Official Information Portal on Anaerobic Digestion. Accessed February 23, 2013. http://www.biogas-info.co.uk/index.php/digestate-qa.html

[6] NNFCC: The Biochemical Consultants. “What is Anaerobic Digestion?”

[7] Sustainable Energy Authority of Ireland. “The Process and Techniques of Anaerobic Digestion.” Accessed on February 23, 2013. http://www.seai.ie/Renewables/Bioenergy/Bioenergy_Technologies/Anaerobic_Digestion/The_Process_and_Techniques_of_Anaerobic_Digestion/

[8] American Biogas Council. “What is Anaerobic Digestion?”

[9] California Energy Commission. “Anaerobic Digestion.” Accessed on February 24, 2013. http://www.energy.ca.gov/biomass/anaerobic.html

degrees Celsius. Agri-food systems and small anaerobic digestion processors will usually operate in this temperature range. Out of the three temperature ranges, this one is considered to be the most stable. The third temperature range Psychrophylic is 15 to 25 degrees Celsius and is suitable for colder climates. These systems require a lower energy input and have a high retention time.[10]

The digestion processes are influenced by several conditions. The first is temperature: an environment that is too hot will result in microorganism death while an environment that is too cold will reduce the speed at which anaerobic digestion takes place. Technical faults such as a lack of mixing can also disrupt microorganism health. An excess input of waste can also hinder the digestion process, as the excess accumulation of fatty acids would disrupt biogas production Other key factors that can influence the rate of digestion and the health of microorganisms are the presence of oxygen, light, disinfectants (e.g. herbicides, heavy metals, trace metals, antibiotics), hydrogen sulfide, and ammonia.[11]

There are a variety of anaerobic digester systems which are commercially available. They fall into four general categories: lagoons, plug flow digesters, complete mix systems, and dry digestion. Anaerobic lagoon digesters are sealed with a flexible cover, and methane is recovered and piped to a combustion device. A plug flow digester is composed of a long, narrow tank with either a rigid or a flexible cover.[12] Manure and other outputs move along as a plug. Because this system is suitable for thicker materials, plug flow digesters are a common form of waste processing on dairy farms.[13] A complete mix digester is an enclosed heated tank in which biomass is mixed in with partially digested materials using either a mechanical, hydraulic, or gas powered mixing system. These systems work best when food waste is diluted in water and are suited for processing centers with a high flow of manure or agri-food. In dry digestion, waste is processed in silo-style digesters made of concrete and steel. These digesters often operate with a high volume of total solids (anywhere between 20% and 40%), require little dilution, and are suitable for dry matter manure and crop residuals.[14]

[10] Ontario Ministry of Agriculture and Food. "Anaerobic Digestion Basics: Fact Sheet."
[11] Sustainable Energy Authority of Ireland. "The Process and Techniques of Anaerobic Digestion."
[12] American Biogas Council. "What is Anaerobic Digestion?"
[13] Ontario Ministry of Agriculture and Food. "Anaerobic Digestion Basics: Fact Sheet."
[14] American Biogas Council. "What is Anaerobic Digestion?"

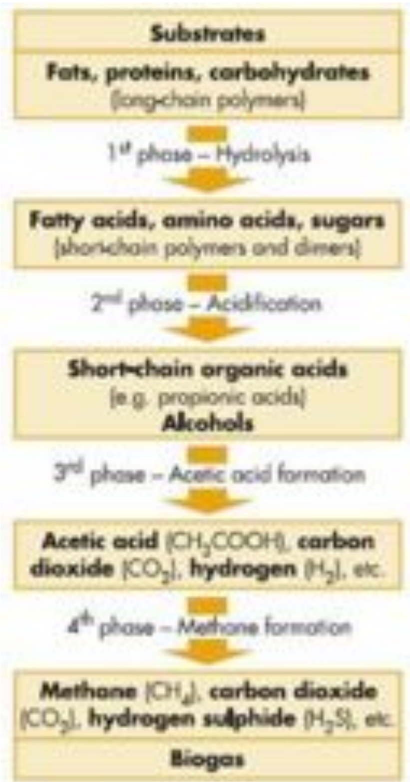

Figure 11-1: The four stages of anaerobic digestion[15]

Anaerobic digestion can be broken down into four phases (Figure 11-1). During hydrolysis, bacteria break down proteins, lipids, and carbohydrates into their simple components – amino acids, fatty acids, and sugars. The next stage is acidogenesis, a process in which these simple organic compounds are metabolized by acideogenic bacteria into even smaller chains of fatty acids. The byproducts of this process are ammonia, carbon dioxide, organic acids (acetic acid, propionic acid, butyric acid, valeric acid), and alcohol.[16] The rate of this process and its yield will depend on the concentration of hydrogen in the system. In the third phase, these organic acids and alcohols are broken down to form acetic acid, along with additional ammonia, carbon dioxide, and hydrogen. These are the necessary initial products for methane formation. In the final stage, methanogenic microorganisms combine the products from the previous phases to form methane and carbon dioxide. The end product of these four phases is a combustible gas called biogas.[17]

11.2 Implementing Anaerobic Digestion at Wellesley College

[15] Sustainable Energy Authority of Ireland. "The Process and Techniques of Anaerobic Digestion." Accessed on February 23, 2013. http://www.seai.ie/Renewables/Bioenergy/Bioenergy_Technologies/Anaerobic_Digestion/The_Process_and_Techniques_of_Anaerobic_Digestion/

[16] American Biogas Council. "What is Anaerobic Digestion?"

[17] Sustainable Energy Authority of Ireland. "The Process and Techniques of Anaerobic Digestion." Accessed on February 23, 2013. http://www.seai.ie/Renewables/Bioenergy/Bioenergy_Technologies/Anaerobic_Digestion/The_Process_and_Techniques_of_Anaerobic_Digestion/

11.2.1 Overview of Implementation at Wellesley

A plug flow anaerobic digester would be the most suitable type of digester for food waste disposal at Wellesley College. A plug flow anaerobic digester requires 11% to 13% of solid food waste and the remainder of the digester is filled with water. This method of anaerobic digestion has a relatively low retention time (15 days) and requires a low level of maintenance. A plug flow digester could also be constructed partially underground.[18] The plug flow digester would be mesophylic (i.e. 25 to 40 degrees Celsius). This is the most stable temperature for an anaerobic digester and is suited for the process of food-waste.

For the purpose of this report, we propose an anaerobic digester at Wellesley that is modeled after one used by Morrisville State College. Morrisville's anaerobic digester can process 10,000 gallons of organic waste per day. The school was chosen due to the fact that the school has a similar student body size to Wellesley. It is also located in a similar climate, which would ensure that energy inputs would be scalable between the two digesters.

The total volume of the Morrisville tank is 249,000 gallons. The waste in the tank is diluted to a 12% solution. At a rate of 10,000 gallons a day, the average amount of time that food waste is processed in the digester is 24.9 days. Because Wellesley's food waste is considerably lower than that of Morrisville, a 10,000-gallon digester would be too large for our campus. The calculations are as follows:

Daily volume of digester filled: (kg of liquid/day)
= (Wellesley's daily food waste kg/day)/.12
= (602.7 kg/day)/.12
= 5,016 kg of liquid/day

Since the wood waste is diluted, we assume that the density of the food waste is similar to that of water (1000 kg/1 cubic meter).

Total daily volume of digester filled (gallons/day)
= (Wellesley's volume kg/day)*(1 cubic meter/1000 kg)*(1000 L/1 cubic meter)*(1 gallon/3.785 L)
= (5,016 kg of liquid/day))*(1 cubic meter/1000 kg)*(1000 L/1 m^3)*(1 gallon/3.785 L)
= 1,325 gallons/day

Percentage of Morrisville input per day
= Wellesley's daily input liquid/Morrisville's daily processing ability
= (1,325 gallons/day)/10,000 gallons/day)
= 13.25 %

As a result, we propose that Wellesley College purchase a plug flow anaerobic digester with a 2,500-gallon capacity. This digester would be used at 53% capacity on average.

[18] Krich, Ken *et al.* "Production of Biogas by Anaerobic Digestion." *Biomethane from Dairy Waste: A Sourcebook for the Production and Use of Renewable Natural Gas in California.* July (2005).

Capacity on a yearly average:
= Wellesley's daily liquid input/daily processing ability of digester
= (1,325 gallons/day)/(2,500 gallons/day)
= 53%

It is important to note that the digester would be able to process excess food waste during the school year. If we assume that 90% of Wellesley's annual waste production happens during the school year, then typical food waste production is about 1000 kg per day. Thus, the highest liquid volume that the digester would fill would be 2,201 gallons/day:

Daily volume of digester filled during the school year: (kg of liquid/day)
= (1000 kg/day)/.12
= 8333.33 kg/day

= (Wellesley's volume kg/day)*(1m^3/1000 kg)*(1000 L/1 m^3)*(1 gallon/3.785 L)
= (8333.33 kg of liquid/day)*(1m^3/1000 kg)*(1000 L/1 m^3)*(1 gallon/3.785 L)
= 2,201.67 gallons/day

The ideal location for an anaerobic digester at Wellesley College would be in the field next to the power plant. This location would provide the campus with a secluded area that would allow for minimal transportation of the biogas to the on-campus co-generation power plant. With this digester, Wellesley College would be able to process and divert all of its food waste on campus.

11.2.2 Technology/Equipment

A plug-flow anaerobic digester is considered to be a low maintenance digester relative to other types of digesters. In order to implement a plug flow digester on campus, we would need technology for both waste disposal and gas collection. For the digestion process, the College would need a large tank to house the food waste that will be input via an access area with a chute. This chute would deposit the matter into the hull of the tank. Leading into this tank, there would be a pipe that will allow for water input. To keep heat in, especially during the winter, the pipe would also require an energy input or a substantial amount of insulation.[19]

During the anaerobic process, biogas is created. In order to collect the biogas, the digester would require a pipe or tube to transport the gas to either another tank or directly to the power plant. This pipe or tube would need a valve inside of it to manage the gas release. Lastly, there would need to be an access area to remove sludge (digestate) from the bottom of the tank.[20]

11.2.3 Inputs

Energy

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[19] "Energy Basics." U.S. Department of Energy. Accessed February 24, 2013. http://www.eere.energy.gov/basics/renewable_energy/anaerobic_digestion.html.
[20] "Murdoch University: Biomass." Murdoch University. Accessed February 24, 2013. http://www.see.murdoch.edu.au/resources/info/Tech/biomass/index.html.

Before food waste can be put into the digester, it will need to first be treated. This can be done with a pulper. The Somat eSHRED requires an energy input of approximately 0.645kW/kg food waste.[21]

Energy needed to prepare metric ton food waste (kWh/metric ton)
= 6.7 kW * (1 hr/544.3 kg)* food waste (4)
= .01231 kWh/kg food waste[1]
= 12.31 kWh/metric ton

The anaerobic digester requires electricity to heat, facilitate digestion, and mix the feedstock. The energy demand will vary based on the solids content of the waste to be digested.[22] We assume that Wellesley's digester will maintain a 10% solid content. The energy demand for Wellesley's anaerobic digester follows:

Energy needed to power 20,000-gallon anaerobic digester
= 40.8 kWh[23]

Wellesley's Total Daily Energy Responsibility (kWh/day)
= Energy needed to power * percent size of Wellesley's digester
= (40.8 kWh)*(.25)
= 10.2 kWh/day

Wellesley's Relative Energy Responsibility (kWh/kg food waste)
= Wellesley total daily energy responsibility / (Wellesley daily food waste)
= (10.2 kWh/day) / .6027397 metric ton food waste
= 16.9227 kWh/metric ton of food waste

Materials

The primary material necessary for the construction of a pulper is steel. The Somat eSHRED pulper has a life span of 20 years.[24]

Wellesley's Food Waste for 20 years kg
= annual food waste * 20 years
= 220 metric ton food waste/year * 20 year
= 4,400 metric ton food waste

Steel Needed for On-Campus Pulper
= mass of steel kg/wellesley's food waste for 20 years kg
= 1400 lbs * (1 kg/2.204 lbs)
= 635.208 kg for 20 years

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[21] Somat Company, "eSHREAD." Accessed March 2, 2013.
[22] AFBI - Agri-Food and Biosciences Institute. "Factors to Consider for Anaerobic Digestion." Accessed February 24, 2013. http://www.afbini.gov.uk/index/services/services-specialist-advice/renewable-energy-2012/re-anaerobic-digestion/re-anaerobic-digestion-intro/re-anaerobic-digestion-factors.htm
[23] Shayya, Walid. "Anaerobic Digestion at Morrisville State College: A Case Study." Accessed May 2013. http://people.morrisville.edu/~shayyaw/anaerobicdigestionatmorrisvillestatecollege.pdf.
[24] Somat Company, "eSHREAD." Accessed March 2, 2013.

= 635.208 kg steel for 20 years/ 4,400 metric ton food waste per year
= .144 kg steel/metric ton food waste

We assume that Wellesley would employ this anaerobic digester for its entire lifespan. The anaerobic digester has a life span of 20 years. [25]

Wellesley's 2,500-gallon anaerobic digester is based off of Morrisville's 10,000-gallon anaerobic digester; since it is half the volume, it will require half of the inputs that were necessary to construct the Morrisville digester.

The primary input material is concrete. The Morrisville anaerobic digester is 36' by 90' with a height of 12' and a concrete thickness of 6". It is divided by one wall. Each portion is cut through by a second wall[26] (Figure XX4); these also have a height of 12'. The height of the Morrisville digester foundation is not given. We assume that the base foundation would have to be at least two feet in height. Wellesley's anaerobic digester would require half the input. The mass of volume required was calculated as follows:

Volume of Concrete of Morrisville Digester
= (volume of 3 walls with length of 90) + (volume of 3 walls with length of 36) + (volume of base)
= (3)(length of 90)(thickness)(height of digester) + (3)(length of 36)(thickness)(height of digester) + (length of 36)(length of 90)(height of base)
= (3)(90 ft)(.5 ft)(12 ft) + (3)(36 ft)(.5 ft)(12 ft) + (36 ft)(90 ft)(2 ft)
= 2268 ft^3
= 2268 ft^3 * (12^3 in ^3/1 ft^3) * (2.54^3 cm^3/1 in^3) * (1 m^3/100^3 cm^3)
= 64.223 m^3

Volume of Concrete of Wellesley Digester
= (64.223 m^3)(.25)
= 16.05 m^3

Density of hardened concrete[27]
= 2,400 kg^m3

Mass of Concrete Required
= volume of concrete in cubic meters * density of concrete
= 16.05 m^3* (2400 kg/m^3)
= 38,530 kg

Contribution to Concrete (kg/metric ton)
= 38,530 kg /4400 metric tons

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[25] CA Energy. "Cogeneration Optimization." Accessed May 2013. http://www.energy.ca.gov/process/pubs/cogen.pdf
[26] Shayya, Walid. "Anaerobic Digestion at Morrisville State College: A Case Study." Accessed May 2013. http://people.morrisville.edu/~shayyaw/anaerobicdigestionatmorrisvillestatecollege.pdf.
[27] Elert, Glenn ed. "Concrete Properties." *The Physics Factbook.* Accessed on March 4, 2013. http://hypertextbook.com/facts/1999/KatrinaJones.shtml

= 8.76 kg/metric ton

Other materials required for the construction of the digester are steel, polyurethane, and epoxy. The calculations for the other materials inputs are as follows:

Reinforcing (Reinforcing steel, at plant/RER S) for Morrisville
= $19,000 / $782 per metric ton[28]
= 24.3 metric tons steel

Reinforcing (Reinforcing steel, at plant/RER S) required for Wellesley (kg/metric ton)
= 0.25 * (24,300 kg)/ (4400 metric tons food waste)
= 1.38 kg steel/metric ton

Polyurethane (Polyurethane, flexible foam, at plant/RER S) for Morrisville
= $64,310/ $1431 per metric ton[29]
= 44.94 metric tons

Polyurethane (Polyurethane, flexible foam, at plant/RER S) for Wellesley (kg/metric ton)
= 0.25 *(44940 kg) /(4400 metric tons food waste)
= 2.55 kg polyurethane / metric ton

Epoxy (Liquid epoxy resins E) for Morrisville
= $ 18,400 / $2500 per metric ton[30]
= 7.36 metric ton

Epoxy (Liquid epoxy resins E) for Wellesley (kg/metric ton)
= 0.25 *(7360 kg)/ (4400 metric tons food waste)
= 0.415 kg/metric ton

11.2.4 Outputs

The only offset from anaerobic digestion on campus would be the production of biogas. We assume that the gas produced by the digester would be used to offset the demand for power generation at the co-generation plant. We gleaned the energy output from anaerobic digesters from a functional digester at Jordan Dairy Farms. Each month, this digester produces 6800KWh.[31] Using the data from Jordan Dairy Farms, a 10,000-gallon digester, we calculated the biogas produced by Wellesley's digester as follows:

Total energy produced by Anaerobic Digester (kWh/metric ton food waste)

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[28] "Steel prices for years 2011 and 2012." Accessed March 20, 2013. http://www.steelonthenet.com/steel-prices.html.
[29] Urethane Blog, "Platts Global Benzene Price Index." Accessed March 20, 2013. http://urethaneblog.typepad.com/my_weblog/pricing/.
[30] Alibaba: Global Trade Forum, "Price Liquid Epoxy Resin." Accessed March 20, 2013. http://www.alibaba.com/showroom/price-liquid-epoxy-resin.html.
[31] PowerDash Inc, "Jordan Dairy Farms Biogas." Accessed February 24, 2013. http://www.powerdash.com/systems/1000499/.

= [(energy produced per month)*(capacity of Wellesley's digester)]/30 days per month
= (6800 kWh)(.25)(1325gal/2500gal.) /30 days per month
=(30.0 kWh per day)/ (.602 metric tons of food per day)
=49.9 kWh per metric ton of food waste

11.3 Environmental Impacts of Anaerobic Digestion On Campus

11.3.1 Collection and Preparation of Food Waste

To optimize anaerobic digestion potential, Wellesley's food waste must be pulverized before entering the system. We assume that Wellesley would install Somat's eSHREAD pulper at the site of the anaerobic digester. The food would be pulped by trained staff and then placed into the digester.

Energy
Energy needed to prepare Wellesley's food waste (kWh/metric ton)
= 12.31 kWh/metric ton of food waste

For the purpose of our study, we assume that Wellesley would not use the biogas from the anaerobic digestion to power its treatment facility. Instead, we assume that the energy to power the pulper would come from the co-generation plant on campus.

Materials
Wellesley's Responsibility for Off-Campus Steel Pulper
= .144 kg steel/metric ton food waste

The material information stems from data on Somat's eSHREAD. Based on the capability of the pulper, this system is a fair proxy for the pulper needed for on-campus anaerobic digestion at Wellesley. After reviewing the materials sheet for the pulper, we assumed that the non-steel parts of the pulper were negligible.

Transportation of Food Waste
The food waste would need to be collected at each dining hall and transported to the digester. We assume that Wellesley would complete its pickup with a diesel-fueled pickup truck to avoiding having to buy a new vehicle. We assume that the truck would have to follow a 3.218-kilometer route around campus. This route would allow workers to pick up at all dining locations and bring waste to the digester. Since we are assuming that Wellesley would build an on-campus anaerobic digester, there would be no need for transportation off campus.

11.3.2 Process

Since the anaerobic digester would be on Wellesley's campus, the College would be responsible for 100% of the environmental impacts from the process.

Table 11-1: Materials for construction of an on-campus anaerobic digester (calculations above)

Material	Mass (kg per metric ton food waste)
Concrete:	8.76 kg
Steel:	1.38 kg
Polyurethane:	2.55 kg
Epoxy:	0.415 kg

Materials
When calculating the materials used, we assumed that the wood and plastic needed for the construction of the digester were negligible. This assumption is valid because a very small amount of these materials is used in the construction of the digester, especially when their use is considered over the 20-year expected lifespan of the equipment.

Energy
Wellesley's anaerobic digester would consume 20.4 kWh of energy per metric ton of food waste. For the purpose of our life cycle assessment, we assume that Wellesley would power its anaerobic digester with electricity from its on-campus co-generation plant.

11.3.3 Avoided Impacts

A positive environmental impact of the anaerobic digestion process is the creation of biogas. Wellesley would have the environmental credit for 3434.2 kWh/metric ton of food waste. We assume that the energy produced by the on-campus digester would replace electricity generated at the on-campus co-generation power plant. While fertilizer is a byproduct of the anaerobic digestion process, this fertilizer will not be used on campus.

11.3.4 Water Use

Because wastewater is removed from the digestate and then circulated back into the system, we assume that the tank would be filled once and the water will be recycled from then on.

264.17 gallons of water = 1 metric ton of water

Filling the Tank
= Total water to fill tank * 90%
= 2,500 gallons * (1 metric ton/265.17 gallons) *.90
= 9.759 metric tons of water *.90
= 8.78 metric tons of water

11.3.5 Summary: Life Cycle Impacts and Assessment of Anaerobic Digestion On-Campus

Table 11-2: Environmental impacts by process stage, on-campus anaerobic digestion

Impact category	Unit	Materials	Collection	Transportation	Method	Avoided Impacts	Total
Global Warming	kg CO2 eq	17.5764	49.7890	0.6446	6.1039	-17.9908	56.1229
Carcinogenics	kg benzen eq	0.0292	0.0030	0.0002	0.0038	-0.0112	0.0250
Ecotoxicity	kg 2,4-D eq	19.0094	0.8415	0.1226	1.3769	-4.0582	17.2922

Table 11-2 outlines the environmental impacts of an on-campus anaerobic digester. The collection process contributes the most to all three impact categories. The disproportionate amount from the collection process is primarily due to the high levels of energy consumed by the pulper. It is possible that Wellesley's could reduce this contribution by selecting a different pulper.

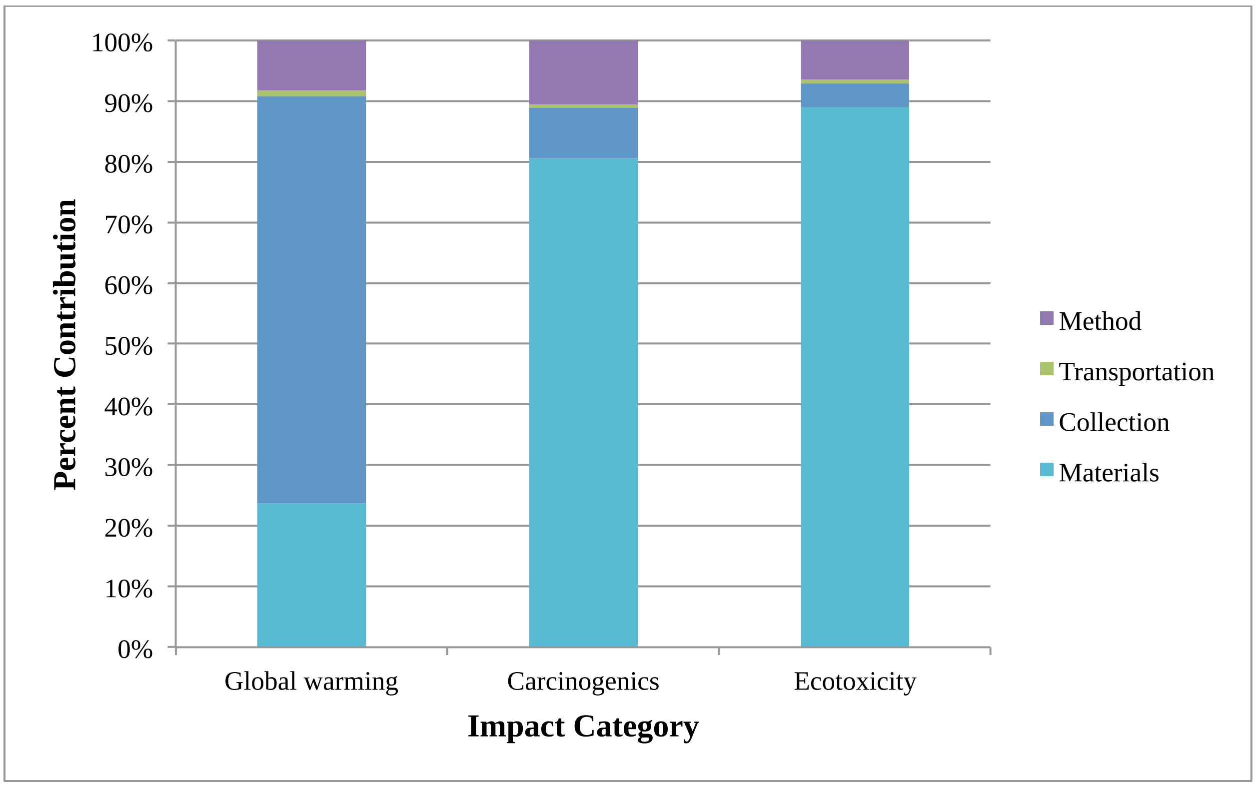

Figure 11-2: Percent contribution of process stages to each impact category, on-campus anaerobic digester

Figure 11-2 shows the relative environmental impacts of each stage of food waste diversion to an on-campus anaerobic digester. While all four stages contribute to impacts, collection demonstrates the highest global warming impact, while materials contributes most to ecotoxicity and carcinogenics.

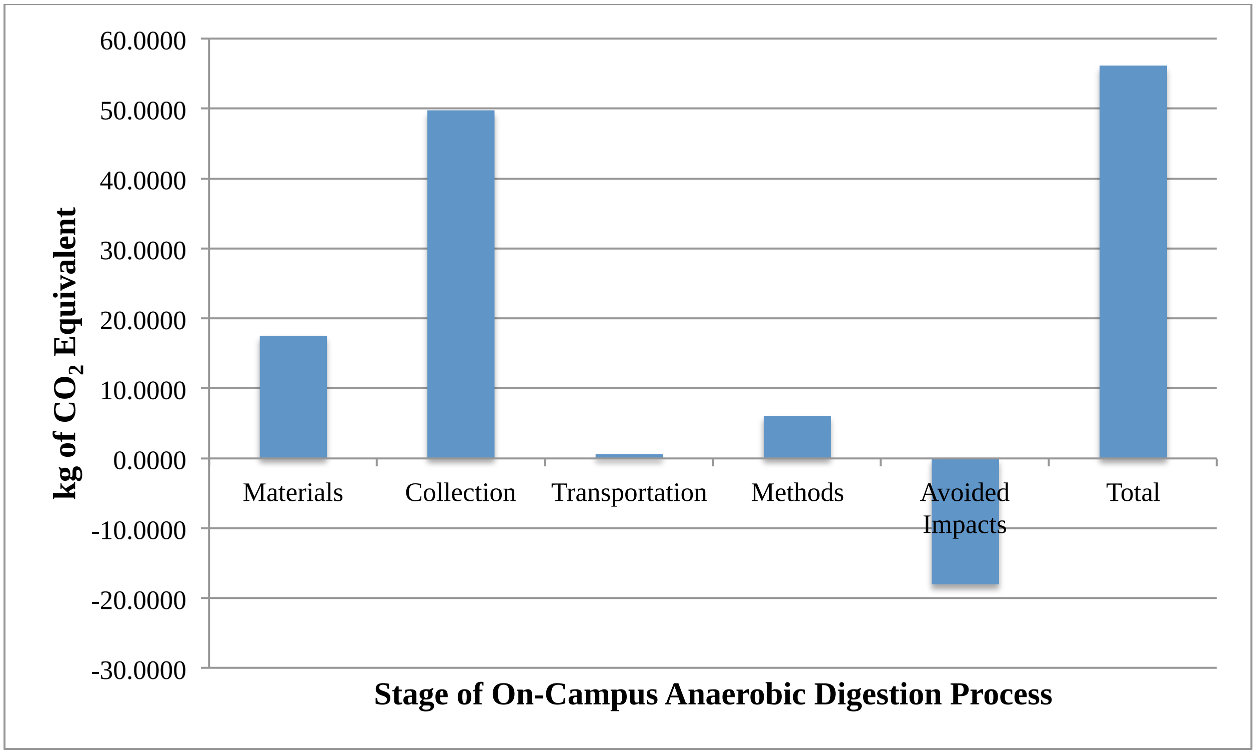

Figure 11-3: Climate change impact of each process stage, on-campus anaerobic digester

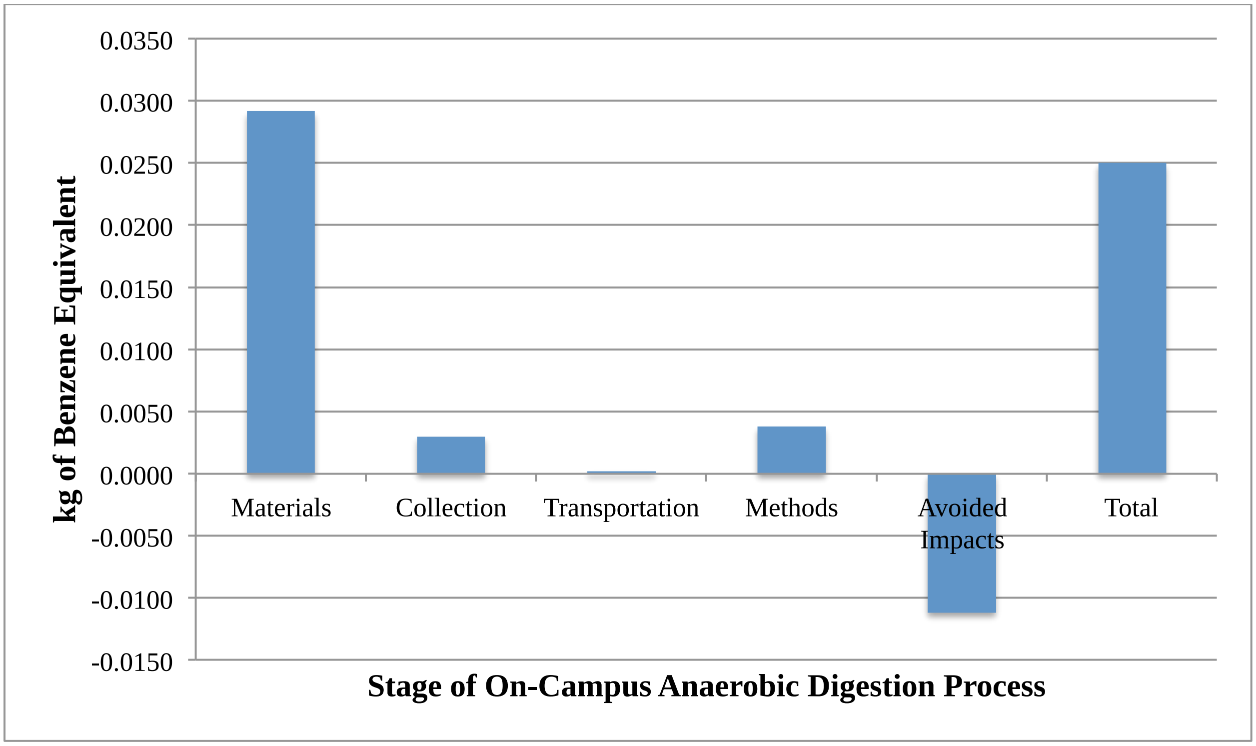

Figure 11-4: Human toxicity impact of each process stage, on-campus anaerobic digester

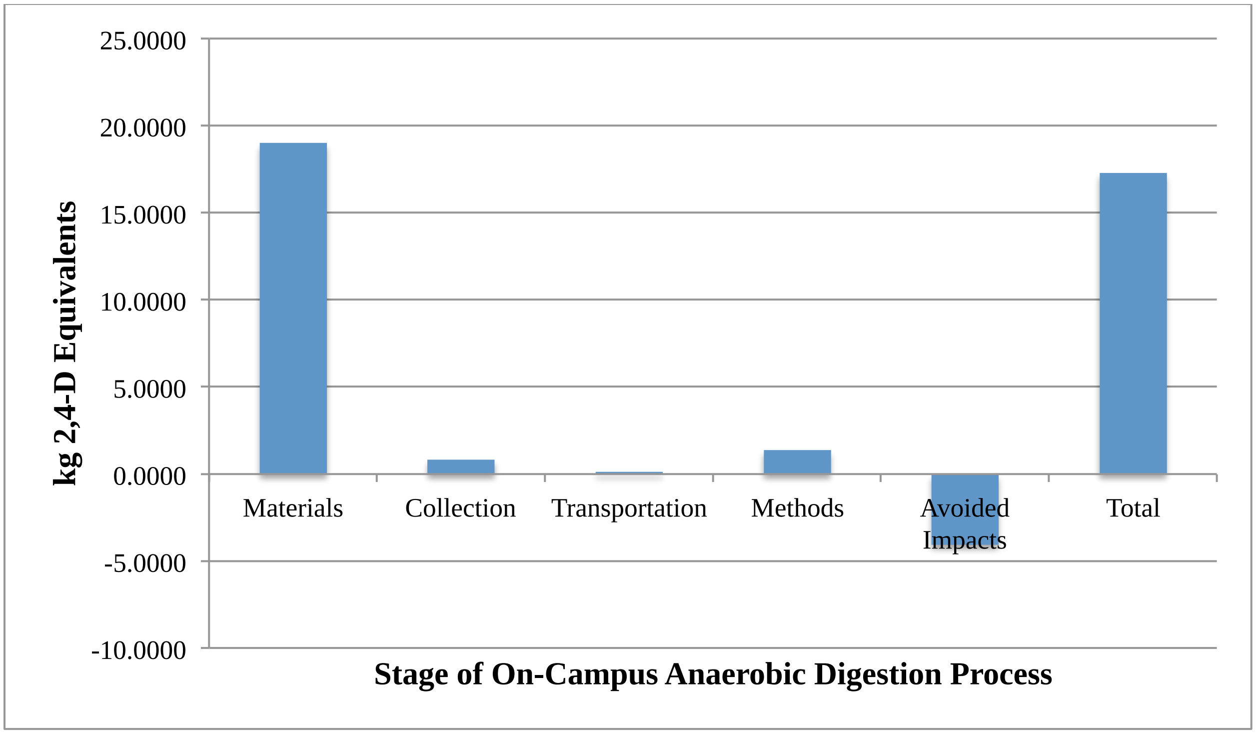

Figure 11-5: Ecosystem toxicity impact of each process stage, on-campus anaerobic digester

Additionally, we examine the net environmental impacts of off-campus anaerobic digestion. To do this, we subtract the adverse impacts from the total transportation, method, and collection impacts for each environmental impact category. Figures 11-3 through 11-5 show the results of this analysis. In these figures, negative numbers represent a positive environmental impact while positive numbers represent a negative impact.

The analysis above shows the collection stage to have the greatest environmental impact. Transportation and methods also impact the environment, due to the fuel and exhaust involved in trucking the waste to the digester, the materials used to construct the digester itself, and the process that went into making those materials in the first place. Collection had the greatest impact in terms of global warming because of the energy required during the pulping phase of the process. The pulper consumes much more energy than the digester, which, although much larger, only requires energy to heat the organic mixture.

Of the environmental impacts we consider, global warming would be offset the most by energy generation from an anaerobic digester. The electricity generated from the biogas byproduct would go towards lowering dependence on fossil fuels that are detrimental to the climate. However, the offsets would also balance out the ecotoxicity and carcinogenic impacts of the digester.

11.4 Costs of Anaerobic Digestion On Campus

11.4.1 Direct Cost

The direct cost is the amount that Wellesley would be paying another service for transportation and waste disposal. Since the waste disposal would be taking place on campus, the direct cost for anaerobic digestion on campus is zero.

Tipping Fees
An off-campus facility would not be needed for anaerobic digestion on campus, so there would be no tipping fee.

Trucking Fees
Wellesley College would not have direct transportation costs, as all transportation will take place on-campus. This is accounted for in operational costs.

11.4.2 Operational Cost

Transportation Cost
Wellesley staff would be responsible with collecting all food waste and transporting it to the digester. A round trip that stops at Bates, Stone-Davis, Tower, Campus Center, and Pomeroy is 6.76 km. We found this information by tracing a route using Google maps, with Bates as the starting point.

The collection will be completed using a diesel swap loader truck with a 12 cubic yard capacity. It has a fuel efficiency of roughly 9 miles per gallon.[32] The cost of diesel is roughly 4 dollars per gallon. Therefore, the cost of each trip will be 1.867 dollars and the cost per kilogram of waste transported is .0015 dollars.

Daily distance (miles/day)
= (daily distance km/day)/(1.609 km/mile)
= (6.76 km/day)/(1.609 km/mile)
= 4.20 miles/day

Daily cost of each round trip ($/day)
= (daily distance miles/day)*(gallons per mile)*(cost per gallon)
= (4.20 miles/day)*(1 gallon/9 miles)*(4.00$/gallon)
= 1.867 $/day

Cost of each round trip ($/metric ton)
= (daily cost $)/(daily food waste kg)
= (1.867 $/day)/(1230.2 kg food waste/day)
= 3.10 $/metric ton

Labor costs
The labor cost of anaerobic digestion can be broken down in two parts: transport labor and operational labor cost.

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[32] Patrick Willoughby, Director of Sustainability, Wellesley College. Interviewed by ES300. March 11, 2013.

Transport labor cost is the cost of labor required to collect and transport the food waste from the five dining halls to the digester. We assumed that the process would require two workers, as one would be needed to drive the vehicle and the other would load the bins into the truck. We estimated that the total collection and transport time would be at most two hours per day. We assumed that each worker would have the same hourly wage as a dining hall deliveries worker - $24.16 dollars per hour.[33] The total cost per day and per kilogram was found by the following method:

Daily Cost of Transportation Labor ($/day)
= (number of workers)*($hourly wage/hour)*(number of hours)
= (2 workers)*(24.16 $/hour)*(2 hours)
= 96.64 $/day

Cost of Transportation Labor per metric ton ($/metric ton)
= (daily cost of transportation labor $/day)/(daily food waste kg/day)
= (96.64 $/day)/(.6027 metric ton/day)
= 160.34 $/metric ton

It is important to note that the collection of food waste is already in place for the current waste-disposal system. Therefore, there is no additional cost for the collection of waste into bins.

The second labor cost is the wage paid to all workers operating the anaerobic digester. It is estimated that seven workers are required in total[34]. Since the operation of an anaerobic digester has similar elements to the operation of Wellesley's power plant, we assumed that an engineer managing the anaerobic digester would have similar duties to a Watch Engineer working in the Wellesley power plant. Therefore, we assumed that a suitable hourly wage of a Watch Engineer would be a suitable estimate for a fair compensation. Under that assumption, each worker would be paid 33.94 per hour, with an additional 30% to cover benefits.[35] The anaerobic digester would have to be monitored at all times. Each worker would cover a shift that is eight hours in length and at least two workers would be needed per shift. There would be three total shifts, resulting in a daily cost of $2,118.48. The per kilogram cost of operational labor, therefore, would be $1.72.

Daily Cost of Operational Labor per worker ($/worker)
= (hourly wage $/hour)*(number of hours)*(benefits)
= (33.94 $/hour)*(8 hours)*(1.3)
= 352.976 $/worker

Daily Cost of Operational Labor ($/day)
= (daily cost of operational labor per worker)*(number of workers)*(number of shifts)
= (352.976 $/worker)*(2 workers)*(3 shifts/day)
= 2,117.856 $/day

Cost of Operational Labor per Metric Ton ($/metric ton)

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[33] Patrick Willoughby, Director of Sustainability, Wellesley College. Interviewed by ES300. March 11, 2013.
[34] Patrick Willoughby, Director of Sustainability, Wellesley College. Interviewed by ES300. March 11, 2013.
[35] Patrick Willoughby, Director of Sustainability, Wellesley College. Interviewed by ES300. March 11, 2013.

= (daily cost of operational labor \$/day)/(daily food waste kg/day)
= (2,117.856 \$/day)/(.6027 metric ton/day)
= 3,513.95 \$/metric ton

The total labor cost is the sum of the transport and operational labor costs:

Total Labor Cost per Metric Ton (\$/kg)
= (Cost of Transportation Labor per metric ton \$/metric ton) + (Cost of Operational Labor per metric ton \$/metric ton)
= 160.34 \$/metric ton + 3,513.95 \$/metric ton
= 3,674 \$/metric ton

Energy costs
Wellesley's energy input required to power an anaerobic digester is 33.845 kWh/metric ton of food waste. During peak hours, the cost of electricity is \$0.11 per kWh.

Direct Operational Cost per metric ton (\$/metric ton)
= (electricity per metric ton required kWh/metric ton)*(cost per kWh \$/kWh)
= (33.845 kWh/metric ton)*(.11 \$/kWh)
= 3.72 \$/metric ton

Other Operational Cost
Since nearly 100% of the water used in anaerobic digestion can be recycled back into the process, we assume that Wellesley will only have to pay a one-time cost to fill the tank with 90% water. The anaerobic digester would hold 16.97 metric tons of water.

Cost per metric ton of food waste (\$/metric ton)
= metric tons of water * conversion to liters * price of water
= 16.98 metric tons * (1000 L/ 1 metric ton) * .00001984 \$ / liter
= \$0.3369/metric ton

11.4.3 Equipment

Because we are modeling our on-campus anaerobic digester after the one at Morrisville College, it is logical that we would have costs that are the same as that digester, or at least comparable. The following is based on the costs that Morrisville encountered and broke down into the following categories and subcategories.[36] Because Morrisville used a 10,000-gallon digester and we will only use a 2,500 gallon digester, we halved the costs that Morrisville encountered to get the following:

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[36] Shayya, Walid. "Anaerobic Digestion at Morrisville State College: A Case Study." Accessed May 2013. http://people.morrisville.edu/~shayyaw/anaerobicdigestionatmorrisvillestatecollege.pdf.

Table 11-3: Contractor cost, on-campus anaerobic digestion

Category	Item	Cost ($)	Cost ($/metric ton)
General			
	Site Mobilization	3,625	16.48
	General Requirements	12,450	56.59
	Insurance and Bondings Fee	5,250	23.86
Site Work			
	Excavation and Backfill for Buildings and Utilities	11,575	52.61
Concrete Work			
	Poured Concrete Work	50,590	229.95
	Pre-cast Concrete Planks	11,625	52.84
Metals			
	Furnish and Install Fabricated Steel	4,750	21.59
Wood and Plastic			
	Equipment Building	9,690	44.05
Thermal and Moisture Protection			
	Polyurethane Insulation System	16,080	73.09
	Coal Tar Epoxy Coating, etc…	4,600	20.91
Mechanical			
	Furnish and Install	47,750	217.05

	Mechanical Equipment and Piping		
Electrical			
	Electrical Work	9,375	42.61
Miscellaneous Charge Orders		7,640	34.73
TOTAL		**195,000**	**886.36**

Table 11-4: Installation and service costs, on-campus anaerobic digestion

Item	**Cost ($)**	**Cost ($/metric ton)**
Consultant	24,610	111.86
Testing of Concrete	1,610	7.32
Tank Sealing	4,870	22.14
Confined-Space Monitoring	2,300	10.45
Slurry Storage	61,650	280.23
Total	**95,040**	**432.00**

The total equipment cost for our on-campus anaerobic digester is the sum of both the digester contractor coasts and also the installation and service costs. This comes out to be a total of $290,040 or $1,309.36 per metric ton.

Table 11-3 gives an in-depth break-down of the costs associated with the digester contractor. This covers the general, materials, protective, mechanical, electrical, and installation costs. These are necessary to not only build and install the digester, but also ensure that it runs properly.

In Table 11-4, we examine the necessity for these items. First, a consultant is needed to advise where and how the digester should be built. This person's job is to give professional advice to maximize the efficiency of the digester for our composting needs. Second, concrete must be tested as a safety precaution in order to assess and quantify its performance and strength.[37] Third, tank sealing is done as a preventative measure for leaks. Unwanted materials need to be kept out of the digester, just as the organic matter needs to be kept inside of the digester, rather than seeping out into the surrounding area. Fourth, confined-space monitoring is done as a means of making sure that everything is running properly and is at par with the standards, regulations, and

[37] Foundations: Ambuja Knowledge Initiative. "Concrete Tests – Ambuja Cement." Accessed March 10, 2013. http://www.foundationsakc.com/process/concrete-tests

recommendations that are in place. Lastly, slurry storage is required during certain times of the year as a means of environmental protection.[38]

11.4.4 Offset Cost

The costs of building and operating an on-campus anaerobic digester would be offset by electricity, a marketable byproduct of the digestion process.

The biogas produced from anaerobic digestion would be used by the College's cogeneration plant. Wellesley College currently pays $0.11 per kWh of electricity consumed. Assuming the same value for 1 kWh of biogas generated per one metric ton of food waste, the following would be the cost of energy offset by the digester:

Offset cost from biogas production ($/metric ton)
= (49.9 kWh/metric ton food waste)($0.11/kWh)
= 5.489 $/metric ton

11.4.5 Summary: Cost of Anaerobic Digestion On Campus

Table 11-5: Overall costs of on-campus anaerobic digestion per metric ton of food waste

Cost Category		**Amount ($/metric ton)**
Direct:		
	Facilities	$0.00
	Transportation	$0.00
Operational:		
	Transportation	$3.10
	Labor	$3,677.00
	Other	$3.72
Equipment		$1,309.36
Offset costs		$5.49
Total Cost		**$4,987.69**

[38] Permastore: Tanks and Silos. "Slurry Storage." Accessed March 10, 2013. http://www.permastore.com/market-sectors/agricultural/slurry-storage

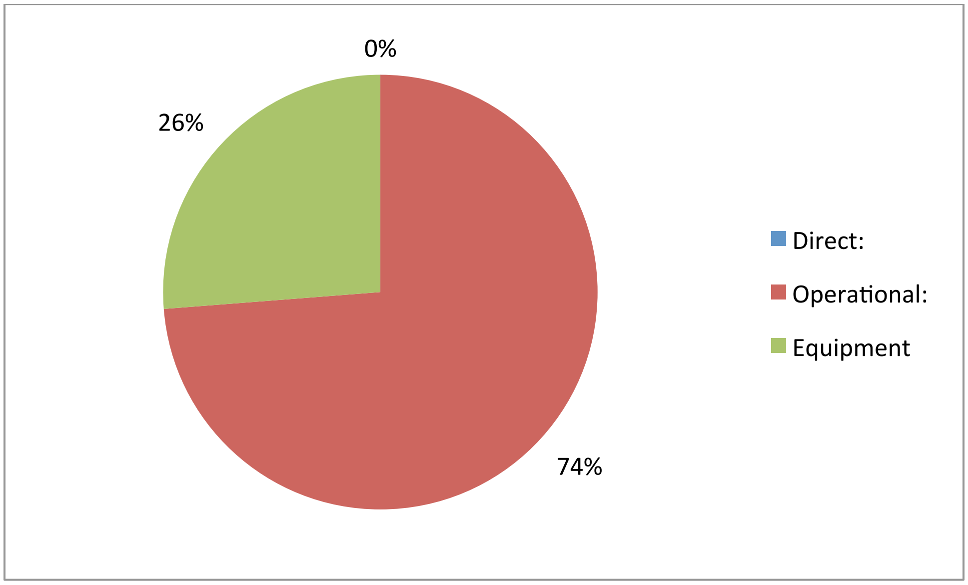

Figure 11-6: Cost of on-campus anaerobic digestion

The total cost of on-campus anaerobic digestion for a 2,500-gallon digester would be $4,987.69. per metric ton of food waste diverted (Table 11-5). The operation of the anaerobic digester accounts for the cradle-to-gate costs of the system. The vast majority of the operational costs stem from labor since the anaerobic digester must be staffed 24 hours/day (Figure 11-6). Without violating labor laws, there is no way to minimize this cost.

11.5 Social Impacts of Anaerobic Digestion

11.5.1 Campus Experience – Neutral

Anaerobic digestion will have a large impact on students' experience on campus. The large, concrete digester would detract from the natural beauty of the campus. The digester does have some beneficial impacts on the campus experience. It may boost the College's eco-image and serve as a source of good publicity in turn creating a sense of pride amongst the members of the College community.

11.5.2 Educational Benefit - Positive

On-campus anaerobic digestion will be visible to students and will provide new academic opportunities. The digester could be integrated into the classroom experience, would provide opportunities for students to visit the site, and would allow students to work or volunteer at the site as well. Ultimately, the entire student body would be aware of the digester and would be able to participate in the waste disposal process to varying degrees.

In the classroom, the anaerobic digester could be incorporated in two ways. First, the construction and operation of the digester, along with the calculation of its inputs and outputs, could be studied in a classroom. Students enrolled in physics or engineering courses could study the process of plug flow systems. Students in biology or chemistry could study the reactive process of converting organic material into methane and carbon dioxide. Students in almost any mathematical or quantitative reasoning course could study the balance of outputs and inputs of the waste disposal process. Once students in physics, environmental science, mathematics, biochemistry, biology, or engineering courses study the various stages of the digestion process, they would be able to visit the site. There, trained staff members would be able to walk students through the waste disposal system, briefly outlining stages that students might not have covered in their classroom overview. These tours already take place for the College's cogen plant; thus, students would be able to tour the anaerobic digester and then proceed to tour the cogen plant; this would allow students to learn about both the process of digestion and the utilization of its byproducts.

Outside of the classroom, the anaerobic digester could provide educational opportunities for students that are completing their work-study or want to learn more about waste disposal. While trained staff members would be needed to oversee and maintain the digester, students would be able to assist as well. Due to the high level of maintenance required to power the digester, students would need to be supervised at all times.

Finally, members of the student body, regardless of area of study or work-study placement, would be aware of the anaerobic digester. The digester would be located by the power plant, in between the College's housing office and the student center. It would, therefore, be visible. Information regarding the digester would also be readily available. Students interested in learning more would have the opportunity to do so.

11.5.3 Implementation Difficulties

Separation - Low
An anaerobic digester can process any form of organic waste that does not contain lignin, a compound found in the cell wall of tough plants and trees. Since this includes all food waste produced at Wellesley, there would be no cultural and behavioral change for the student body. Dining hall staff would require minimal training on food separation. Staff would only have to ensure that only food waste is processed in the pulverizer and then deposited into the collection bins.

Permitting and Regulations - High
To construct and run an anaerobic digester on campus, Wellesley College would have to obtain permits from the Massachusetts Department of Environmental Protection. In an effort facilitate compliance with the new regulations regarding organic waste, the Massachusetts Department of Environmental Protection has reduced the number of permits required for the siting of an anaerobic digester and simplified the permitting process.[39] Additionally, because the proposed

[39] Kimmell, Kenneth. "Streamlining Organic Waste Rules to Foster Clean Energy." Massachusetts Department of Environmental Protection. Accessed March 11, 2013. http://www.mass.gov/dep/public/publications/0611andi.htm

digester holds only 2,500 gallons, a tank inspection permit will not be necessary.[40] As long as the digester is not receiving more than 100 tons of organic waste per day, a general permit encompassing composting and recycling activities would suffice.[41] Wellesley College is under the jurisdiction of the Worcester permit office[42] and can file for these permits online. Anaerobic digesters are not listed on the Department's fee schedule.[43]

Time until Implementation - High
On-campus anaerobic digestion would take a few years in order to implement due to the time it would take to acquire permits, get any materials needed for the assembly of our digester, assemble it, and get it up and running. This means that implementation would occur post-deadline.

Risk - Medium
All processing of our food waste would take place on campus under careful monitoring and within our digester that has been constructed with numerous safety features and preventative measures. The probability of contamination occurring is low, but the risk is high. If there is a leak in the tank, then the matter could seep into the surrounding area, adversely impacting the environment. Emissions could also leak from the digester,[44] which would then negatively affect air quality. This not only affects the environment, but also poses health concerns for people..

11.5.4 Social Justice – Neutral

An on-campus anaerobic digester poses no concerns in terms of social justice to students, faculty, and staff at Wellesley College. There are no additional labor risks because staff members will only be separating food waste from all other waste into the appropriate bins. While this is a high-risk method in terms of contamination, there is such a low probability of any potential threats to the environment or to humans that it is overall null.

11.5.5 Summary: Social Impacts of Anaerobic Digestion On-Campus

On-campus anaerobic digestion has a number of social costs, which are summarized in Table 11-6. Because of construction and permitting barriers, Wellesley would not be able to implement this waste diversion method by the 2014 deadline. Thus, it would have to be considered as a long-term solution for food waste diversion. Moreover, the installation of such a facility poses a risk to Wellesley students and has the potential to greatly impact the campus experience. Because of the nature of these social costs, there is no clear way to reduce them. Wellesley must decide whether having the ability to divert 100% of its waste on campus and producing valuable byproducts is a priority

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[40] "General Laws." The 188th General Court of the Commonwealth of Massachusetts. Accessed March 9, 2013. www.malegislature.gov/Laws/GeneralLaws/PartI/TitleXX/Chapter146/Section22

[41] "Clean Energy via Anaerobic Digestion." Mass.gov | Energy and Environmental Affairs. Accessed March 9, 2013. www.mass.gov/eea/docs/doer/green-communities/pubs-reports/anaerobic-digestion-handouts.pdf

[42] "Central Region | MassDEP." Accessed March 9, 2013. http://www.mass.gov/dep/about/region/centralr.htm

[43] "Schedule of Timelines and Fees." Massachusetts Department of Environmental Protection. Accessed March 9, 2013. www.mass.gov/dep/service/approvals/fy10fees.pdf

[44] "Project and leakage emissions from anaerobic digesters." *EB 66 Report. Annex 32.* UNFCCC/CCNUCC. http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-14-v1.pdf

Table 11-6: Social impacts of on-campus anaerobic digestion

Social Impact		**Score**
Campus experience		Neutral
Educational benefit		Positive
Difficulty:		
	Separation	Low
	Permitting and regulations	High
	Time until implementation	High
	Risk	Medium
Social justice		Neutral

11.6 Conclusions

On-campus anaerobic digestion would allow Wellesley College to divert 100% of its food waste while also providing useful byproducts such as energy and fertilizer. An on-campus anaerobic digester performs well across all three impact categories - environmental, financial, and social. The largest environmental and financial impacts come from the construction of the digester rather than the process itself. The primary challenge for on-campus anaerobic digestion is its lengthy implementation time given that Wellesley would have to attain permits and construct the digester. Thus, on-campus anaerobic digestion would not be a viable method for Wellesley's immediate need to comply with the 2014 deadline. Instead, anaerobic digestion on campus should be considered a long-term solution for effectively diverting Wellesley's food waste.

12.0 Anaerobic Digestion Off Campus

12.1 Introduction to Off-Campus Anaerobic Digestion

The best example of an off-campus anaerobic digestion facility currently in operation is at Jordan Dairy Farms in Rutland, Massachusetts. AGreen Energy, LLC, a corporative of farmers working to build anaerobic digesters, runs the digester at Jordan Dairy Farms with aid from Casella Organics,[1] a waste consulting firm which aims to convert food waste into usable byproducts. Casella Organics has a track record of successful partnerships with educational institutions. For example, Casella works with Colby College in Maine to divert food waste from dining halls to a local dairy farm for anaerobic digestion.[2] A similar agreement could be forged between Wellesley College and Jordan Dairy Farms.

Over the next few years, each farm in the consortium will build an anaerobic digester to process farm manure and local food waste. Once the anaerobic digesters are operational on all five farms, the Massachusetts government estimates that the consortium will be able to process up to 15% of the state's food waste.[3]

A representative from Jordan Dairy Farms asserted that the new anaerobic digesters would have the capability to process any food waste produced at an institution like Wellesley.[4] Therefore, the College could divert 100% of this food waste to anaerobic digesters off campus. Wellesley would be able to divert its food waste to one of these facilities. It is also likely that, with the upcoming 2014 Organic Waste Ban, more similar facilities will be created in the next year.

Based on the estimation of Wellesley's annual food waste and data from Jordan Dairy Farms, we assume that Wellesley will contribute 13.25% to the daily load of a 10,000-gallon anaerobic digester. We calculate this contribution as follows:

Daily volume of digester filled: (kg of liquid/day)
= (Wellesley's daily food waste kg/day)/.12
= (602.7 kg/day)/.12
= 5,016 kg of liquid/day

Since the wood waste is diluted, we assume that the density of the food waste is similar to that of water (1000 kg/1 m^3).

Total daily volume of digester filled (gallons/day)
= (Wellesley's volume kg/day)*(1m^3/1000 kg)*(1000 L/1 m^3)*(1 gallon/3.785 L)
= (5,016 kg of liquid/day))*(1m^3/1000 kg)*(1000 L/1 m^3)*(1 gallon/3.785 L)

[1] Casella Organics, Inc. "AGreen Anaerobic Digester." Accessed February 24, 2013. http://casellaorganics.com/business/source-separated/agreen.
[2] Casella Organics, Inc. "Colby College." Accessed February 24, 2013. http://casellaorganics.com/business/source-separated/agreen.
[3] MassDEP. "Anaerobic Digestion Case Studies: Agricultural Uses." Accessed February 24, 2013. http://www.mass.gov/dep/energy/adfarms.htm
[4] Jorgenson, Bill, AGreen Energy, LLC employee. Kelly Mercer. February 28, 2013.

= 1,325 gallons/day

Percentage of Morrisville input per day
= Wellesley's daily input liquid/Morrisville's daily processing ability
= (1,325 gallons/day)/10,000 gallons/day)
= 13.25 %

Jordan Dairy Farms completed its anaerobic digestion system in 2011[5] and, has since offset over 1133.98 metric tons of carbon dioxide emissions and biogas energy equivalent to powering 64,174 homes for one day.[6] Each year, the anaerobic digestion facility at Jordan Dairy Farms processes 14,900 metric tons of source-separated organics (SSO),[7] which is food waste from local businesses. The digesters accept any food waste, so long as it free from all non-food matter.

All of the farms run by AGreen Energy, LLC source their waste from institution within a two-hour radius.[8] The commute between Wellesley College and Jordan Farms, for example, is just over an hour, making the institution a great potential client. While Jordan Dairy Farms currently requires SSO to arrive to their farm pretreated and in an airtight container,[9] within the next year the company will be building a food waste treatment plant.[10] The addition of this plant will alleviate the need for Wellesley to pre-treat its food waste. Instead, the College will just have to gather all waste and truck it in the mandated 8,000-gallon tanker truck to the digester site. AGreen Energy, LLC will then process the food, suspending it in water and removing any potential contaminants.

Once it arrives at the digester, the food is placed in a holding area for three days. Here, it is mixed with cow manure from the five consortium farms[11] until it reaches the proper consistency for the digester.[12] Once the organic waste enters the digester, it is processed for thirty days, after which it provides useful outputs. Many of these outputs are used on the farm. For example, the waste heat and organic fertilizer generated by the digester are used to maintain the greenhouses. Moreover, the energy produced in the anaerobic digestion process acts as revenue for the farm, which sells it to the sources of the SSO and the Massachusetts power grid.[13]

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[5] Casella Organics, Inc. "AGreen Anaerobic Digester." Accessed February 24, 2013. http://casellaorganics.com/business/source-separated/agreen.
[6] PowerDash Inc. "Jordan Dairy Farms Biogas." Accessed February 24, 2013. http://www.powerdash.com/systems/1000499/.
[7] MassDEP. "Anaerobic Digestion Case Studies: Agricultural Uses." Accessed February 24, 2013. http://www.mass.gov/dep/energy/adfarms.htm.
[8] Austin, Anna. "Diary Diversification." *Biomass Magazine*, July 28, 2011. Accessed February 24, 2013. http://biomassmagazine.com/articles/5694/dairy-diversification.
[9] Casella Organics, Inc. "AGreen Anaerobic Digester." Accessed February 24, 2013. http://casellaorganics.com/business/source-separated/agreen.
[10] Jorgenson, Bill, AGreen Energy, LLC employee. Kelly Mercer. February 28, 2013.
[11] AGreen Energy, LLC. "A Green Energy's Digester Ecosystem." Accessed February 24, 2013. http://jordandairyfarms.com/wp-content/uploads/2012/05/digestergraph1.jpg.
[12] Austin, Anna. "Diary Diversification." *Biomass Magazine*, July 28, 2011. Accessed February 24, 2013. http://biomassmagazine.com/articles/5694/dairy-diversification.
[13] AGreen Energy, LLC. "A Green Energy's Digester Ecosystem." Accessed February 24, 2013. http://jordandairyfarms.com/wp-content/uploads/2012/05/digestergraph1.jpg.

12.2 Implementing Anaerobic Digestion Off Campus at Wellesley College

12.2.1 Overview of Implementation at Wellesley

If Wellesley were to divert its food waste to a facility like Jordan Dairy Farms, the College would have to do very little preparation. With the installation of organic waste treatment facilities at AGreen Energy, LLC's anaerobic digestion sites, Wellesley would simply have to separate its food waste from the rest of its waste stream.[14] The College would have to contract a hauler to bring its food waste to the digester site.

12.2.2 Technology/Equipment

Wellesley would not have to buy any equipment for off-campus anaerobic digestion. It would have to employ an 8,000-gallon trucker to haul its waste from Wellesley to the digestion site. Wellesley is responsible for the transportation of its waste from the College to the farm's treatment plant. Jordan Dairy Farms mandates that all food waste be delivered in 8,000-gallon tanker trucks.[15] Wellesley, on average, produces 2,048.6 gallons of deliverable (95% water, 5% food) food waste each day. The College has two options to optimize trucking: it could have its waste picked up as one stop on a larger trucking route, or it could send one truck every 15 days.

12.2.3 Inputs

Energy

To calculate the energy needed to prepare Wellesley's food waste for anaerobic digestion, we used Somat's eSHRED pulping as an example of a pulping system with low energy demand.[16] We selected this system because it is the largest offered by Somat, thus best reflecting the pulper used at the processing facility. It also has minimal energy and water demands with limited waste products. This seemed to best reflect the theoretical system planned by AGreen Energy. We calculated the energy demand as follows:

Energy needed to prepare Wellesley's food waste (kWh/metric ton)
= 6.7 kW * 1 hr/544.3 kg * food waste (4)
= .01231 kWh/kg food waste
= 12.31 kWh/metric ton * (.6027)
= 7.41 kWh/metric ton

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[14] Austin, Anna. "Diary Diversification." *Biomass Magazine*, July 28, 2011. Accessed February 24, 2013. http://biomassmagazine.com/articles/5694/dairy-diversification.
[15] Austin, Anna. "Diary Diversification." *Biomass Magazine*, July 28, 2011. Accessed February 24, 2013. http://biomassmagazine.com/articles/5694/dairy-diversification.
[16] Somat Company. "Somat Super 60 Close Coupled Pulping System." Accessed March 2, 2013. http://www.somatcompany.com/uploadedFiles/Content/Products/SPC-60S.pdf.
Somat Company. "Somat ecoShred Compostable Waste Shredder." Accessed March 2, 2013. http://www.somatcompany.com/uploadedFiles/Content/Products/EcoShred.pdf.

We also account for Wellesley's share of the energy needed to power the digester. We assume the energy provided to the digester comes from the Eastern US grid. We calculated Wellesley's energy contribution as follows:

Energy needed to power an anaerobic digester
= 40.8 kWh[17]

Wellesley's Total Energy Responsibility (kWh)
= total energy demand * percent of Wellesley's food waste
= 40.8 kWh * .018
= .7344 kWh

Materials
Even though we are employing an off-campus anaerobic digester, we must assume responsibility for Wellesley's share of the construction materials, since the College's load will contribute to the wear and tear of the equipment.

We assume that the Somat eSHRED is a sufficient proxy for organic waste pretreatment. While this machine does not have a large capacity, it is the biggest that we could find. Its contribution is measured per metric ton so it is scalable. Since Wellesley will be sending its waste to the pre-treatment facility at an anaerobic digester like those being created by AGreen Energy, LLC, we account Wellesley's share as follows:

Wellesley's Responsibility for Off-Campus Steel Pulper
= mass of steel kg/Wellesley's food waste for 20 years kg
= 1400 lbs * (1 kg/2.204 lbs)
= 635.208 kg
= 635.208 kg steel / 4400 metric ton food waste
= .144 kg steel/metric ton food waste
= .144 kg steel *.6027
= .087 kg steel/Wellesley's food waste

We assume that Wellesley would employ this off-campus anaerobic digester for its entire lifespan. This is a safe assumption since many digesters are currently under construction. We calculate Wellesley's contribution as follows:

Total Concrete Needed
= 154.134 metric tons concrete
= 154,134 kg concrete/(33.97 metric tons/day * 365 days/year * 40 years)
= .3108 kg concrete/metric ton

Total Steel Needed
= 24.3 metric tons steel
= 24,300 kg/(33.97 metric tons/day * 365 days/year * 40 years)

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[17] Shayya, Walid H. "Anaerobic Digestion at Morrisville State College: A Case Study." Accessed May 2013. http://people.morrisville.edu/~shayyaw/anaerobicdigestionatmorrisvillestatecollege.pdf.

= .0484 kg steel/metric ton food waste

Total Polyurethane Needed
= 44.94 metric tons
= 44,940 kg/(33.97 metric tons/day * 365 days/year * 40 years)
= .0906 kg polyurethane / metric ton food waste

Total Epoxy Needed
= 7.36 metric ton
= 7360 kg/(33.97 metric tons/day * 365 days/year * 40 years)
= .0148 kg/metric ton

12.2.4 Outputs

An anaerobic digester of similar size to Jordan Dairy Farms' would produce two main outputs: energy and fertilizer. Jordan Dairy Farms produces enough energy daily to power a 13-watt light bulb for 317,000 hours.[18] In addition to providing energy for the digester, the farm is also able to sell excess power to the Massachusetts' electricity grid. The energy created by anaerobic digestion was calculated as follows:

Total energy produced by Anaerobic Digester (kW/day)
= total energy produced per day * conversion from watt to kilowatt
= 13W x 317,000 hours/day
= 4,121,000 W/day
= 4,121 kW/day

Total energy credited to Wellesley College (kWh)
= total energy produced hourly * percent of Wellesley food waste
= 4,121 kWh * .018
= 74.18 kWh/metric ton food waste

We assume that the energy produced by the digester will be sold to the Eastern US grid and have a positive environmental impact.

Another main byproduct of anaerobic digestion is digestate, a nutrient-rich substance that can be used as a substitute for commercial fertilizer. Jordan Dairy Farms uses the digestate from its anaerobic digester to alleviate its need for non-organic chemical fertilizer. Thus, the digestate contributes to a positive environmental impact.

Since the specific amount of fertilizer produced by the digester at Jordan Dairy Farms was unavailable, we assumed it would produce the same amount as a similar-size anaerobic digester at Washington State University. We calculated fertilizer production as follows:

[18] PowerDash Inc. "Jordan Dairy Farms Biogas." Accessed February 24, 2013. http://www.powerdash.com/systems/1000499/.

Amount of Dry Fertilizer from Digestate (7) (kg/day)
= 855,496 kg/day (Ammonia Sulfate) + 3,421,875 kg/day (Phosphorus rich soil)
+ 7,031 kg/day (fiber)
= 4,284,402 kg dry fertilizer/year
= 11,738 kg dry fertilizer/day

Total fertilizer credited to Wellesley College (kg/day)
= total amount of dry fertilizer * .018
= 11,738 kg fertilizer/day *.018
= 211.28 kg fertilizer/day

Total relative fertilizer credited to Wellesley College (kg fertilizer/kg food waste)
= total fertilizer credited to Wellesley / Total daily food waste
= 211.29 kg fertilizer day / .60274 metric tons food waste
= 350.5 kg/metric ton food waste

12.3 Environmental Impacts of Anaerobic Digestion Off-Campus

12.3.1 Collection and Preparation of Food Waste

To optimize anaerobic digestion potential, Wellesley's food waste must be pulverized and suspended in water before entering the system. While Jordan Dairy Farms does not currently have the facilities to complete this preparation stage, it plans to build a fully operational processing plant before 2014.[19] Thus, this study assumes that Wellesley will send its unprocessed food waste to the preparation facility, where it will be prepared for digestion.

Energy
Energy needed to prepare Wellesley's food waste (kWh/metric ton)
= 7.41 kWh/metric ton of food waste

For the purpose of our study, we assume that AGreen Energy, LLC does not plan to use the biogas from the anaerobic digestion to power its treatment facility. Since it is still unclear what type of machinery AGreen Energy, LLC will use at their processing facility, this study uses on-campus pulping as an energy proxy. This assumption may not accurately reflect the energy demand of a large-scale industrial pulping facility. We also assume that the energy to power the pulper will come from the Eastern US grid rather than from the combustion of biogas produced in this process.

Materials
Wellesley's Responsibility for Off-Campus Steel Pulper
= .087 kg steel/Wellesley's food waste

To optimize anaerobic digestion potential, Wellesley's food waste must be pulverized and suspended in water before entering the system. The material information stems from data on

[19] Jorgenson, Bill, AGreen Energy, LLC employee. Kelly Mercer. February 28, 2013.

Somat's eSHRED. We assume that this is a fair proxy for the actual pulper used by the facility. We also assume that Wellesley will be responsible for 60.27% of the wear and tear based on the College's food waste diversion needs.

Transportation of Food Waste
The transportation cost for Wellesley will be zero, as the hauling company will be taking the food waste to the anaerobic digester. Since SimaPro does not have data on tanker trucks, we calculated load equivalence to determine a similar mode of transport. To complete our calculations, we assumed that the truck was hauling 100% water, a reasonable assumption since the deliverable compound is 95% water. We calculated an equivalent vehicle as follows:

Weight of 8,000-gallon tanker truck (metric tons)
= 8000 gallons water * (1 metric ton water/264.17 gallons water)
= 30.3 metric tons

We used "Truck 28t" as a proxy for transportation in SimaPro. While this truck is slightly smaller than the one that Wellesley would use to transport its food waste to Jordan Dairy Farms, it is the best available representative of the vehicle we would use. We calculated the distance that the truck has to travel as follows:

Distance to Jordan Dairy Farms
= 46.5 miles = 74.8 kilometers

Roundtrip Distance to Jordan Dairy Farms
= 74.8 kilometers * 2 = 149.6 kilometers

Each day, Wellesley will have to send .6027 metric tons of food waste to the farm. This will fill 2% of a 30.0 metric ton (8,000-gallon) tanker truck. Here, however, we assume that the truck would make a trip to Wellesley every 15 days. Under this scenario, Wellesley would fill the entire truck during each trip. We divided the round-trip distance by four to reflect the daily distance traveled.

Kilometers traveled daily (on average)
= 149.6 kilometers / 4 day cycles = 9.73 kilometers/day

12.3.2 Process

Wellesley's contribution to the composting process is 13.25% of the total energy and materials needed. Justification for this percentage is provided above.

Materials
When calculating the materials used, we assumed that the wood and plastic needed for the construction of the digester were negligible. This assumption is valid because a very small amount of these materials is used in the construction of the digester, especially when their use is considered over the 20-year lifespan of the equipment.

The following numbers were used to calculate Wellesley's contribution to the construction of an anaerobic digester. Calculations can be found above.

0.3108 kg concrete/metric ton food waste
0.0484 kg steel/metric ton food waste
0.0906 kg polyurethane / metric ton food waste
0.0148 kg epoxy/metric ton food waste

Energy
Wellesley is responsible for .7344 kWh of energy per metric ton of food waste.
For the purpose of our study, we assume that AGreen Energy, LLC does not plan to use the biogas from the anaerobic digestion to power its treatment facility. Instead, we assume that the energy comes from the Eastern US grid.

12.3.3 Avoided Impacts

In addition to the negative environmental impacts from the anaerobic digestion process, there are also two positive impacts: the creation of biogas and digestate. Wellesley's environmental credit from these two byproducts is 13.25% of the total amount produced. Wellesley will have the environmental credit for 74.18kWh/metric ton of food waste. We assume that the energy produced by the digester will be sold to the Eastern US grid and have a positive environmental impact. Wellesley will also have the environmental credit for 350.5 kg fertilizer per metric ton of food waste. We assume that the fertilizer produced by the digester will substitute for phosphorus-rich fertilizer and entered it into SimaPro as such. We also assume that the farm will use this fertilizer on-site, rather than selling it to another location. This distinction is important because it eliminates the environmental impacts associated with the transportation of fertilizer.

12.3.4 Water Use

We assume that the digester will be using 100% reclaimed water. As such, we have not included it in our environmental impact calculations.

As is evident from the environmental impact analysis, the environmental impacts of off-campus anaerobic digestion vary greatly by life cycle stage. For off-campus anaerobic digestion, the transportation of food waste from Wellesley to the digester caused greater than 50% of the environmental impacts across all categories. The impacts from transportation may be reduced over the next few years as more digesters are installed closer to Wellesley College. At this point, however, there are no closer facilities and no other trucks we could use for this process. This is likely to change as the 2014 deadline approaches.

12.3.5 Summary: Life Cycle Impacts and Assessment of Anaerobic Digestion Off-Campus

Table 12-1: Environmental impacts by process stage, off campus anaerobic digestion.

Impact category	Unit	Equipment	Collection	Transportation	Method	Avoided Impacts	Total
Global Warming	kg CO2 eq	0.6405	0.0796	2.1721	0.3887	-9.6392	-6.3583
Carcinogenic	kg benzene eq	0.0013	0.0018	0.0068	0.0001	-0.1760	-0.1660
Ecotoxicity	kg 2,4-D eq	0.7865	-0.0049	0.8807	0.0288	-5.5711	-3.8801

Table 12-1 summarizes the environmental impacts of off-campus anaerobic digestion. It is important to note that the numbers in the table represent the environmental impact of anaerobic digestion for each metric ton of food waste diverted to the anaerobic digesters.

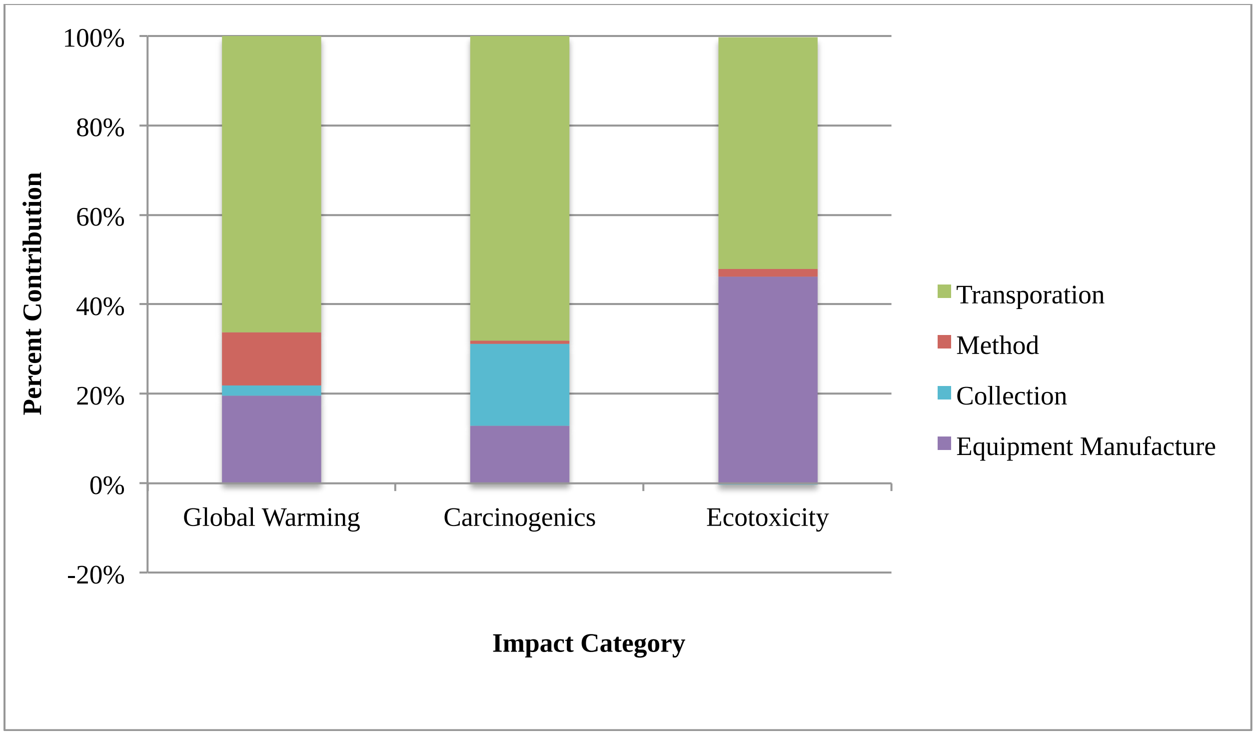

Figure 12-1: Percent contribution of process stages to each impact category, off-campus anaerobic digester (10,000 gallon digester).

Figure 12-1 shows the negative environmental impacts of off-campus anaerobic digestion. It is important to note that the numbers in Figure 12-1 represent the environmental impact of anaerobic digestion for each metric ton of food waste diverted to the anaerobic digesters. The avoided impacts of off-campus anaerobic digestion are not included in this graph.

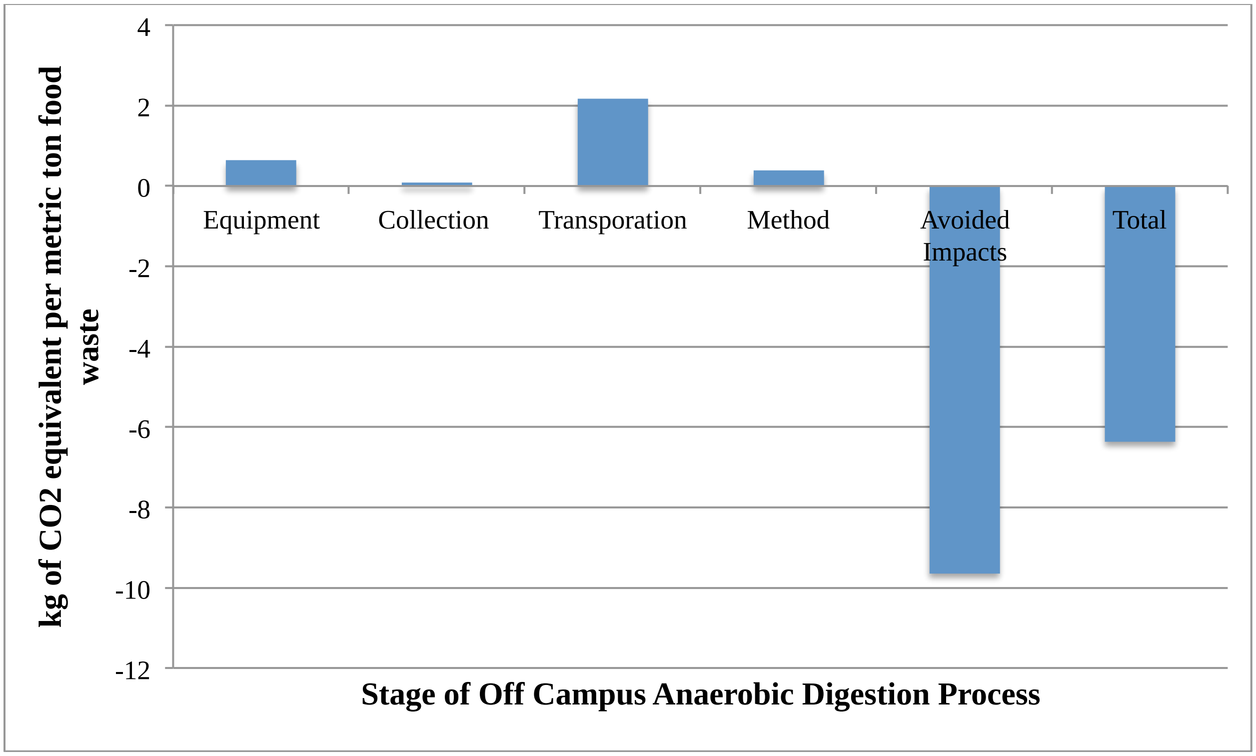

Figure 12-2: Climate change impact of each process stage, off-campus anaerobic digester.

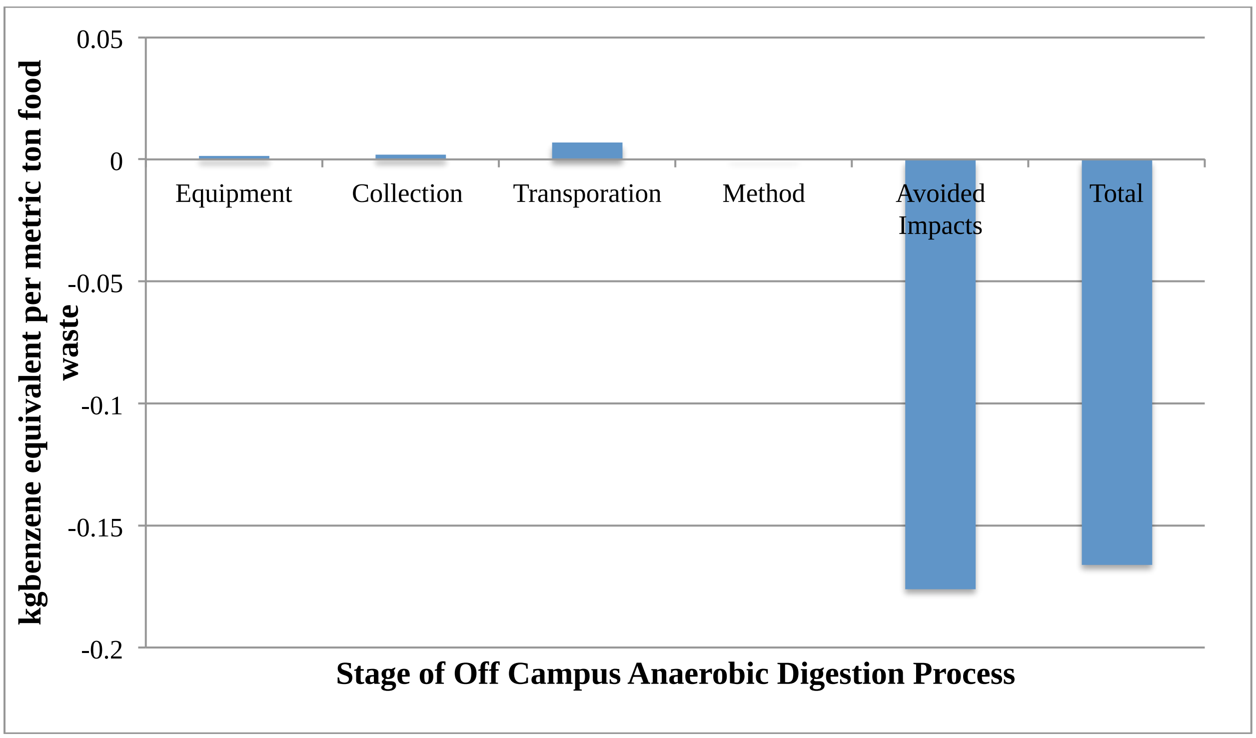

Figure 12-3: Human toxicity impact of each process stage, off-campus anaerobic digester.

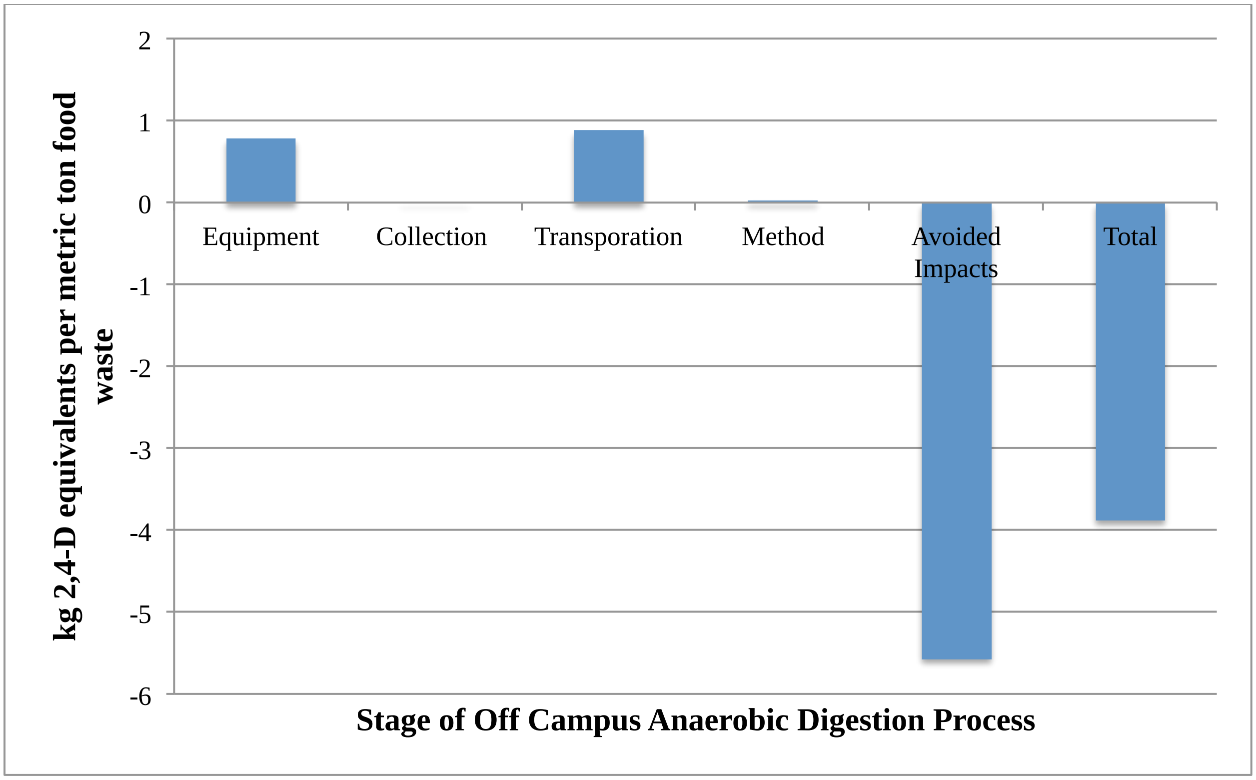

Figure 12-4: Ecosystem toxicity impact of each process stage, off-campus anaerobic digester.

Additionally, we examine the net environmental impacts of off-campus anaerobic digestion. To do this, we subtract the adverse impacts from the total materials, transportation, method, and collection impacts for each environmental impact category. Figures 12-2, 12-3, and 12-4 show the net environmental impacts of anaerobic digestion for each impact category. In these figures, negative numbers represent a positive environmental impact while positive numbers represent a negative impact.

12.4 Costs of Anaerobic Digestion Off-Campus

12.4.1 Direct Cost

Tipping Fees

To estimate the tipping fee for off-campus anaerobic digestion, we compared it to a similar facility in Delaware. Similar to the facilities at AGreen Energy, LLC, the anaerobic digester in Delaware has an on-site processing facility to treat organic waste and the ability to process both pre- and post-consumer organic waste. The main difference is the digester's capacity; the one in Delaware is nearly 15 times larger than Jordan Dairy Farms. We assumed that the capacity of the digester would not drastically alter the price per ton and that the tipping fee was representative of the baseline price for using a source-separated anaerobic digester in Massachusetts.

In 2005 the estimated tipping fee for the Delaware anaerobic digester was $40/metric ton of food waste.[20] Thus, we assume that Wellesley would have to pay $40 per metric ton food waste. It is possible that this estimate is lower than the cost Wellesley would incur. The main limitations to this pricing are its possible outdated-ness and situation. The tipping fee estimation is nearly eight years old, meaning it may not account for recent market changes. Moreover, the price for this digester does not take into consideration the massive demand for composting that will occur in Massachusetts as institutions attempt to adhere to the July 2014 policy deadline. It also ignores the potential that an increased supply of organic waste diversion options would have in reducing market prices. It is possible that the high demand would drive the market price for anaerobic digesters.

Trucking Fees
Wellesley would have to contract an outside organic waste hauling company to take its food waste to the anaerobic digester. Since processing will take place at the on-site pre-treatment facility, Wellesley will only be responsible for moving the waste, not pulping it or suspending it in water. The price of the hauling will vary depending on the frequency of collection and the load carried. For the purpose of this assessment, we assumed that Wellesley would pay $45/metric ton of diverted food waste for hauling. This price is based on two studies about food waste hauling to anaerobic digesters.[21] Assuming that Wellesley needs to divert 220 metric tons of food waste each year,[22] the College would have to pay $9,900 each year for food waste hauling. It should be noted that Wellesley may be able to negotiate a cheaper food-hauling contract because of the volume of food that it needs to divert.

12.4.2 Operational Cost

Transportation Cost
The transportation cost for Wellesley will be zero, as the hauling company will be picking up the food waste at all locations on campus and taking it to the anaerobic digester.

Labor Costs
There will be no additional labor costs to Wellesley College for an off-campus anaerobic digester. To divert food to an off-campus anaerobic digester, dining services will have to sort food and place it outside for pickup. The labor needed to do these tasks is no greater than what the dining halls currently employ. Dining hall staff will have to sort food independent of the composting method. Moreover, whether Wellesley diverts its waste or not, the College still has

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[20] Olivares, Cristina, and Nora Goldstein. "Food Composting Infrastructure." Accessed May 2013. http://www.biocycle.net/2008/12/food-composting-infrastructure-5/.
[21] MassDEP Bureau of Waste Prevention. "Supermarket Composting Handbook 2005." Accessed May 2013. http://www.mass.gov/dep/recycle/reduce/smhandbk.pdf
Gabrielli, Julie. "Waste Neutral offers practical, affordable hauling to turn smelly food scraps into rich compost." Accessed March 9, 2013. http://www.examiner.com/article/waste-neutral-offers-practical-affordable-hauling-to-turn-smelly-food-scraps-into-rich-compost.
[22] Wellesley College ES 300 2012. "Waste Not, Want Not: An Environmental Impact Assessment of the Wellesley College Waste Stream and Steps for a More Sustainable Future." Accessed May 2013. http://new.wellesley.edu/sites/default/files/assets/departments/environmentalscience/files/es300-2012-wastenotwantnot.pdf.

to place waste outside. Thus, there are no additional labor costs for off-campus anaerobic digestion.

Energy Costs
Since all of the processing and treatment for anaerobic digestion will take place off campus, the operational costs for off-campus anaerobic digestion will be included in the price Wellesley pays the digester facility. Wellesley will incur no additional cost.

Other Operational Cost
The price of water is included in the tipping fee that Wellesley would pay to divert its food waste to the anaerobic digester.

12.4.3 Equipment

Since all of the processing and treatment for anaerobic digestion will take place off campus, Wellesley will not have to purchase any specialized equipment.

12.4.4 Offset Cost

By employing an off-campus anaerobic digester, Wellesley will not receive financial offsets. Profits made from selling the energy and fertilizer generated by the digester would go to the farm to which Wellesley would export its waste. The farm would then sell the energy back to the Massachusetts grid and use the fertilizer on site. Thus, the offset costs that Wellesley would incur are part of the calculation for the direct costs of diverting our food waste to the farm's anaerobic digester.

12.4.5 Summary: Cost of Anaerobic Digestion Off-Campus

All costs that Wellesley would have to pay for off-campus anaerobic digestion at a site similar to the one at Jordan's Dairy Farms are direct costs paid either as a tipping to the farm or to an organic waste hauling company. Wellesley's total cost for off-campus anaerobic digestion is $85.00 per metric ton of food waste (Table 12-2).

Direct costs account for the entire cost for off-campus anaerobic digestion. This makes sense since Wellesley only has to pay a tipping and hauling fee. Since the digester and treatment facilities are off campus, the operational and equipment costs are included in the tipping fee.

Table 12-2: Cost of off-campus anaerobic digestion

Cost Category		Amount ($/metric ton waste)
Direct:		85
	Facilities	40
	Transportation	45
Operational:		
	Transportation	0
	Labor	0
	Other	0
Equipment		0
Offset Costs		0
Total Cost		**85.00**

12.5 Social Impacts of Off-Campus Anaerobic Digestion

12.5.1 Detriment to Campus Experience – Neutral

Off-campus anaerobic digestion will have little impact on the campus experience. The process takes place 50 miles away from Wellesley. This will eliminate the opportunity for raising environmental awareness, which composting could create. Finally, with frequent pickups, the risk of pests or smell from the collection bins would be no greater than that of the College's waste.

12.5.2 Lack of Educational Benefit – High

Off-campus anaerobic digestion will offer no additional educational opportunities. Once the food is sorted in the dining halls, it will immediately be placed into a collection bin and taken away from Wellesley. This composting method will not be visible to students, nor will there be many academic opportunities to integrate the off-campus anaerobic digester into on-campus discussion.

12.5.3 Implementation Difficulty

Separation - Low
Since all of the processing and treatment would occur off campus, there would be no cultural and behavioral change among Wellesley's student body. Dining hall staff would require minimal

training on separating food. The training would not have to be extensive since the anaerobic digestion facilities have on-site processing plants.

Permitting and Regulations - Low
With anaerobic digestion occurring off campus, Wellesley would not be responsible for any permitting.

Time until Implementation – Medium
Off-campus anaerobic digestion could begin by the 2014 deadline. The implementation, however, would not be immediate. The current anaerobic digester at Jordan's Dairy Farms is at capacity. Wellesley would be able to divert its food waste, however, to one of many similar digesters, run by the same company, at other farms in Massachusetts. These digesters and their corresponding processing facilities are currently under construction. AGreen Energy, LLC, the organization installing and operating the anaerobic digesters, predicts that the new facilities will be completed well before the July 2014 deadline.[23]

Risk - Medium
There would be a medium potential for contamination of food waste through this composting method. If there is on-campus contamination of food waste, the processing facility would be able to resolve this issue before placing the waste into the anaerobic digester.

12.5.4 Social Justice – Neutral

The off-campus anaerobic digester would pose no additional risk to Wellesley College students, faculty, and staff. Additionally, it would not add any labor risks since staff would only be separating food from other waste. Finally, since the off-campus anaerobic digesters considered by this study are located on farms, there would be minimal environmental justice concerns about their placements in underserved communities.

12.5.5 Social Impacts of Anaerobic Digestion Off-Campus

As seen in Table 12-3, the largest social cost that Wellesley would incur from off-campus anaerobic digestion is from the lack of educational opportunities. Since the entire process will take place over 50 miles from campus, students and professors would not have a chance to integrate the process into their curriculum or coursework. Aside from venturing to the site, there is not much that could be done to minimize this cost.

[23] Jorgenson, Bill, AGreen Energy, LLC employee. Kelly Mercer. February 28, 2013.

Table 12-3: Social impacts of off-campus anaerobic digestion.

Social Impact		**Score**
Campus experience		Neutral
Education		High
Difficulty:		
	Separation	Low
	Permitting and regulations	Low
	Time until implementation	Medium
	Risk	Medium
Social justice		Neutral

12.6 Conclusions

Off-campus anaerobic digestion is a viable option that Wellesley could employ to comply with the 2014 Organic Waste Ban deadline. It has low social impacts and a minimal cost. Most importantly, off-campus anaerobic digestion offers many environmental benefits and useful byproducts. When considering both the impacts and offsets of off-campus anaerobic digestion, the method is environmentally beneficial. It would eliminate the need for industrial fertilizer on local farms and reduces the energy demand of these establishments. It would also provide a method of income for farmers in Massachusetts who can sell excess power to the Massachusetts grid.

The main issue with off-campus anaerobic digestion would be the availability of sites as the July 2014 deadline approaches. Many farms are building digesters in preparation of the regulatory deadline. The sheer number of institutions needing to divert their food waste may overwhelm the existing infrastructure for anaerobic digesters. If Wellesley wants to employ this method, it will have to act quickly to secure a spot in these up-and-coming facilities.

13.0 Traditional Dehydration

13.1 Introduction to Traditional Dehydration

Figure 13-1. An example of a dehydrator system.[1]

Many colleges in the United States have chosen to pursue dehydration systems as a method of food waste diversion and an alternative to incinerating waste. Dehydration of waste is a process in which water is removed from food waste in order to reduce the waste's overall volume and weight. The products of this process include both the dried waste, which can be used as a soil amendment, and wastewater, which can be used in landscaping and gardening. A dehydration unit requires only the food input and electricity, and does not need other treatment chemicals, enzymes, or microorganisms to break down the waste.[2] Dehydration systems generally require little maintenance and operations oversight. Dehydrators can typically process all types of food waste, including cardboard and compostable dishware.[3]

A commonly used dehydrator model is the ECORECT Smart Composter. We examine the ET-300W model, which handles up to 293.8 kg of waste daily. This model is used most frequently in

[1] Ecco Technologies. "Somat ECORECT." Accessed May 4, 2013. http://www.ecco-technologies.com/somat.html.
[2] Ecco Technologies. "Somat ECORECT." Accessed May 4, 2013. http://www.ecco-technologies.com/somat.html.
[3] Ecco Technologies. "Somat ECORECT." Accessed May 4, 2013. http://www.ecco-technologies.com/somat.html. Though dehydrators *can* process all organics, some separation may be needed if the biosolid outputs are to be used as a soil amendment without prior treatment. Thus, the quality of the soil amendment depends on the composition of the College's food waste. If there are minimal amounts of meat, dairy, and compostable dishware, the ratio of these materials to the other food waste may be small, and separation may not be required.

school cafeterias, restaurants, and other medium- to large-scale food preparation institutions.[4] This model requires no freshwater or venting connections.[5]

The dehydration process is simple: food waste, including compostable disposables, is put inside the dehydrator and the machine runs for 12 to 18 hours. During this time water is removed in a few steps. First, the waste is mixed thoroughly by an agitator. It then undergoes the heating process, which reduces the overall mass of the waste by 83% to 93% and the overall volume of the waste by around 80%.[6] This process occurs in a chamber that reaches temperatures of up to about 180 degrees Fahrenheit, which ensures that bacteria, pathogens, and seeds are killed and odor is eliminated, and produces a sterilized material.[7] For the purposes of this report, the density of wet waste is estimated at 17.97 kg/cubic foot.[8]

Many institutions choose to use both a pulper and a dehydrator. The pulper pulverizes the food waste into a homogenous slurry, making it easier to dehydrate. The two components are usually combined into a single closed system, a close-coupled pulper-dehydrator. With these machines, food is fed into the pulper before moving automatically into the dehydration chamber. During the pulper stage, food is mixed with water to create a well-mixed pulp. This pulp is usually about 95% water. Once the pulp is dehydrated, water is recycled from the dehydration process back to the pulper in order to minimize the amount of freshwater required as an input. Pulpers can also process waste that is not compostable, such as plastics and aluminum foil. The addition of non-compostable waste limits the utility of the end product as a soil amendment.[9] We assume that a dehydration system at Wellesley will only process compostable wastes, and will include a close-coupled pulper-dehydrator.

There are two major disadvantages to using a dehydration system. The primary disadvantage is the energy use. A dehydration unit is estimated to require 144 kWh for an 18-hour cycle, which is equivalent to 712.9 kWh per metric ton of waste processed. In addition, dehydration systems are expensive. Pricing for a system similar to the ECORECT Smart Composter starts at around $70,000.[10]

This method aligns with two of the Office of Sustainability's existing Landscape and Water

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[4] ECORECT Technology. "ECORECT Smart Composter Product Specifications." Accessed May 4, 2013. http://www.ECORECT.com/uploads/6/3/9/6/6396564/ECORECT_product_specs_portrate.pdf.

[5] ECORECT Technology. "ECORECT Smart Composter Food Waste Reduction & Conversion System: Frequently Asked Questions." Accessed May 4, 2013. http://www.ECORECT.com/uploads/6/3/9/6/6396564/ECORECT_smart_composter_faq.pdf.

[6] Ecco Technologies. "Somat ECORECT." Accessed May 4, 2013. http://www.ecco-technologies.com/somat.html.

[7] ECORECT Technology. "ECORECT Smart Composter Food Waste Reduction & Conversion System: Frequently Asked Questions." Accessed May 4, 2013. http://www.ECORECT.com/uploads/6/3/9/6/6396564/ECORECT_smart_composter_faq.pdf.

[8] Wellesley College ES 300 2012. "Waste Not, Want Not: An Environmental Impact Assessment of the Wellesley College Waste Stream and Steps for a More Sustainable Future." Accessed May 2013. http://www.wellesley.edu/sites/default/files/assets/departments/environmentalscience/files/es300-2012-wastenotwantnot.pdf.

[9] Somat. "Close-Coupled Waste Pulping System." Accessed February 25, 2013. http://www.somatcompany.com/Products/Close-Coupled-Pulpers/.

[10] Somat. "Somat DeHydrator System." Accessed May 4, 2013. http://www.somatcompany.com/Products/Dehydrator-System/.

Conservation goals, which prioritize using "cutting edge techniques in our landscape" and reducing water consumption on campus.[11] Dehydrators do not necessarily align with the Office of Sustainability's fourth goal regarding reducing energy consumption on campus.

13.2 Implementing Traditional Dehydration at Wellesley College

13.2.1 Overview of Implementation at Wellesley

There are three significant variables that will affect how traditional dehydration would be implemented at Wellesley. First, the volume capacity of the dehydrators will affect where the dehydrators are located. Second, the way we transport food waste on campus will depend on the location(s) of the dehydrators and storage facilities for the dry biogenous output. Third, the composition and quantity of food waste will affect the dehydrators used, the quality of biogenous and liquid outputs, and subsequent treatment needs.

We assume that dehydration of food waste would occur on campus, as opposed to at an off-campus facility. It would not make sense for food to be transported off campus prior to pulverization and dehydration. We assume that industrial-sized dehydrators would be used to process the waste, rather than using solar dehydration or "open-air" dehydration. It seems that solar-powered dehydrators on the market currently would not manage the volume of waste that the College produces.

To implement a comprehensive dehydration system, Wellesley would need to either install dehydration units in each dining hall, or install fewer units and transport waste to them. Either way, we assume that this method would prioritize dehydration of food waste from dining halls. For the purposes of this report, we assume a decentralized model of waste diversion as seen in Figure 1, with one 294.8 kg capacity ECORECT ET-300W in each of the campus's five dining halls. We assume this method will only process waste from the dining halls rather than waste collected from other parts of campus. This model makes sense for controlling the inputs of waste into the dehydrators within each dining hall. It is also the most feasible from a transportation perspective. Because post-dehydrated food waste takes up less volume and weight than pre-dehydrated waste, there would be less total transportation needed for moving dry material to a new location from many points on campus than to transport wet waste from many points to one central location. Though not examined in this report, having a dehydrator at each dining hall could facilitate future incorporation of residence hall food waste from individuals' kitchen use and events.

[11] Wellesley College Office of Sustainability. "Wellesley Office of Sustainability." Accessed February 25, 2013. http://www.wellesley.edu/AdminandPlanning/Sustainability/.

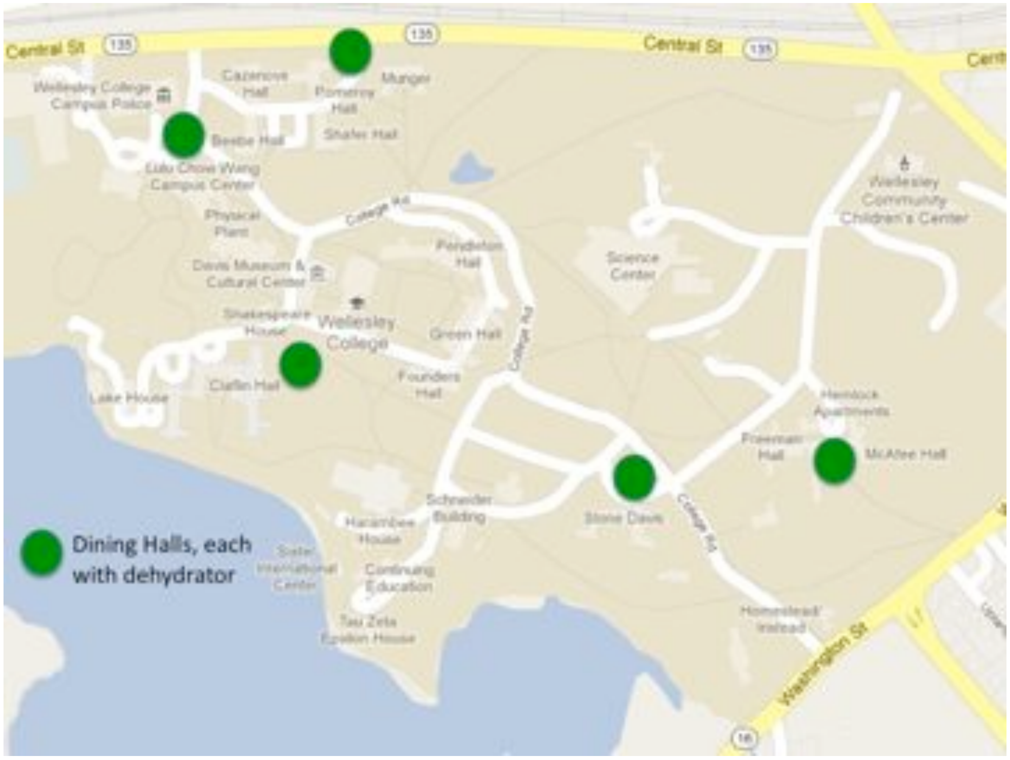

Figure 13-2. Decentralized model for on-campus dehydration**.** One ECORECT unit in each dining hall.

While not considered for traditional dehydration, the alternative system would be a centralized model, with one larger-capacity dehydrator—such as the ET-500w, with an input capacity of 1100 lbs. (about half a metric ton)—in a central location.[12] This method would require transportation of wet waste (with a high volume/weight).

If there were a 294.8 kg capacity ECORECT ET-300W in each of Wellesley's five dining halls, the whole system would be able to process all of the dining hall waste produced daily. According to our estimates, the College produces 220 metric tons of food waste annually. The dining halls are responsible for approximately 214 metric tons of this total, or around 1.01 metric tons of food waste per day (assuming 212 days in the school year). Under our implementation assumptions, the ECORECT machines would not be running at full capacity. Though not explicitly considered in our report, the ECORECT machines would have a volume capacity to process *all* food waste produced on campus, and could process food waste produced by students in dorms.

With a decentralized system as shown in Figure 13-2, AVI's waste would already be located near the dehydrators, meaning that only transportation of dehydrated biosolids would be required. If we wanted to dehydrate all food wastes, then waste from residence hall kitchens, student cafés, and academic departments would need transportation to the dehydrators. For the purpose of this report, we assume that there will be no transportation of wet food waste to the dehydrators, and that the system will only process waste from the dining halls. Running at full capacity, the

[12] ECORECT Technology. "ECORECT Smart Composter Product Specifications." Accessed May 4, 2013. http://www.ECORECT.com/uploads/6/3/9/6/6396564/ECORECT_product_specs_portrate.pdf.

dehydrators would not be able to process all of the dining halls' waste, and thus there would be no need to transport waste from other sources to the dining halls.

We assume that the dry biogenous material produced will all be used on campus and will be thus stored on campus. We would likely be able to use all of the material on the grounds, especially with future on-campus building and renovations. Dry biosolids would likely not need to be treated, although this is somewhat dependent on the composition of organic material that goes into the system. For example, the University of Maryland uses the biosolids as a direct soil amendment without prior treatment and has not experienced issues with using the dry product this way.[13] On the other hand, a recent study on dehydrated food waste at Loyola Marymount University found that unprocessed dehydrated food waste is not suitable as a soil amendment and that rehydration of the dehydrated material produces large quantities of fungus.[14] Regardless, we would need to transport dry biogenous waste from the dehydrators to a storage facility, likely on Service Drive, where current yard waste is composted. For the purposes of this report, we assume that the dry biosolids will not need to be treated and can be mixed with existing on-campus landscaping material in an appropriate ratio to be used as a soil amendment.

We would likely use a diesel truck for transportation. Our Director of Sustainability, Patrick Willoughby, suggests that the College will likely need a swap loader or similar truck, with a 12 cubic yard capacity and a typical fuel economy of nine miles per gallon (or 14.48 km per gallon). The truck would need a customized truck body, much like a compactor trash truck with a toter lift. We do not currently have this transportation option and would most likely need to purchase the customized truck.

We assume that in each dining hall one load of food waste will be done each day. This load can dehydrate overnight (12 to 18 hours per load), and be emptied the next day before more wet food waste is added. The volume and weight of food waste would be reduced significantly after dehydration, thereby minimizing the volume- and weight-carrying capacity of the transportation vehicles. Assuming an 80% reduction in volume, dehydrating half a metric ton of food waste per day in the five-dehydrator system would result in 4.2 cubic meters of dehydrated biosolids per day. We assume that transport of dry food waste from the dining halls to Service Drive will happen every day. Due to the volume capacity of the assumed transportation truck, it is also possible to transport dry biosolids for storage every two days. This method would require additional storage of dry food waste in the dining halls for a day, as the dehydrator would need to be emptied in order to process another load. We assume that AVI and the Board of Health would not find this option plausible due to space and storage concerns.

We suggest further exploring transportation options that use waste vegetable oil and electricity, which are not customary on campus but would be beneficial in terms of environmental impact. These vehicles have minimized fuel input requirements and could be purchased in a customized size appropriate for daily transport of food waste. The Office of Sustainability already has an

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[13] Somat. "University of Maryland Uses DeHydrator Compost as a Quality Soil Amendment." Accessed March 21, 2013. http://www.somatcompany.com/News/University-of-Maryland-Uses-DeHydrator-Compost-as-Quality-Soil-Amendment/.

[14] Rasmussen, Joe. "Implementing and Studying an Innovative Food Waste Diversion Program." Accessed May 2013. http://www.biocyclewestcoast.com/2012/Presentations/Tuesday/Rasmussen_s.pdf.

electric vehicle and would likely support the transition to electric vehicle use on campus to transport dehydrated food waste material to Service Drive.

We would need storage units for wet food waste in dining halls before it is dehydrated. Each dining hall would need separation containers for food waste during pre- and post- consumer stages. These containers are needed across all methods considered and are therefore not included in this method section. Meat and dairy products should be separated so that there is a controlled composition of material put into the dehydrator. If there is too much meat and dairy in the mix of food waste, then the dry material will not be as good a soil amendment as desired and will likely need treatment post-dehydration. It is likely that five-gallon sterile plastic buckets could be used for separated meat and dairy products. We assume that meat and dairy will be taken into consideration via an additional waste diversion method that could process these materials. Therefore, the storage buckets are not included in our analysis. It is unlikely that they will affect our overall suggestions for this method.

Dehydrated material would need to be stored on campus, likely in covered piles or wooden or plastic bins. For the purposes of this report, we assume that the dry material will be stored in piles at the Service Drive location. The dry material would be piled on specialized plastic liners to prevent any future leaching and would be covered with plastic tarps or specialized liners.

There are seasonal variations in the volume of dry organic material that we can use on campus. In the late spring, summer, and fall, we will be able to use the dry material as a soil amendment. We assume that no dry organic material will be used for landscaping in the winter. The storage facility must therefore be able to contain the volume of waste produced in the winter when none is being actively used on campus.

13.2.2 Technology/Equipment

With a decentralized traditional dehydration system, we would need to purchase five close-coupled pulper-dehydrator machines. For the purposes of this report, we assume we would purchase five ECORECT ET-300W dehydrators, which have internal pulpers.

We would need to purchase the customized truck mentioned above for on-campus collection and transportation of dry material from each dining hall to the storage location. This truck would likely be a customized compactor trash truck with a toter lift.

We would need to purchase non-permeable plastic liners, potentially specialized for preventing leachates, for use in on-campus storage of dry biogenous material.

13.2.3 Inputs

Energy
We assume that the dehydrators would process 202 kg per day (0.202 metric tons)[15] for 212 days of the year. The ECORECT ET-300W dehydrator requires AC 200v/220, 50/60 Hertz three-

[15] This is one-fifth of our estimated total food waste production per day. We assume that the waste would be split evenly between the five units.

phase electricity,[16] and 712.9 kWh of electricity per metric ton of food waste. Because each unit requires 144 kWh per 18-hour cycle and we assume the five units would process all of Wellesley's food waste, this method would require 720 kWh of electricity daily.

The five dehydrators would require 152,640 kWh of electricity per year to accommodate the food waste production for the 212 days that school is in session. For this report, we assume negligible energy use for summer and Wintersession programs.

The electricity source for running the dehydrators is the Wellesley College Co-Generation Plant on campus. The co-gen plant generates 5.6 megawatts (MW) of electricity and currently supplies surplus energy to the town of Wellesley.[17] We use the process "Cooling energy, natural gas, at cogen unit with absorption chiller 100 kW/CH S" for our analysis in SimaPro.

For the purposes of the report, we assume that no additional treatment of dry waste will be needed and therefore no additional energy will be required. If, on the other hand, food waste was put into the dehydrating unit without attention paid to composition, a treatment process would be required before the outputs could be used. If this were to occur, more energy would need to be factored in.

Materials

The primary manufacturing materials of the dehydrator machine are listed in Table 13-1 as we use in our SimaPro analysis.[18] An ECORECT ET-300W weighs 1433 lbs.[19] (650 kilograms). The primary material component for the dehydrator is stainless steel (645 kilograms). We assume that the additional materials used in the machine comprise 5 kilograms of the overall machine weight. We assume that the other material components aside from the stainless steel are all approximately equivalent, with a slightly higher weight for aluminum. We assume that two of the five kilograms of additional materials is aluminum, that wire and polyethylene terephthalate each comprise 1.1 kilograms of the additional materials, and that the remaining 0.8 kilograms is synthetic rubber.

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[16] ECORECT Technology. "ECORECT Smart Composter Food Waste Reduction & Conversion System: Frequently Asked Questions." Accessed May 4, 2013. http://www.ECORECT.com/uploads/6/3/9/6/6396564/ECORECT_smart_composter_faq.pdf.

[17] William Sloan Associates. "Cogeneration Plant: Wellesley College." Accessed February 25, 2013. http://williamsloan.com/WSA/Industrial/2F223F9F-1102-11DB-99C9-000A95B741A6.html.

[18] Somat. "Operation/Instruction Manual and General Information: eCorect ET-100w." Accessed May 4, 2013, http://www.cpsohio.com/app/load/manual1.aspx?id=SOM0049.
Primary material inputs were determined using the ECORECT ET-100w operating manual and through a conversation with Sean Leid, an engineer at the Somat Company.

[19] FRG Waste Resources. "Stainless is the New Green: Introducing the eCorect." ECORECT Accessed May 4, 2013. http://www.frgwaste.com/LinkClick.aspx?fileticket=q2ksIpvkWhg%3D&tabid=165.

Table 13-1. Manufacturing materials, traditional dehydration.

Material
Stainless steel hot rolled coil, annealed & pickled, elec. arc furnace route, prod. mix, grade 304 RER S
Aluminum extrusion profile, primary prod. mix, aluminum semi-finished extrusion product RER S
Synthetic rubber, at plant/RER S
Copper wire, technology mix, consumption mix, at plant, cross section 1 mm² EU-15 S
Polyethylene terephthalate, granulate, amorphous, at plant/RER S

We assume that this method only requires transportation of dry waste to the final deposit location. The transportation vehicle would pick up dry waste at each of the five dining halls once a day, and transports it to the grounds facility for storage. We assume the truck we will use is closest to a 1.5-ton truck (around the size of a large pickup truck). In SimaPro, the closest vehicle to match our needs is a van (Van (<3.5 t/RER U). The van would only need to make one trip each day, according to our calculations for the daily output volume of dry food waste and given the capacity of the transport vehicle. The vehicle would pick up 4.2 cubic meters feet waste from all five dehydrators each day, equivalent to 99.73 kg of dry waste per day. The total transport distance for the truck is assumed to be four kilometers.

The processed dehydrated organic material would require storage on campus at the Service Drive location. The storage location would need to be large enough to store the whole year's worth of food waste. We assume that the dehydrated material collected from the dining halls could be stored in piles, with plastic lining covering the ground and with a tarp liner covering.[20] These liners would be used to prevent water from soaking the dehydrated waste and prevent possible leachate from infiltrating into the soil. For the purposes of this report and for our SimaPro analysis, we assume the liners would be made of polyethylene terephthalate (Polyethylene terephthalate, granulate, amorphous, at plant/RER U).

To find the tarp and liner size and quantity required, we calculate the yearly output of dry waste from the five dehydrators. With an average 80% reduction of waste by volume and using the density of food at 634.6 kg per cubic meter, [21] we calculate that the dehydrator method has an output with a total volume of about 15.4 cubic meters per year. A 15.4 cubic meter storage space could have, for example, the dimensions of 5'x10'x11' (depth by width by length). This is equal to 1.52 meters by 3.05 meters by 3.35 meters. We assume these dimensions for this report.

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[20] To properly store dehydrated materials, it is likely that specialized non-permeable plastic liners must be used for storage. We were not able to acquire any information on this.
[21] Wellesley College ES 300 2012. "Waste Not, Want Not: An Environmental Impact Assessment of the Wellesley College Waste Stream and Steps for a More Sustainable Future." Accessed May 2013. http://www.wellesley.edu/sites/default/files/assets/departments/environmentalscience/files/es300-2012-wastenotwantnot.pdf.

A blue economy grade poly tarpaulin weighs four ounces per square yard (0.136 kg per square meter).[22] For the purposes of this report, we assume that the liners used for storing the dry materials will also weigh 0.136 kg per square meter. We assume that two tarps or liners of this weight will be needed for ground coverage below the piled dry food waste, and that two tarps or liners will be needed to cover the dry waste piles. We assume a total of four plastic tarps or liners with dimensions 10'x12'. This is 3.05 meters by 3.66 meters, which is 11.16 square meters. Each liner or tarp would weigh 52 ounces (or 1.47 kg), for a total weight of 5.88 kg for all four liners.

13.2.4 Outputs

The primary output from the dehydration system is dry biogenous material, but the output also includes a minimal amount of wastewater. Mixed with sand and other materials for a proper nutrient and pH balance, biogenous material can be used on campus as a soil amendment. While we assume that 100% of the material will be used, we also recognize that there are potential problems with the biosolids: testing has shown that rehydrated biosolids have a low pH and can contain fungus.[23] The College would likely need to test the biosolids to make sure they can be used.

The majority of the wastewater from the dehydrating process is recycled back into the pulper and dehydration system, thereby reducing the amount of water that requires disposal. Any wastewater requiring disposal would enter into the College's wastewater system, eventually receiving treatment at the MWRA Deer Island Anaerobic Digestion facility. For the purpose of this report, we assume the wastewater output is negligible.[24]

13.2.5 Other Implementation Details

We assume that the only renovations needed to install the dehydrators are an electrical outlet to accommodate the 220-volt power connection and a drain hookup for wastewater.

For the purposes of this report, we assume that the same workers who normally put food waste in the garbage disposal will put it in the dehydrator instead. Additional labor would be required to transport the solid waste around campus, which we assume will be performed by a grounds maintenance worker. We assume this would require about 1.5 hours of labor each day, and involve driving to each of the dining halls and putting processed waste into the truck before delivering the waste to the storage site.

13.3 Environmental Impacts of Traditional Dehydration

13.3.1 Collection and Preparation of Food Waste

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[22] Sigman Tarp. "Poly Tarps." Accessed February 25, 2013. http://www.sigmantarp.com/poly-tarp/.
[23] Rasmussen, Joe. "Implementing and Studying an Innovative Food Waste Diversion Program." Accessed May 2013. http://www.biocyclewestcoast.com/2012/Presentations/Tuesday/Rasmussen_s.pdf.
[24] All Somat materials advertise a 95% recapture efficiency for wastewater and claim that there is minimal water that requires drain disposal. Personal correspondence with Biogreen360 representative Pete Grillo indicates that there may be more wastewater than the Somat Company claims.

Energy
No additional energy would be required for pre-dehydration collection and preparation of food waste.

Materials
No additional materials would be required for pre-dehydration collection and preparation of food waste.

Transportation of Food Waste
To calculate the distance traveled by truck per metric ton of wet food waste, we divide the total distance by the daily wet weight of food waste produced: 4 km/1.01 metric tons = 0.253 km per metric ton of wet food waste.

13.3.2 Process

Materials
To determine the quantity of each manufacturing material per metric ton of food waste processed, we calculate the approximate amount of food waste that an ECORECT ET-300W unit would process over its lifetime. We assume a 20-year lifetime of the entire machine and assume that the machine will process 202 kg per day for the 212 academic days of the year. Thus, we find the total mass of food processed in a year to be 20 years x (212 days/year) x (0.202 metric ton/day) = 856.48 metric tons of food waste.

To determine the mass of each material input per metric ton of food waste processed, we dividedthe mass of each of the ECORECT manufacturing input materials by 856.48 metric tons. Table 13-2 shows each material input for the manufacture of and the mass of each input material per metric ton of food waste diverted. These are the materials and amounts our SimaPro analysis uses.

Table 13-2: Material inputs per metric ton food waste, traditional dehydration.

Material	Amount (kg)
Stainless steel hot rolled coil, annealed & pickled, elec. arc furnace route, prod. mix, grade 304 RER S	0.753
Aluminium extrusion profile, primary prod., prod. mix, aluminium semi-finished extrusion product RER S	0.0023
Synthetic rubber, at plant/RER S	0.00093
Copper wire, technology mix, consumption mix, at plant, cross section 1 mm² EU-15 S	0.0013
Polyethylene terephthalate, granulate, amorphous, at plant/RER S	0.0013

Energy
The energy requirements of the ET-300W unit were calculated to be 712.9 kWh per metric ton of

food waste. We use the process "Cooling energy, natural gas, at cogen unit with absorption chiller 100 kW/CH S" for our SimaPro analysis.

Storage Process
To calculate the mass of material input from the liners from the storage process, we divide the total mass of all four liners by the weight of wet food waste diverted with this method each year. The traditional dehydration process requires for storage 5.88 kg of plastic liner (Polyethylene terephthalate, granulate, amorphous, at plant/RER U) for the total 0.202 metric tons processed daily. Assuming a two-year life span of the tarps, 0.013 kg of tarp is required per metric ton of food waste.

13.3.3 Avoided Impacts

We assume no avoided impacts from a dehydration system.

13.3.4 Water Use

ECORECT's website claims that there are no freshwater requirements for processing food waste using the ECORECT dehydration units.[25]

13.3.5 Summary: Life Cycle Impacts and Assessment of Traditional Dehydration

Table 13-3: Environmental impacts by process stage, traditional dehydration.

Impact category	Unit	Dehydrator Manufacture	Dehydrator Use	Collection	Storage (post-dehydration)	Total
Global warming	kg CO2 eq	5.526848	2515.704	0.004758	0.157981	2521.378
Carcinogenics	kg benzen eq	0.015291	0.425968	1.55E-05	0.000491	0.441761
Ecotoxicity	kg 2,4-D eq	0.658754	202.4784	0.007043	0.280044	203.419

[25] ECORECT Technology. "ECORECT Smart Composter Food Waste Reduction & Conversion System: Frequently Asked Questions." Accessed May 4, 2013. http://www.ECORECT.com/uploads/6/3/9/6/6396564/ECORECT_smart_composter_faq.pdf.

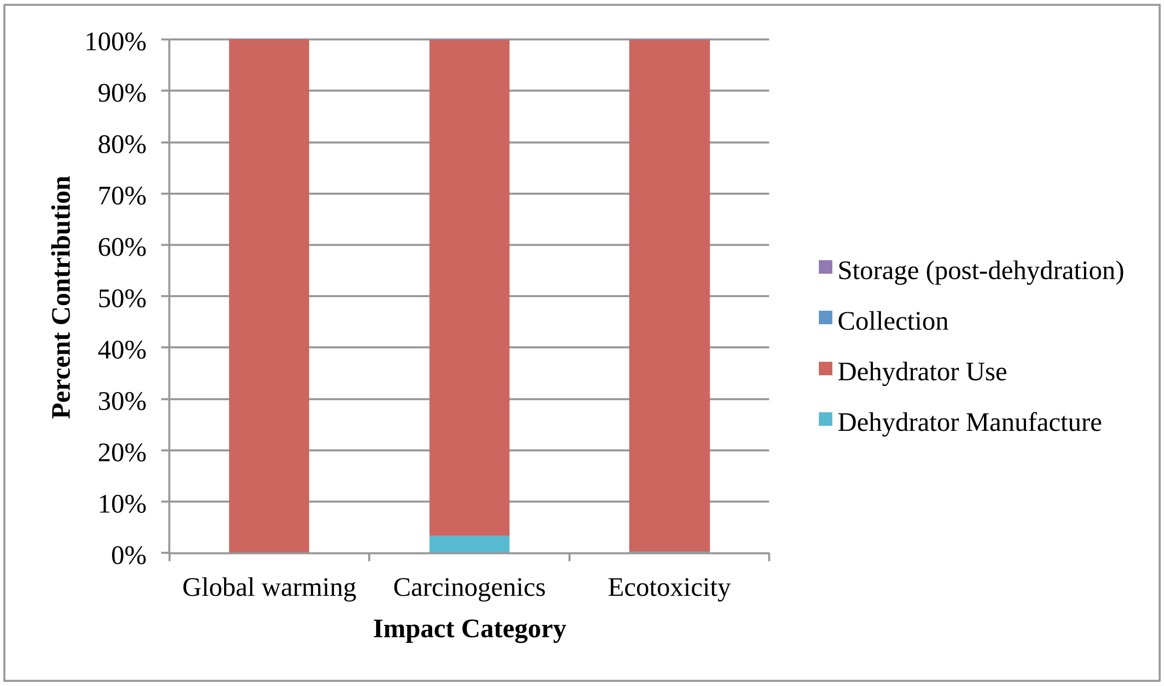

Figure 13-3: Percent contribution of process stages to each impact category, traditional dehydration.

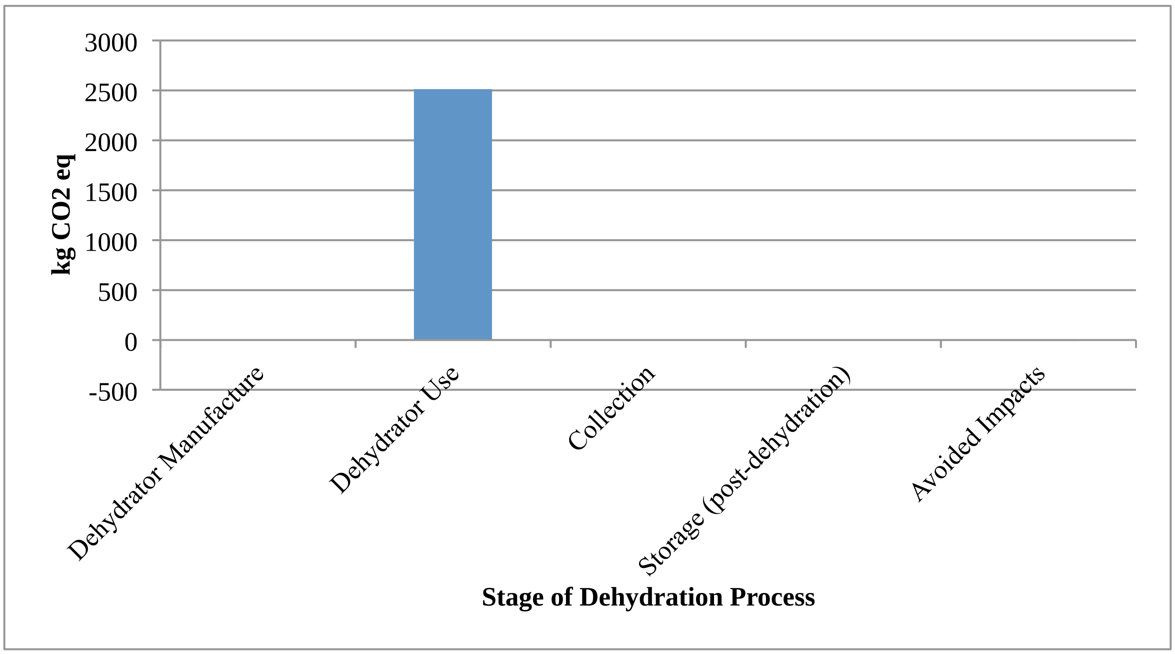

Figure 13-4: Climate change impact of each process stage, traditional dehydration.

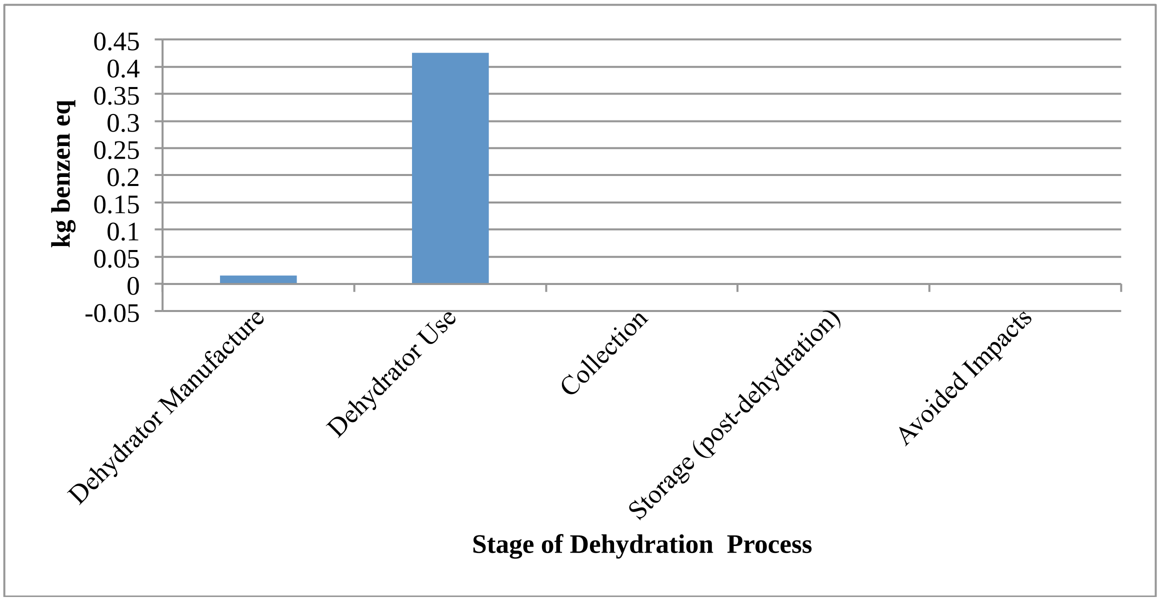

Figure 13-5: Human toxicity impact of each process stage, traditional dehydration.

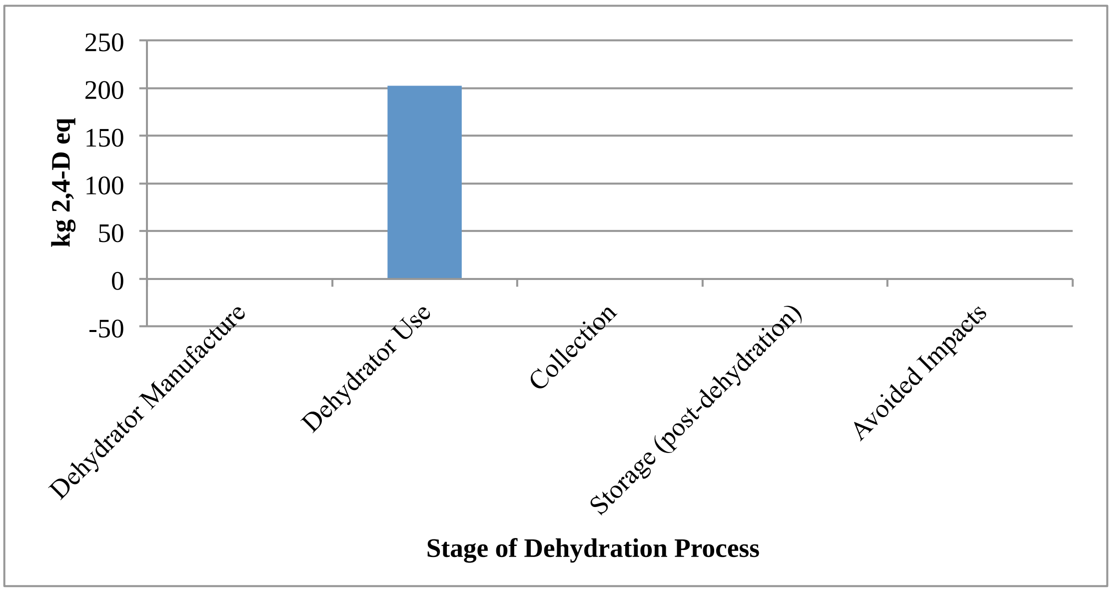

Figure 13-6: Ecosystem toxicity impact of each process stage, traditional dehydration.

Dehydrator use accounts for the greatest environmental impacts in all categories compared. The dehydrator manufacturing contributes slightly to the human toxicity impact. Collection, storage, and avoided impacts do not account for a significant environmental impact in any category considered.

To examine the life cycle impacts of the traditional dehydration system, we examine the impacts of the dehydrator's use, the inputs in its manufacture, the collection of dry waste from each campus dining hall, the storage of the dry waste, and offsets from undertaking the dehydration process. Table 13-3 displays the environmental impacts of each phase per metric ton of food waste diverted. Figure 13-3 compares the overall percent contribution of each life cycle phase for each impact category. Figures 13-4, 5, and 6 indicate the numerical impact of each life phase for the three categories of global warming potential, carcinogenics, and ecotoxicity. Energy use for running the dehydrator machines is chiefly responsible for negative impacts in each of the three impact categories considered. The impacts of the use of dehydrators far outweigh all other processes in the method. Therefore, we should seriously consider the required energy inputs for this method and evaluate whether the electricity usage could be moderated in any way. We are unlikely to switch to a different electricity source, and it is doubtful that the machines could be upgraded to more efficient technologies without replacing the entire machine. From an environmental and human health impact perspective, the use phase of the dehydrator is the only one that requires serious consideration in whether or not to adopt this method of food waste diversion.

13.1.4 Costs of Traditional Dehydration

13.4.1 Direct Cost

Tipping Fees
Dehydration would occur on campus, and the College would not need to pay another facility to take the waste.

Trucking Fees
The food waste processed in this method would be handled on campus, and therefore there would be no trucking fees.

13.4.2 Operational Cost

Transportation Cost
Assuming there would be one dehydrator in each of the five dining halls, we assume transportation would be necessary to bring processed dry food waste to a storage site on the College’s grounds. The most likely truck would be the Freightliner truck, which runs on diesel and has a capacity of 12 cubic yards (9.17 cubic meters) depending on the type of container picked up. Assuming a four-kilometer loop around campus daily to each of the five dining halls and to the storage site, we calculate 3.96 km of transportation per kilogram of food waste. With a typical fuel economy of nine miles per gallon (or 14.48 km per gallon) and an assumed diesel price of $4.00 per gallon, we calculate:

Cost of transport per metric ton of waste
= (price / (gallon of gas)) * (gal / (km traveled)) * ((km travelled) / (metric ton))
= ($4.00/gal) * (1 gal/14.48 km) * ((3.96 km) / metric ton waste)
= $1.01/metric ton of waste.

Labor Costs
Additional labor would be required to transport the solid waste around campus, which we assume will be performed by a grounds maintenance worker. This kind of work would be similar to the kind of work that landscaping staff already does on campus. We assume processed waste transport would require about 1.5 hours of labor each day, and would involve driving to each of

the dining halls and putting processed waste into the truck before delivering the waste to the storage site.

With an assumed wage of $25.36 per hour, including benefits, for a grounds maintenance worker at Wellesley,[26] we calculate the labor cost:

Labor cost of dehydration per metric ton of food waste

= (wage/hour) * ((hours of labor) / day) * (day /kg of food transported) * (kg/metric ton)

= ($25.36/hour) * (1.5 hours/day) * (1 day/1.01 metric ton)

= $37.66/metric ton

Energy Costs

We calculate the energy cost of using a dehydrator using the kilowatt hours required per cycle and the cost of electricity on campus. The energy use of an ET-300W unit is 144 kWh per cycle, or 712.9 kWh per metric ton of waste. Using the cost of energy on campus of $0.11 per kWh,[27] we calculate the energy cost:

Energy cost per metric ton of waste

= (kWh/metric ton) * (cost/kWh at Wellesley)

= (712.9 kWh/metric ton) * ($0.11/kWh)

= $78.42/metric ton of waste.

Other Operational Cost

According to the ECORECT materials, the dehydration process for food waste does not require any additional water inputs.[28] Using a closed-circuit system with a pulper and a dehydrator allows for the recirculation of water after dehydration back to the pulper. There would be no additional operational cost for water. *If* the ECORECT Company is incorrect in their assumption that no additional water is required, the additional cost of water required per kilogram of food waste should be calculated. This cost should be calculated per liter of water required by using the cost of chemical treatment for Wellesley's water: $0.00001984 per liter.

13.4.3 Equipment

The equipment cost for a dehydration system consists of the cost of the system and its installation cost. Purchasing and installing a Somat DH-100 (100 kilogram capacity) close-circuit pulper and dehydrator system at Oberlin College cost about $114,000.[29] This included preparing the dining hall space for the unit, the installation process, and the purchase of the actual machinery. We assume that the equipment cost would be $15,000 more for the higher-capacity ECORECT unit – a total of $129,000. Assuming a lifetime of 20 years, each dehydrator would process a total of 856.48 metric tons of food over its lifetime. Therefore, we were able to

[26] Estimate by Wellesley College Office of Sustainability. March 11, 2013.
[27] Estimate by Wellesley College Office of Sustainability. March 11, 2013.
[28] "ECORECT Technology. "ECORECT Smart Composter Food Waste Reduction & Conversion System: Frequently Asked Questions." Accessed May 4, 2013. http://www.ECORECT.com/uploads/6/3/9/6/6396564/ECORECT_smart_composter_faq.pdf.
[29] Nagy, Amanda. "New pulper brings campus closer to carbon-neutral dining." Accessed May 2013. http://new.oberlin.edu/home/news-media/detail.dot?id=3521011.

calculate the cost of a dehydrator per metric ton of food waste:

Cost of purchasing and installing a dehydrator per kg of food waste
= (price of 1 dehydrator) / (metric tons of food waste processed in product's lifetime)
= $129,000 / 856.48 metric tons
= $150.62/metric ton

In addition, we assume a service contract for the maintenance of the equipment, including both labor and parts. We estimate the price of such a contract to be $1000/year.[30] We assume that this cost would be per unit installed. Using the price of the contract per year, along with our calculation that a 5-dehydrator system processes around 214 metric tons of food waste per year (42824 kg per dehydrator unit), we calculate the cost of a service contract per metric ton of food:

Cost of servicing per metric ton of food waste
= ((price of service contract) / year) / ((kg of food waste processed) / year) * (kg/metric ton)
= ($1000/year)/ (42824 kg food waste/year) * (1000 kg/metric ton)
= $23.35/metric ton

The total cost of equipment per kilogram of waste is the sum of the costs of purchasing, installing, and maintaining the equipment per metric ton of waste.

Equipment costs per metric ton of food waste
= ($150.62 + $23.35) / (metric ton of food waste)
= $173.97 per metric ton food waste.

13.4.4 Offset Cost

We assume no offset costs from the dehydration process.

13.4.5 Summary: Cost of Traditional Dehydration

As shown in Table 13-4, the total cost of implementing a dehydration system would be $292.71 per metric ton of waste diverted, without any additional costs for water inputs. The total costs can be broken down into the three major categories illustrated above: direct, operational, and equipment. There are no direct costs for the system. Operation of the system would cost $117.09 per metric ton (or about 40% of the total cost, as seen in Figure 13-7). Equipment installation, purchase, and maintenance would account for $173.97 (or about 60% of the total) per metric ton. Operational costs of a close-circuited pulper and dehydrator are lower than the purchase of the system itself, yet are still high due to the high energy usage of a dehydration system and the daily labor associated with transporting processed waste. There are few options available to reduce operational costs, the most feasible being making the transportation of processed waste either more efficient or less frequent. While the process of purchasing and installing the equipment cannot be avoided, other companies could be explored in order to determine the most cost-

[30] Willoughby, Patrick, Wellesley College Director of Sustainability. ES 300 2013. March 6, 2013. We assumed that the service contract would be $1000 per ECORECT dehydrator unit installed.

effective option. It also may be possible to negotiate a lower service contract with the provider.

Table 13-4: Cost of traditional dehydration.

Cost Category		**Amount ($)**
Direct:		
	Facilities	0.00
	Transportation	0.00
Operational:		
	Transportation	1.01
	Labor	37.66
	Energy	78.42
	Other (water)	0.00
Equipment		173.97
Offset costs		-0.00
Total Cost		292.71

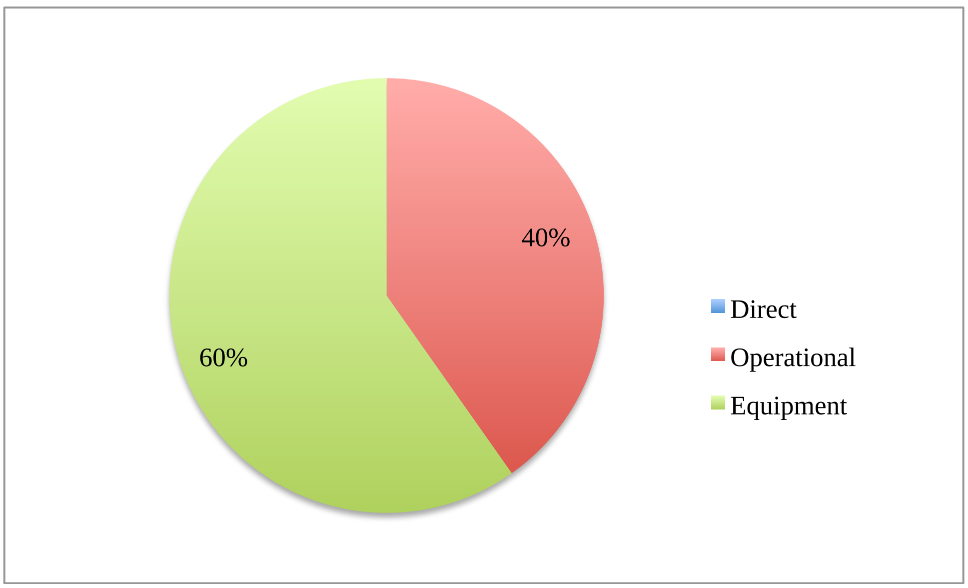

Figure 13-7: Cost of traditional dehydration.

13.1.5 Social Impacts of Traditional Dehydration

13.5.1 Campus Experience - Neutral

The use of dehydrated biosolids on campus as a soil amendment would support the beauty of the campus and would help with landscaping, campus, and arboretum upkeep—all components of the campus that lend to its physical beauty. The use of dehydrated food waste as a soil amendment would likely only support the current level of natural beauty, rather than improve the campus' physical appearance. The dry biosolids would most likely be best suited for use as a planting mixture,[31] and could be used seasonally on the grounds. The biosolids may be used during the 2025 building renovations,[32] thereby assisting with on-campus physical improvements.

Wellesley would be able to use 100% of the food waste produced as a direct input for soil supplements on campus.[33] It is possible that using food waste as an input would increase on-campus pride.

There would be little to no smell from dehydration equipment and post-dehydrated biosolids**,** which will benefit the campus experience. There would be little to no risk of pests at the diversion sites, which is beneficial from a Board of Health perspective, but there would be a potential risk of pests at the on-campus storage site. This site would need to be monitored periodically to ensure that no pests have gotten into the dry and covered food waste.

Using a dehydration system may prompt negative press on dehydration system's energy use. The use of the dehydrator system would also impact Wellesley's LEED credit score or energy credits, though the effect is ambiguous. (LEED is an internationally recognized program that provides third-party certification of green buildings.)[34] Due to the high electricity requirements of the ECORECT unit, using the dehydrator could negatively impact Wellesley's LEED energy credits.[35] The ECORECT unit may receive LEED credits for water efficiency and innovation in design in exchange.[36] As the College has committed to LEED Silver, consideration of the impacts of the Somat DH system on LEED credits is useful and important.

13.5.2 Educational Benefit - High

Classes could visit the dining halls to learn more about the dehydration system, and visit the final storage site for dry biosolids to learn more about the use of dehydrated food waste as an on-campus soil amendment. Furthermore, classes could assist with collecting dry biosolids from the dining halls and transporting them to the storage site as a "field visit" experience although dining halls are not easily accessible for large classes or frequent visits.

There would also be limited visibility of this diversion method due to the location of the dehydrators within the dining halls and the storage of dry materials on Service Drive. Regular volunteer opportunities would be unlikely.

13.5.3 Implementation Difficulty

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[31] Willoughby, Patrick, Wellesley College Director of Sustainability. Eliana Blaine. March 6, 2013.
[32] Willoughby, Patrick, Wellesley College Director of Sustainability. Eliana Blaine. March 6, 2013.
[33] "University of Maryland."
[34] U.S. Green Building Council. "LEED." Accessed May 2013. http://www.usgbc.org/leed.
[35] Somat. "LEED Research and Analysis for Somat DeHydrator System." Accessed March 24, 2013. http://www.somatcompany.com/uploadedFiles/Content/Sustainable_Solutions/LEED%20Research%20and%20Analysis%20for%20Somat%20DeHydrator%20System.pdf.
[36] Somat. "LEED Research and Analysis for Somat DeHydrator System." Accessed March 24, 2013. http://www.somatcompany.com/uploadedFiles/Content/Sustainable_Solutions/LEED%20Research%20and%20Analysis%20for%20Somat%20DeHydrator%20System.pdf.

Separation - High
In order for the dry biosolids to be usable on campus as a soil amendment without prior treatment, meat, dairy, and compostable dishware should only be added to the dehydrator in limited amounts.[37] These three categories of food waste would require a separation system. Though they could be put into the dehydrator in a limited amount, students and/or dining staff would need to monitor the composition of materials put into the dehydration system. Dining hall staff would also need to separate out meats, dairy, and compostable dishware (if any) from pre-consumer food waste. Waste pickup from dining halls would be a standard procedure, but requires little training. The dehydration equipment in the dining halls would only need one person for operating each machine.

Permitting and Regulations - Medium
This method may require building and renovation permit from the town of Wellesley if a component of the installment or dining hall renovation requires inspection.[38] We would likely not need an EPA permit or other permits for storage of dry biosolids on campus, as the Service Drive location is already used for composted on-campus landscaping material. Over the long term, we may face issues with disposal of liquid waste from the dehydrator. Though minimal, if water monitoring occurs in the future, the solid content may be too high for drain disposal.[39]

Time until Implementation - Medium
The dehydration method would require dining hall renovations for all five dining halls.[40] The ECORECT ET-300W dehydrator requires three-phase 220-voltage electricity, and would require electrical and technical changes. The dining halls would need a drain hookup for each dehydrator machine for wastewater disposal. We would need to order and install dehydrator equipment and train dining hall workers in using the equipment. Renovations and training could conceivably be completed before 2014.

Risk - Medium
There is a high probability but low risk of contamination with the dehydrator method. It is likely that students and/or dining hall workers will not fully comply with the waste separation requirements. The majority of maintenance requests and issues reported to dehydrator companies are due to user error.[41] If the food waste is put in the machine in the right composition, there will be little to no technical issues.[42] The dehydration equipment can technically support any type of organic material and compostable dishware. Dehydrated biosolids that are not usable for all applications as a soil amendment could likely be used in some other way, or “diluted” with other material so that they can become usable.

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[37] In order to determine whether this is absolutely needed, the composition of the College’s disposed food waste should be assessed. It may be the case that there is not a high proportion of meat, dairy, and compostable dishware, which would reduce the separation requirements of this method.
[38] Willoughby, Patrick, Wellesley College Director of Sustainability. Eliana Blaine. March 6, 2013.
Danielle Gaglini, Wellesley College Office of Sustainability Coordinator. Eliana Blaine. March 9, 2013.
[39] Grillo, Pete, Biogreen360 representative. Eliana Blaine. March 11, 2013.
[40] Bates dining hall will only need a drain connection, as it has already been renovated to have a 220-volt plug for an ECORECT dehydrator.
[41] Grillo, Pete, Biogreen360 representative. Eliana Blaine. March 11, 2013.
[42] There is a risk of breaking the agitator component if non-compostable materials, such as metal dishware or cloth (dishrags, aprons), are accidentally placed in the machine.

13.5.4 Social Justice - Medium

Employees of the College responsible for managing the machine would be unlikely to face labor issues. Union and dining hall employees would likely be responsible for the equipment, for which they will be compensated accordingly.[43] Employees would face minimal safety concerns with this method because the ET-300W is equipped with multiple safety features. There are multiple safety switches and safety labels, and the internal impeller automatically stops when the hopper door is open.[44] Employees would face a low probability but high risk of harm from electrocution from the dehydration machine. The machine requires high voltage and should not be repaired without turning off the main power.[45] Employees would enjoy a low probability and low risk of harm from vehicle-related accidents during transportation of dry biosolids to the storage facility. Contracted workers for maintenance and repairs would have a low risk and medium to low probability of harm from machine repairs.

13.5.5 Summary: Social Impacts of Traditional Dehydration

Table 13-5: Social impacts of traditional dehydration.

Social Impact		**Score**
Campus experience		Neutral
Educational benefit		High
Difficulty:		
	Separation	High
	Permitting and regulations	Medium
	Time until implementation	Medium
	Risk	Medium
Social justice		Medium

Table 13-5 shows the relative score for each factor and sub-factor considered in our social impact analysis. The difficulty category indicates the greatest social impacts in a negative way. The separation requirements for the method cause the most social impact. These requirements

[43] Dining service workers may or may not face labor issues already. We are only considering the labor issues that would occur or would be avoided by using dehydrators as an alternative food waste diversion system.
[44] Somat. “Operation/Instruction Manual and General Information: DH-100w.” Accessed May 2013. http://www.somatcompany.com/uploadedFiles/Content/Service_Resource_Center/DH%20100%20Operations%20Manual.pdf.
[45] Somat. “Operation/Instruction Manual and General Information: DH-100w.” Accessed May 2013. http://www.somatcompany.com/uploadedFiles/Content/Service_Resource_Center/DH%20100%20Operations%20Manual.pdf.

are based on the assumption that the College will want to use the biogenous output on campus as soil amendment without treatment. It is possible that the College could use the biogenous material as a soil amendment with less separation and without treatment if the material is mixed in a low proportion to other landscaping materials.[46]

To enhance the visibility and academic merits of the dehydration method, the Environmental Studies Program or another academic department could conceivably create a new class devoted to studying on-campus waste diversion methods. This class could be responsible for monitoring the system and testing the biogenous outputs for quality. This role could also be filled by an on-campus student organization.

To fully implement the dehydration system, there are no other noticeable changes that could be made to reduce the social impacts of the method. To enhance the College's overall waste diversion method, a dehydration system should be paired with methods that have low social impacts or positive effects. For example, the dehydration method paired with a donation to people method and a vermicomposting method would enhance social justice and education, thereby resulting in an improved overall waste diversion system.

13.6 Conclusions

A dehydration system would likely work best as a decentralized system, with daily pickup of dry biosolids from each dining hall. Food waste diversion using a dehydration system would likely cover 100% of the dining hall waste (214 metric tons per year). The dehydrator system could also accommodate 100% of the College's overall food waste (220 metric tons per year), if an additional system of collection from dorms and student cafes is considered. This was not considered in this report.

The primary advantages of traditional dehydration include its ability to manage the College's volume of food waste in a consistent manner, regularly accept both pre- and post-consumer waste, significantly reduce the output volume of food waste, and transform food waste into a usable soil amendment for on-campus use. After the system is in place in the dining halls, it would take minimal coordination to dispose of waste this way (beyond trucking dry material to an on-campus storage facility). After the initial installation, the dehydration machines would need infrequent maintenance and repair and pose a minimal hazard to dining hall staff and students. We assume that there will be negligible additional social justice concerns from this method.

A Life Cycle Assessment of the dehydration system indicates that the primary negative human health and environmental impacts result from the system's use phase. This is due to the high electricity requirements for processing food waste using an ECORECT dehydrator system. This highlights one of the method's primary disadvantages: it requires a significant electricity usage at approximately 720 kWh per year.

[46] This possibility is only an assumption and should be explored further through conversations with Wellesley College Facilities Management personnel and soil analyses. Further study is needed on the proportion of meat, dairy, and compostable dishware allowable to still permit a valuable soil amendment without needing prior treatment.

Another primary challenge with this method is that it would require a significant upfront financial investment for purchasing and installing the dehydration equipment. The total cost of equipment per metric ton of food waste diverted is 60% of the total cost. The equipment cost is $173.97 for every metric ton diverted, and includes the costs of purchasing, installing, and maintaining the ECORECT dehydrator equipment.

Dehydration also ranks medium for difficulty of implementation, partly due to its high level of difficulty related to separation. In order for the biogenous output to be used on campus as a valuable soil amendment, the method would require limited processing of meat, dairy, and compostable dishware. Another limitation of dehydration is that it provides few student educational opportunities and would not be visible to students in the dining halls. The College could consider adopting an additional low-capacity diversion method to increase the educational opportunities for food waste diversion. Though minimal, this method would require renovation of each dining hall. Even given this renovation, a decentralized traditional dehydration system could conceivably be implemented before 2014.

14.0 Dehydration with Enzymes

Figure 14-1: A Biogreen360 dehydrator unit.[1]

14.1 Introduction to Dehydration with Enzymes

In this report we are also considering the use of a Biogreen360 dehydration system. This method has started to be used by universities (such as Harvard University) and restaurants. It is a new technique of food waste dehydration that utilizes microorganisms before the process of removing water from the food. This system differs from the traditional dehydration method primarily in that it accelerates the food waste's natural decomposition process prior to dehydration.[2] The system maintains appropriate levels of aeration, moisture, and temperature in order to ensure the end product is sterile, decomposed waste that can be used as a soil amendment. The Biogreen360 can decompose vegetable and fruit scraps, raw and cooked meats, fish, poultry, and dairy products. It cannot process large bones (unless pre-ground), paper and cardboard, shellfish shells, and liquids or cooking oils.[3] The Biogreen360 is similar to traditional dehydration methods in that the method reduces the overall volume and weight of food waste, and processes food waste

[1] Biogreen360. "Our Commercial Food Waste Disposers." Accessed May 2013. http://www.biogreen360.com/commercial-food-waste-disposer.
[2] Biogreen360. "The Biogreen360 Food Waste Disposers." Accessed March 24, 2013. http://www.biogreen360.com/how-our-recycling-food-waste-units-work.
[3] Biogreen360. "Biogreen360 Acceptable and Unacceptable Forms of Food Waste for our Food Waste Recycling Units." Accessed March 24, 2013. http://www.biogreen360.com/acceptable-and-unacceptable-food-waste.

in such a way that it can be used as a soil amendment.

The primary difference with the Biogreen360 is that it uses microorganisms to decompose waste prior to dehydration. The enzyme-enhanced microbial technology is classified as BIO Safety Level 1, and is safe for human and animal contact.[4] The Biogreen360 digester and dehydrator is a continual feed unit.[5] Waste food is loaded into the recycling unit's insulated "hopper" throughout the day, and can be put in at any point during dining hall hours. The hopper contains microorganisms that would be specially formulated[6] for our composition of food waste. The microbes decompose the food in the hopper, turning it from solids into a liquid pulp via the process of decomposition.[7] This liquid is pulled through a stainless steel screen with pinholes by gravity into a secondary reservoir.[8] The liquid is then pumped into a sequential rotating ager system, where it is heated between 260 to 360 degrees Fahrenheit.[9] The heating process essentially bakes the liquid off of suspended solids and kills all pathogens, bacteria, and seeds.[10] Vacuum tubes channel the steam off and run it through a venting machine. The connected air exchange unit uses outdoor air to cool the steam; the steam is around 75 degrees Fahrenheit upon final venting.[11] The vent would connect to the exterior of the building where the machine is installed, or connected to an existing vent system. The system uses an insulated heating jacket and heating oil to minimize the electricity requirements.

The entire process, from putting food waste into the hopper until final discharge, takes approximately 3.5 hours.[12] The final biogenous output is reduced in weight by 90% of the waste input. The material is considered bio-sterile after the process, which is not the case with traditional dehydration. It is 95% dry, and can be stored for several months.[13] The discharged material has a soil composition similar to that of potting soil, and has a pH of around four. It is possible to slow down the auger system and/or turn up the temperature on the unit, depending on how wet the discharged material can be and depending on the rate of discharge desired.[14]

There are four models of the Biogreen360; each varies in the volume capacity of the machine. The smallest model (250 model) has a full load capacity of 250 lbs., or 113 kg. Biogreen360 also has 500, 1000, and 1500 models; each has a volume capacity of 227kg, 454 kg, and 680 kg respectively. The most popular models for high-volume-producing institutions is the 1000 or

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[4] "Biogreen360. "The Biogreen360 Food Waste Disposers." Accessed March 24, 2013. http://www.biogreen360.com/how-our-recycling-food-waste-units-work.
[5] Biogreen360. "Food Waste Disposer FAQs." Accessed March 24, 2013. http://www.biogreen360.com/faq.
[6] Biogreen360 has five strains of microbes. We would use the strain that best suits the food waste that we produce. If the microbes are not a good match for our food waste, they can take longer to break down the food waste. Grillo, Pete, Biogreen360 representative. Eliana Blaine. March 11, 2013.
[7] Grillo, Pete, Biogreen360 representative. Eliana Blaine. March 11, 2013.
[8] Grillo, Pete, Biogreen360 representative. Eliana Blaine. March 11, 2013.
[9] Grillo, Pete, Biogreen360 representative. Eliana Blaine. March 11, 2013.
[10] "Biogreen360. "The Biogreen360 Food Waste Disposers." Accessed March 24, 2013. http://www.biogreen360.com/how-our-recycling-food-waste-units-work.
[11] Grillo, Pete, Biogreen360 representative. Eliana Blaine. March 11, 2013.
[12] "Biogreen360. "The Biogreen360 Food Waste Disposers." Accessed March 24, 2013. http://www.biogreen360.com/how-our-recycling-food-waste-units-work.
[13] "Biogreen360. "The Biogreen360 Food Waste Disposers." Accessed March 24, 2013. http://www.biogreen360.com/how-our-recycling-food-waste-units-work.
[14] Grillo, Pete, Biogreen360 representative. Eliana Blaine. March 11, 2013.

1500 model. All models require 208/220 voltage, three-phase electricity connections.

For the purposes of this report, we assume that the College would use five Biogreen360 500 model units. These units have a capacity similar to the ECORECT ET-300w units. We assume a decentralized system, with one Biogreen360 unit in each of the campus dining halls, primarily so that we can better compare the traditional dehydration system (using the ECORECT ET-300W machines) and the Biogreen360 technologies.

14.2 Implementing Dehydration with Enzymes at Wellesley College

14.2.1 Overview of Implementation at Wellesley

We assume a similar decentralized model to the traditional dehydration system, with one Biogreen360 Model 500 in each of the five dining halls on campus.

If there is a model 500 with 500 lb (226.8 kg) capacity Biogreen360 dehydrator in each dining hall, the whole system would be able to process 1134 kg, or 1.134 metric tons of food waste per day. This is only 73.6 kg less than with the Traditional Dehydration system. We assume that dining halls are responsible for approximately 214 metric tons of the total annual food waste production, which is equivalent to ~1.01 metric tons per day, or ~202 kg per day from each dining hall. The rest of the food waste is produced by events and in dorms.

Under this assumption, the Biogreen360 units could process 240,408 kg of food waste per year (240.4 metric tons). Using the 500 model Biogreen360machine would allow for the College to process 100% of the dining hall food waste produced, with additional capacity to of 24.8 kg more food waste than is currently produced daily in the dining hall. Thus, the Biogreen360 model would have the volume capacity for processing 100% of the total food waste produced on campus (including events and in dorms) *if* there was an additional method of transporting food waste to the dining halls for processing. For this assessment, we assume the dehydration method will only process dining hall waste. We assume the Biogreen360 units will be running at 89% volume capacity, due to the current gap in what the units are able to process and the volume of food waste produced.[15] These estimates were determined using our class estimates for total and dining hall food waste production at Wellesley, and under the assumption that there are 212 days in the school year.

The transportation and storage using the Biogreen360 system would be quite similar to the transportation and storage required by the traditional dehydration model. Again, we assume that all of the material processed would be used as a soil amendment on campus and that the biogenous material would not need treatment before use as an amendment.[16] Similar to

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[15] For this assessment, we analyze a system that could process more waste than dining halls currently produce. The smaller Biogreen systems would only have the volume capacity to process 50% of dining hall food waste. Thus, to process a higher percentage of dining hall waste, we assume the use of larger machines. This will also allow for additional processing of residential hall waste in the future.

[16] Compost analyses of Biogreen compost produced from the University of Vermont and University of Maine machines indicate that the dry material could be used as a soil amendment without treatment.
Hanley, Bill, vice president of Biogreen360. Eliana Blaine. March 11, 2013.

traditional dehydration, we assume that in each dining hall will process one load of food waste per day, or 202 kg. Dehydrating 1010 kg of food waste per day using the Biogreen360system results in 5.62 cubic yards of dehydrated biosolids per day, assuming a 90% reduction in volume.[17] This results in 1191.65 cubic yards of dehydrated solids per year. We assume that transport of dry food waste will happen every day, from the dining halls to Service Drive, as with the traditional dehydration system. All dehydrated waste will be stored at Service Drive. Unlike the traditional dehydration system, the Biogreen360 system requires post-dehydration dry biosolid storage in dining halls throughout the day prior to final pick-up by the transportation vehicle. This is required because the Biogreen360systems operate on continual-feed and continual-output. We assume the use of five-gallon buckets with airtight lids for the storage of dry material pre-pickup in each dining hall.

14.2.2 Technology/Equipment

Similar to the traditional dehydration system, with the decentralized Biogreen360 method, the College would need to purchase five machines. For the purposes of this report, we assume Wellesley would purchase five 500 lb model dehydrators.

The College will need to purchase the same kind of customized truck mentioned with traditional dehydration, Section 13.

The College will need to purchase five-gallon buckets with lids for storing post-dehydration biosolids for each dining hall.

The College will need to purchase non-permeable plastic liners, potentially specialized for preventing leachates, for use in on-campus storage of dry biogenous material.

14.2.3 Inputs

Energy
The electricity source for running the dehydrators is the Wellesley College Co-Generation Plant on campus. We use the process "Cooling energy, natural gas, at cogen unit with absorption chiller 100 kW/CH S" for our SimaPro analysis. The energy consumption of one Biogreen360 unit is estimated to be 51.38 kWh per day of processing, for a total of 256.9 kWh electricity requirement per day. This equates to a yearly energy requirement of 54,462.8 kWh. We assume 202 kg of waste is processed per day using this method (or 0.202 metric tons), or 214 metric tons per year. We assume no extra treatment for biogenous outputs, thereby contributing no extra energy needs.

Materials

[17] Biogreen360. "Food Waste Disposer FAQs." Accessed March 24, 2013. http://www.biogreen360.com/faq.

Table 14-1: Manufacturing materials, dehydration with enzymes.

Material	Assumed amount in unit (kg)
Stainless steel hot rolled coil, annealed & pickled, elec. arc furnace route, prod. mix, grade 304 RER S	704
Cast iron, at plant/RER S	2
Silicon, electronic grade, at plant/DE S	1.1
Copper wire, technology mix, consumption mix, at plant, cross section 1 mm² EU-15 S	1.1
Polyethylene terephthalate, granulate, amorphous, at plant/RER S	0.8

The BioGreen360 unit is composed primarily of stainless steel (303).[18] We assume the remaining composition of the machine to include the following materials: cast iron, silicon, copper, and plastic.[19] An entire 500 pound (226.9 kg) capacity model unit is listed as 1653 lbs, or 709 kg. For our analysis, we assume that 704 kg of the total materials are stainless steel, with a remaining five kilograms comprised by the additional materials. We assume that there is more cast iron than the other materials (two kilograms), and a little less plastic (0.8 kg), with an equal amount of copper wire and silicon used (1.1 kg). Table 13-6 shows each material input for the manufacture of the Biogreen360, and the names of the materials as used for our SimaPro analysis.

Our assumptions for the vehicle to transport the biosolids are the same as for traditional dehydration in Section 13. We assume one pickup from each dining hall per day, making for a transport distance by truck of three miles (4.83 km). We assume the truck is closest to a 1.5 ton truck (around the size of a large pickup truck). In SimaPro, the closest vehicle to match our needs was a van (Van (<3.5 t/RER U).

In terms of post-dehydration storage, each dining hall requires a system of storing dry waste prior to pickup by the transportation vehicle at the end of the day. Each dining hall produces and can process 202 kg wet food waste per day, resulting in 20.2 kg of dry waste per day for each dining hall. Using the density of wet food waste (17.97 kg/cubic foot), each dining hall will produce 1.12 cubic feet of dry waste daily, equivalent to 8.38 gallons. Thus, we assume each dining hall requires two five-gallon buckets with lids, for a total of 10 buckets.

For storage at Service Drive, we assume a similar system to that for Traditional Dehydration. Dehydrating 214 metric tons of dining hall food waste per year using the Biogreen360system results in the production of 1191.65 cubic yards of dehydrated solids per year, assuming a 90%

[18] Biogreen360. "Biogreen360 Commercial Food Waste Recycling Technical Information." Accessed March 24, 2013. http://www.biogreen360.com/commercial-food-waste-recycling-technical-information.
[19] Hanley, Bill, vice president of Biogreen360. Eliana Blaine. March 11, 2013.

reduction in volume. Thus, we assume storage of these materials will require approximately eight liners (the same as in the Traditional method). The weight for eight liners is 416 oz, or 11.79 kg. For the purposes of this report and for our SimaPro analysis, we assume the liners would be made of polyethylene terephthalate (Polyethylene terephthalate, granulate, amorphous, at plant/RER U).

14.2.4 Outputs

The primary output material is a sterile biogenous material, a compost product. Similar to the traditional dehydration method, we assume all material will be used on campus.

The only other output of the system is water vapor from the heated auger system. The water vapor is sent through a cooling unit, such that it is released at around 75°F.[20] There is no liquid output, and thus no required drainage.

14.2.5 Other Implementation Details

Using the Biogreen360, the College would process 100% of the food waste produced by the dining halls, as it would use the traditional dehydration system. The Biogreen360 unit does not need any additional water inputs, and thus would not require a hookup to freshwater in the dining halls. Similar to the traditional dehydration method, the Biogreen360 machines will require renovations to the dining halls to accommodate 220-volt three-phase power.

14.3 Environmental Impacts of Dehydration with Enzymes

14.3.1 Collection and Preparation of Food Waste

Energy
There is no energy required for the collection or preparation of waste.

Materials
There are no materials required for the collection or preparation of waste.

Transportation of Food Waste
To calculate the distance traveled by truck per metric ton of wet food waste, we divided the total distance by the per day wet weight of food waste produced: 4 km/1.13 metric tons = 3.54 km per metric ton of wet food waste.

14.3.2 Process

Materials

[20] Grillo, Pete, Biogreen360 representative. Eliana Blaine. March 11, 2013.

Table 14-2: Material inputs per metric ton food waste, dehydration with enzymes.

Material	**Amount per metric ton waste (kg)**
Stainless steel hot rolled coil, annealed & pickled, elec. arc furnace route, prod. mix, grade 304 RER S	0.8220
Cast iron, at plant/RER S	0.0023
Silicon, electronic grade, at plant/DE S	0.0013
Copper wire, technology mix, consumption mix, at plant, cross section 1 mm^2 EU-15 S	0.0013
Polyethylene terephthalate, granulate, amorphous, at plant/RER S	0.00093

To determine the quantity of each manufacturing material per metric ton of food waste processed, we calculate the approximate amount of food waste that a Biogreen360 would process over its lifetime. We assume a 20-year lifetime of the entire machine, and assume that if the machine were to run at full capacity, it would be able to process all of Wellesley's food waste. Assuming 202 kg per day of waste in each dining hall per day and 212 days of the year in service, we calculated the total mass of food processed over the machine's lifetime to be:

Food processed by Biogreen360
= 20 years * (212 days/year) * (202 kg/day)
= 856,480 kg per lifetime = 856.48 metric tons per lifetime

To determine the mass of each material input per metric ton of food waste processed, we divide each of the Biogreen360 manufacturing input materials, by weight, by 856.48 metric tons of food waste. Table 13-7 shows these material inputs and the amount per metric ton of food waste diverted we use in our SimaPro analysis.

Energy

We use a yearly energy requirement of 54,462.8 kWh and a yearly dining hall food waste production and processing of 214 metric tons to calculate the per metric ton energy requirements of the Biogreen360 method. The energy requirement to process the food waste via this method would be 0.2545 kWh per metric ton of waste.

Biogreen360 advertises the energy use of its 226 kg capacity unit to be 60 kWh per day. Assuming Wellesley dining halls would each be using a unit to process 202 kg per day, we calculate the energy required per metric ton of waste as follows,

Energy requirement
= (kWh/day of processing) * (day of processing/metric tons processed)
= 60 kWh/day *(day/0.202 metric tons)
= 297.03 kWh per metric ton of waste

Storage
Assuming diversion of a total of 240.4 metric tons per year and assuming a two-year lifetime for tarps, the 11.79 kg (or 8 tarps) total, which would each handle 480.8 (240.4*2) metric tons waste over their lifetime, we calculate the plastic tarp required per ton of waste equal to 11.79/480.8 = 0.025 kg per metric ton of waste.

Because the Biogreen360 runs with continuous feed and output (waste can be inserted at any time and processed waste is produced consistently), storage would be required for processed waste. We assume a single daily trip around campus would be sufficient to bring waste to longer-term storage. Each day's 202 kg of waste per dining hall would require two five-gallon (18.9 L) bins based on the food density assumed of 15.97 kg per cubic foot. These bins would be separate from the dining hall collection bins to be required of all composting methods. Each bin weighs three pounds, or 1.4 kg. Therefore, assuming a 10-year lifetime of each plastic bin, the Biogreen360 would require 0.0042 kg plastic per metric ton of food waste for temporary storage.

14.3.3 Avoided Impacts

We assume no avoided impacts from dehydration with enzymes.

14.3.4 Water Use

The Biogreen360 unit requires no freshwater inputs.

14.3.5 Summary: Life Cycle Impacts and Assessment of Dehydration with Enzymes

Table 14-3: Environmental impacts by process stage, dehydration with enzymes.

Impact category	Unit	Manufacture	Use	Collection	Storage
Global warming	kg CO2 eq	2.91076	253.40879	0.05417	0.01794
Carcinogenics	kg benzen eq	0.00735	0.04291	0.00018	0.00006
Ecotoxicity	kg 2,4-D eq	0.35235	20.39580	0.08019	0.03180

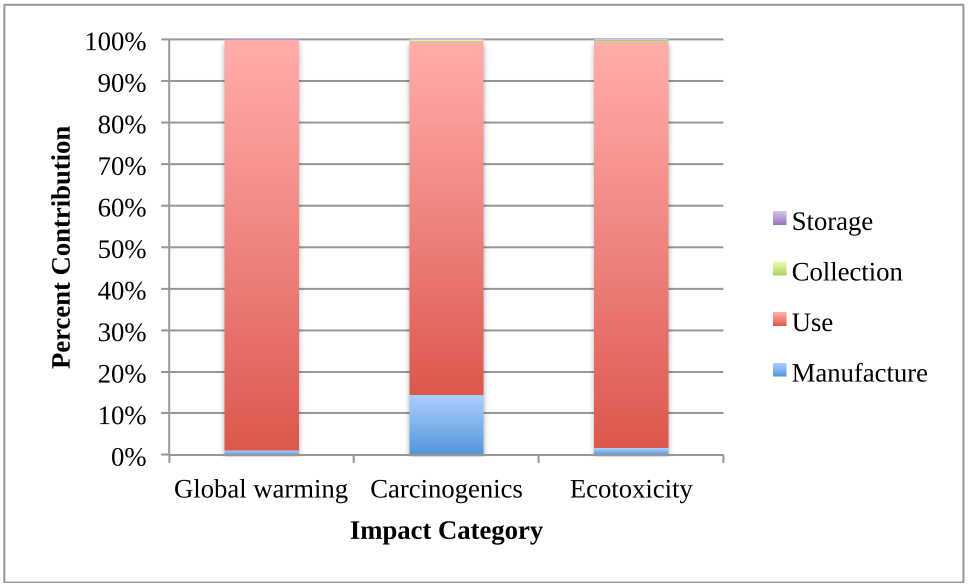

Figure 14-2: Percent contribution of process stages to each impact category, dehydration with enzymes.

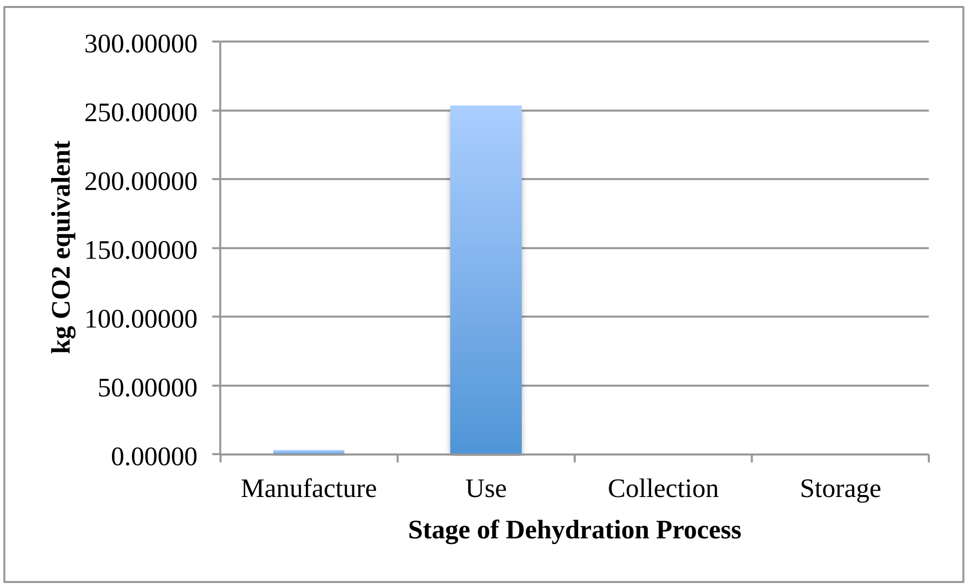

Figure 14-3: Climate change impact of each process stage, dehydration with enzymes.

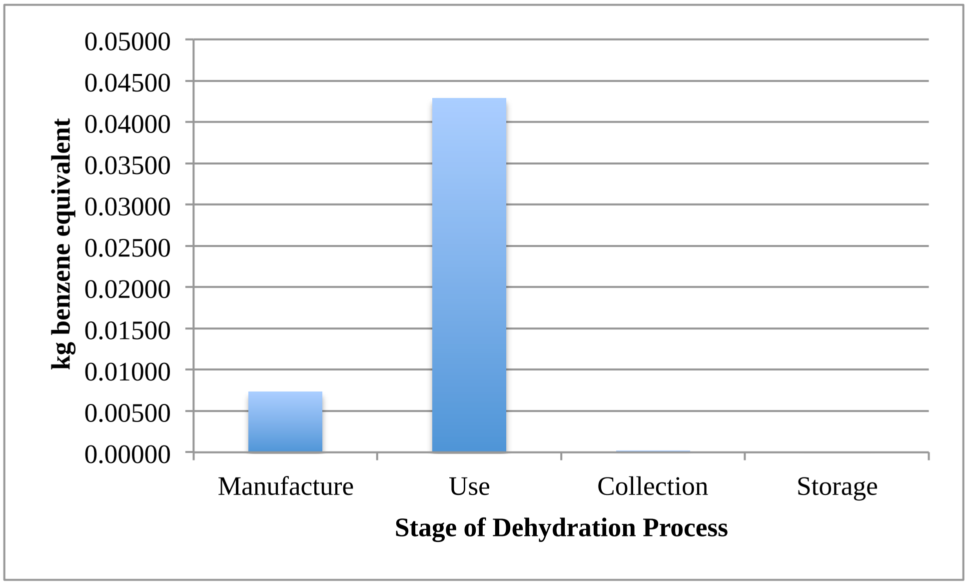

Figure 14-4: Human toxicity impact of each process stage, dehydration with enzymes.

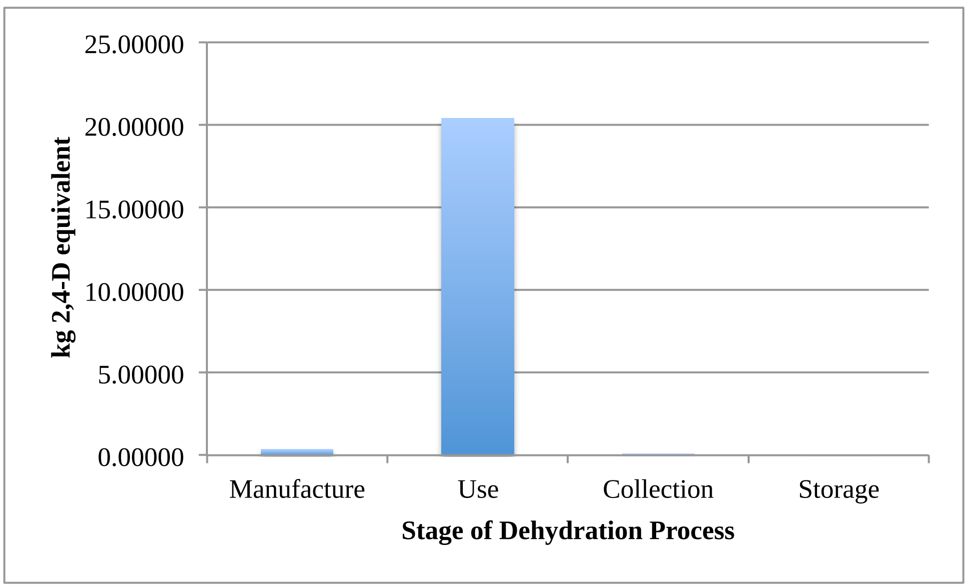

Figure 14-5: Ecosystem toxicity impact of each process stage, dehydration with enzymes.

The environmental impacts for each process stage of the SimaPro analysis are shown in Table 14-3 and Figures 14-2, 3, 4, and 5. Even with the decreased amount of energy required relative to a traditional dehydrator from the additional help of microorganisms, the Biogreen360 would still have its greatest impact in the use phase. The electricity use (about 60 kWh per day) is the biggest contributor to all impact categories. In addition, the manufacture of the machine (in particular, the steel use) produces a carcinogenics impact per metric ton of waste of 0.0073 kg benzene equivalent.

14.4 Costs of Dehydration with Enzymes

14.4.1 Direct Cost

Tipping Fees
There would be no tipping fees because another facility would not be taking the waste.

Trucking Fees
The waste would not be handled by a trucking company. Therefore, there would be no external trucking fees.

14.4.2 Operational Cost

Transportation Cost
Processed waste would be transported around campus, most likely with the same frequency (daily) and in the same vehicle as with traditional dehydration, which had fuel efficiency 3.83 km per liter. Because we assumed the installation of one unit in each of the five dining halls, it would travel about 4 km daily. Assuming the fuel cost of $4.00 per gallon, or $1.06 per liter, the total cost would be:

Transportation cost of Biogreen360 processed waste
= (cost/liter) * (liters/km) * (km/day) * (day/metric tons processed)
= $1.06/liter * (1 L/3.83 km) * (4 km/day) * (day/1.01 metric ton)
= $1.10/metric ton of waste

Labor Costs
Labor costs would also be the same as those with a traditional dehydrator, for the same reasons as above. Therefore labor cost for a Biogreen360 would be $37.66 per metric ton of waste.

Energy Costs
The energy consumption of a Biogreen360 unit was estimated to be 60 kWh per day of processing. This assumed about 202 kg of waste processed per day (or 0.202 metric tons), and the energy would therefore be 297.03 kWh required for one metric ton of waste. Using the cost of energy on campus of $0.11 per kWh,[21] we calculate the energy cost to be:

Energy cost per metric ton
= (energy required in kWh/metric ton) * (cost of energy per kWh at Wellesley)
= (297.03 kWh/metric ton waste) * ($0.11/kWh at Wellesley)
= $32.67 per metric ton of waste.

Other Operational Cost
The Biogreen360 unit consumes (and discharges) no freshwater, and the cost of water associated with this method would thus be $0.00.

14.4.3 Equipment

[21] Estimate by Wellesley College Office of Sustainability. March 11, 2013.

A Biogreen360 500 model (226.8 kg per day) unit would cost about $53,000 including the installation process. Over a 20-year lifetime, during which about 856.48 metric tons of waste would be processed total, we calculated the cost per metric ton of waste to be $53,000/856.48 metric tons, or $61.89 per metric ton.

In addition, maintenance costs, including the yearly replacement of microorganisms, are estimated to be about $300 per year. Assuming each unit would process 202 metric tons of waste per year, maintenance would cost $300 for 202 metric tons, or $1.49 per metric ton.

Adding the purchase, installation, and maintenance of the Biogreen360, we calculated the total cost of the equipment per metric ton to be $63.37.

14.4.4 Offset Cost

We assume no offset cost from dehydration with enzymes.

14.4.5 Summary: Cost of Dehydration with Enzymes

Table 14-4: Cost of dehydration with enzymes per metric ton of food waste

Cost Category		**Amount ($/metric ton)**
Direct:		
	Facilities	$0.00
	Transportation	$0.00
Operational:		
	Transportation	$1.10
	Labor	$37.66
	Energy	$32.67
	Other (water)	$0.00
Equipment		$63.37
Offset costs		-$0.00
Total Cost		**$34.80**

As seen in Table 13-9, the highest cost category for implementation of the Biogreen360 method is the equipment cost. Labor and use costs are also high, since waste would need to be transported around campus daily to a storage site, and because the unit requires around 60 kWh of energy for a day of processing. In order to reduce such costs, the most feasible solution would be to reduce labor costs. If waste did not need to be transported out of dining halls daily, such costs would be reduced. It is unlikely that the fixed costs of equipment or energy could be reduced at all.

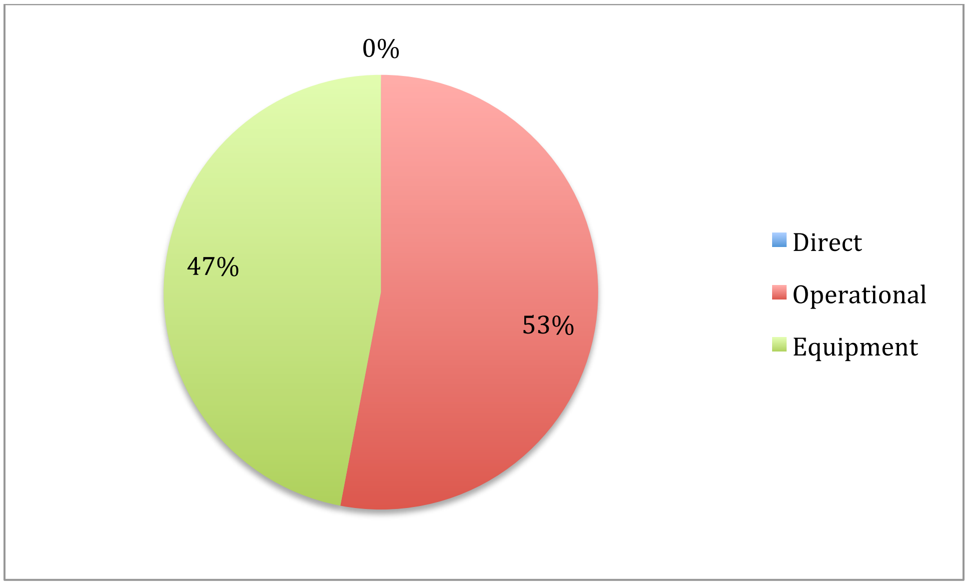

Figure 14-6: Cost of dehydration with enzymes

When the operation costs of energy use and labor are combined into one figure, the total operation costs were found to be greater than the equipment costs (Figure 13-10). Therefore, the biggest area for improvement in cost would be in reducing operational costs.

14.5 Social Impacts of Dehydration with Enzymes

14.5.1 Campus Experience - Neutral

The campus experience impacts are approximately equivalent to the impacts using a traditional dehydration system.

14.5.2 Educational Benefit - Negative

This method would have approximately equivalent academic opportunities as the traditional dehydration method would have. Dehydration with enzymes would provide useful education about the process of using microorganisms in waste decomposition at an industrial scale, whereas traditional dehydration does not include this component of dehydration.

Similar to traditional dehydration, this method would have limited visibility due to its location and process on campus.

14.5.3 Implementation Difficulty

Separation - Medium

This method requires that compostable dishware, any large bones, and oils or grease to be separated from the food waste material prior to processing.[22] The units can process no material other than food waste.

Permitting and Regulations - Medium
This method may require building and renovation permits from the town of Wellesley if a component of the installment or dining hall renovation requires inspection,[23] as is the same with traditional dehydration. This method will also need similar renovations for energy capabilities; each dining hall will need to have a 220-volt power outlet.[24] While the traditional dehydration method requires renovations that will only change the power plug, this method will also require a vent system plumbed to the exterior of the building, or hooked up to an existing venting system.[25]

Time until Implementation -Medium
This method is likely to have the same projected implementation time horizon as the traditional dehydration method, and would likely be implemented by the Massachusetts 2014 deadline.

Risk - High
There is a high risk of contamination using the Biogreen360 method, at least at the outset of using the machines. Compostable dishware and other non-food materials, as well as large and medium sized bones are not acceptable in the machine. The microorganisms cannot process any waste other than food waste. There is also a high risk because any cloth or metal utensils that accidentally enter the machine have a high potential of breaking the machine.[26]

14.5.4 Social Justice - Low

The social justice impacts are approximately equivalent to the impacts using a traditional dehydration system.

14.5.5 Summary: Social Impacts of Dehydration with Enzymes

Table 14-5 shows the relative score for each factor and sub-factor considered in our Social Impact analysis. Similar to the Traditional Dehydration system, the Biogreen360 method has the highest social impacts in the Difficulty category. The Biogreen360 method's greatest impacts are due to the risk of contamination, rather than the separation challenges. It is not possible for the machine to operate with any materials other than food waste, and thus there are not many methods for changing the risk of contamination by these materials. A couple possibilities are to frequently train students or staff to sort through all food waste prior to processing. Another possible challenge with the Biogreen360 is due to its continual discharge mechanism. Staff will

[22] If the Biogreen360 unit purchased includes a grinder, then bones can go into the machine but will need to be put into the grinder separate from other organic waste. Thus, regardless of whether the machine includes the grinder, larger meat bones should be separated prior to processing.
[23] Willoughby, Patrick, Wellesley College Director of Sustainability. Eliana Blaine. March 6, 2013.
Danielle Gaglini, Wellesley College Office of Sustainability Coordinator. Eliana Blaine. March 9, 2013.
[24] Bates dining hall has already been renovated to include a 220-volt power plug.
[25] Grillo, Pete, Biogreen360 representative. Eliana Blaine. March 11, 2013.
[26] Grillo, Pete, Biogreen360 representative. Eliana Blaine. March 11, 2013.

need to ensure that the waste discharged from the machine is going into the proper buckets for temporary storage throughout the day, and that these buckets do not overflow.

Table 14-5: Social impacts of dehydration with enzymes

Social Impact		Score
Campus experience		Neutral
Educational benefit		Negative
Difficulty:		
	Separation	Medium
	Permitting and regulations	Medium
	Time until implementation	Medium
	Risk	High
Social justice		Neutral

14.6 Conclusions

The Biogreen360 dehydration system would likely be implemented in a decentralized model similar to that for traditional dehydration. In this way, our analysis can be easily compared to the traditional dehydration system. This assumption allows for a diversion system whereby wet food waste does not require additional transportation on campus. Both the Biogreen360 and the traditional system could process all of the College's food waste.

The traditional and the Biogreen360 methods have different cost ratios between operational and equipment costs. For Biogreen, the costs are 53% and 47%, for operational and equipment respectively. For traditional, the costs are 40% and 60% respectively.

The highest environmental impacts of the Biogreen360 are attributable to the use phase. Yet, the Biogreen360 unit requires significantly lower energy requirements. This difference affects the global warming potential significantly. The global warming potential (in kg CO2 equivalents) of the Traditional Dehydration unit is approximately 8.5 times higher than the Biogreen360 during the use phase. The carcinogenics impacts of the Biogreen360 unit are around eight times higher using the Traditional method, and ecotoxicity impacts reach 10 times higher. The energy use requirements for the Biogreen360 system are still high, around 297 kWh per metric ton of waste processed.

Both the traditional dehydration method and the Biogreen360 do not need any additional freshwater inputs. With the Biogreen360 method, the only organic items that need to be separated prior to processing are compostable dishware and large bones. While this makes the

Biogreen360system less difficult, there is a higher risk of contamination - if the wrong materials are put into the machine, there is a greater risk for damage than with the ECORECT units. The Biogreen360 units are continual feed, continual disposal, and thus may be more challenging to coordinate collection and storage of material throughout the day. These units would not require more work overall because the ECORECT machines would need to be unloaded at the end of the day anyways.

The primary differences with the Biogreen360 unit, in addition to the lower energy requirements, are the use of microorganisms and the decomposition of the organic material. The Biogreen360machine requires replacement of microorganisms each year. The dry biogenous material is fully decomposed at the end of the process using the Biogreen360, whereas there is a risk of rehydration and fungal rot with the traditional process. Both dehydration methods could conceivably be implemented in time for the Massachusetts 2014 Organic Waste Ban deadline.

15.0 In-Sink Disposal

Figure 15-1: InSinkErator® SS-300™, model assumed to be currently used at Wellesley College.[1]

15.1 Introduction to In-Sink Disposal

In-sink disposal units are commonplace at college campuses and other institutions, including Wellesley College, as a way to prevent food waste from going into the garbage. Food waste is instead sent down the sink as wastewater. These units are able to process all pre-consumer and post-consumer waste into fine particles that are then flushed into the septic system.

In-sink disposal systems are effectively used as a garbage bin for food and have been installed in sinks worldwide. In-sink disposals have been in use since 1927 after architect John W. Hammes came up with the idea, patented it, and founded the company InSinkErator® that has since become the world's largest manufacturer.[2] Currently, Wellesley College has a total of 10 in-sink disposal units installed in its five dining facilities.

In-sink disposal systems can process essentially any and all food waste. Both pre-consumer and post-consumer food waste is dumped into the in-sink disposal units by dining hall staff where the

[1] "SS-300™." Accessed May 12, 2013. www.insinkerator.com.
[2] "How A Disposer Works." Accessed March 30, 2013. www.insinkerator.com.

unit is turned on manually. The food is then ground by impellers mounted on a spinning plate that uses centrifugal force to continuously force food waste particles against a stationary grind ring. The grind ring breaks down the food waste into fine particles that are flushed by water out of the grinding chamber and into the wastewater pipe. From there, the wastewater flows to a wastewater treatment plant (in our case, Deer Island) or a septic system.

In-sink disposal units require both electricity and water to function. The unit uses electricity to process the food particles. Water must be run before, during, and after food processing to ensure that the food is ground properly and that the unit itself stays free of food particles that could corrode the unit.[3]

15.2 Implementing In-Sink Disposal at Wellesley College

15.2.1 Overview of Implementation at Wellesley

Wellesley already diverts a portion of its food waste through in-sink disposal. However, because the amount of waste currently diverted by this method is so small, we have not included in-sink disposal in our analysis of the College's organic waste stream. In total, there are 10 InSinkErators® in campus dining halls. (For the purpose of our study, we are not analyzing the InSinkErators® located in the dormitories.) To use the InSinkErators®, dining hall employees run the water tap as they scrape food waste into the disposal. Once the InSinkErator® pulverizes it, the food waste travels through pipes to the Deer Island Sewage Treatment Plant, where it is processed in anaerobic digesters.[4]

We assume that the pipes through which the food waste travels are outside of the boundaries of our analysis. We also assume that all of Wellesley's InSinkErators® have been installed in the past five years. This assumption is reasonable, since many of the dining halls have been renovated during that period.

15.2.2 Technology/Equipment

Wellesley already has much of the equipment necessary to divert 100% of its food waste through in-sink disposal. There are 10 industrial InSinkErators® on campus: three in Stone-Davis; two in Bates, Lulu, and Tower; and one in Pomeroy. We assume that Wellesley is using the InSinkErator SS-300™ model, which has the capacity to treat food waste for 300-750 people per meal.[5]

Wellesley will also be responsible for some wear and tear to the anaerobic digester at the Deer Island Sewage Treatment Plant. The anaerobic digester accepts, on average, 365 million gallons

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[3] "How A Disposer Works." Accessed March 30, 2013. www.insinkerator.com.
[4] Wong, Shutsu Chai. "Tapping the Energy Potential of Municipal Wastewater Treatment: Anaerobic Digestion and Combined Heat and Power in Massachusetts." Accessed April 1, 2013. http://www.mass.gov/dep/water/priorities/chp_11.pdf.
[5] "3-10 H.P. Disposer Models." Accessed April 1, 2013. http://www.InSinkErator.com/en-us/Documents/Foodservice/SS300_to_SS1000_spec_sheet.pdf.

of sewage water daily but has the capacity to accept 1313 million gallons a day.[6] For more information on anaerobic digesters see section 3.6.

Wellesley's Daily Contribution
= Wellesley's daily organic food waste + water demand to dispose in-sink
= .602 metric tons food waste + 54.5 metric ton water
(see water calculation below)
= 55.1 metric tons of wastewater
= 14,560 gallons/day

Percent Contribution
= Wellesley's Wastewater/average plant capacity
= 14,560 gallons/365 million gallons
= .004%

15.2.3 Inputs

Energy
This method would require electricity to run the in-sink disposals as well as electricity and heat at the wastewater treatment plant. The 10 three-horsepower disposals at Wellesley would collectively run approximately 30 hours per day if all of the College's organic waste were disposed using this method. They would consume about 67 kWh of electricity per day or 111 kWh per metric ton of food waste.

The Deer Island wastewater treatment facility uses about 164 MWh per year of electricity.[7] Wellesley's food waste would be responsible for .004% of that amount, about 6.5 kWh per year, which equates to 0.03 kWh per metric ton of food waste. The cogeneration plant that burns biogas from the digestion process produces 95% of the heat required by the facility so heating oil was not considered as a significant input.

Materials
The primary material input for this method is water. The 10 disposal units that Wellesley uses each require a water flow-rate of 30.28 liters per minute. The dining halls that have multiple disposals do not usually run them all at the same time. We assume that each dining hall would run one disposal about six hours per day, whenever dishes are being accepted during mealtimes. On average, Wellesley produces 0.602 metric tons of food waste per day; this means that Wellesley uses 90.5 metric tons of water per metric ton of food waste.

Water Needed
=30.28 Liters per minute*360 minutes per day*5 dining halls / 0.602 metric tons

[6] Wong, Shutsu Chai. "Tapping the Energy Potential of Municipal Wastewater Treatment: Anaerobic Digestion and Combined Heat and Power in Massachusetts." Accessed April 1, 2013. http://www.mass.gov/dep/water/priorities/chp_11.pdf.
[7] "Anaerobic Digestion Case Studies: Wastewater: Deer Island Wastewater Treatment Plant, Massachusetts Water Resources Authority (MWRA), Boston, MA." Accessed April 1, 2013. http://www.mass.gov/dep/energy/adwwtp.htm

=90,538 liters/ metric ton
by mass = 90.5 metric tons of water/ metric ton

The equipment material needs for this method would come from the in-sink disposal units and the wastewater treatment plant. The three-horsepower disposal units weigh around 63 kg each. About half of the mass belongs to the electric motor, the rest are mainly stainless steel parts. These units have a typical lifetime of about 12 years.

We approximate the material needs for the Deer Island facility by scaling up the Anaerobic Digester materials described in Chapter 11. This material consists mainly of steel, concrete, and plastics with a lifetime of 40 years.

Stainless Steel Needed
=31.5kg * 10 / (12 years *220 tons)
=0.119 kg/ metric ton

Electric Motor Needed
=31.5kg * 10 / (12 years *220 tons)
=0.119 kg/ metric ton

Even though we are employing an off-campus anaerobic digester, we must assume responsibility for Wellesley's share of the construction materials, since the College's load will contribute to the wear and tear of the equipment. We use the estimations from Chapter 11 as an estimation of the materials per metric ton of food waste diverted.

We assume that the lifespan of the Deer Island anaerobic digesters is 40 years, and that Wellesley would divert 100% of its food waste to the digesters for the entirety of this period. This assumption accounts for the greater efficiency of the larger digesters. The material calculations are as follows:

Total Concrete Needed
= 154.134 metric tons concrete
= 154,134 kg concrete/(33.97 metric tons/day * 365 days/year * 40 years)
= .3108 kg concrete/metric ton

Total Steel Needed
= 24.3 metric tons steel
= 24,300 kg/(33.97 metric tons/day * 365 days/year * 40 years)
= .0484 kg steel/metric ton food waste

Total Polyurethane Needed
= 44.94 metric tons
= 44,940 kg/(33.97 metric tons/day * 365 days/year * 40 years)
= .0906 kg polyurethane / metric ton food waste

Total Epoxy Needed
= 7.36 metric ton

= 7360 kg/(33.97 metric tons/day * 365 days/year * 40 years)
= .0148 kg/metric ton

15.2.4 Outputs

The outputs from in-sink digestion originate from the anaerobic digestion process that occurs once the wastewater reaches the sewage treatment facility. The digester produces electricity and fertilizer. The electricity produced is used by other parts of the facility, and in total supplies 24% of the demand from the facility.[8]

The byproduct that the facility produces is digestate, a nutrient rich substance that can be used as a substitute for commercial fertilizer. The digestate produced at the Deer Island Sewage Treatment Facility is sold to the general public as a substitute for chemical fertilizer.[9] Thus, the digestate contributes a beneficial environmental impact.

Amount of Digestate Created (kg/day)
= 105 short tons/day [10]
= 95,2544 kg/day

Total Fertilizer Credited to Wellesley College (kg)
= total digestate * percent contribution from Wellesley College
= 95,254.4 kg fertilizer *.004%
= 3.81 kg fertilizer/.6027 metric tons
= 6.33 kg fertilizer/metric ton food waste

15.3 Environmental Impacts of In-Sink Disposal

15.3.1 Collection and Preparation of Food Waste

In-sink disposal requires no additional collection or preparation.

Transportation of Food Waste
The food waste diverted through in-sink disposal would not require any additional transportation because the waste flows with water to the treatment plant at Deer Island. The pipes, which carry the wastewater to the facility, are outside of the boundaries of this study.

15.3.2 Process

Materials

[8] Wong, Shutsu Chai. "Tapping the Energy Potential of Municipal Wastewater Treatment: Anaerobic Digestion and Combined Heat and Power in Massachusetts." Accessed April 1, 2013. http://www.mass.gov/dep/water/priorities/chp_11.pdf.
[9] "Bay State Fertilizer: The Natural Choice for Seasons to Come." Accessed April 1, 2013. http://www.mwra.state.ma.us/publications/fertilizerbrochure.pdf
[10] Wong, Shutsu Chai. "Tapping the Energy Potential of Municipal Wastewater Treatment: Anaerobic Digestion and Combined Heat and Power in Massachusetts." Accessed April 1, 2013. http://www.mass.gov/dep/water/priorities/chp_11.pdf.

The materials impact for this process comes from the in-sink disposal equipment and the digester plant. As described in Chapter 11.3.3, the disposal equipment requires 0.119 kg of stainless steel per metric ton of food waste and 0.119 kg of electric motor per metric ton of food waste. We assume that the motor makes up half of the equipment's mass and that the motor has a similar makeup to those used in electric vehicles.

The materials impact from the digester was estimated by scaling the values estimated in Chapter 11 based on the Jordan Farms digester. We assume that the material requirement per metric ton of food waste is roughly the same, with the exception that the Deer Island Facility has twice the lifespan. This results in the following material requirements:

0.3108 kg concrete/metric ton food waste
0.0484 kg steel/metric ton food waste
0.0906 kg polyurethane / metric ton food waste
0.0148 kg epoxy/metric ton food waste

The material that goes into the piping infrastructure and wastewater treatment other than the digester were considered beyond the scope of our study.

Energy
Assuming all 10 of Wellesley's disposals collectively run for 30 hours per day, the electric requirement is 111 kWh/metric ton as described in Chapter 11. This assumes that one unit in each dining hall is running at full capacity for six hours.

The energy use for the wastewater facility is 0.03 kWh per metric ton of food waste (as shown in Chapter 11). Of this amount, 24% comes from the plant with minimal environmental impact. The resulting amount, 0.023 kWh per metric ton, comes from the electricity grid.

15.3.3 Avoided Impacts

Wellesley would receive avoided environmental impacts for .004% of the fertilizer produced by the anaerobic digester at Deer Island. The College would receive an environmental credit for 6.33 kg of fertilizer per metric ton of food waste that it diverts via in-sink disposal. We assume that the fertilizer produced by the facility would be sold within the state as an organic substitute to chemical fertilizer.[11]

15.3.4 Water Use

In-sink disposal requires large amounts of water. In total, this disposal method would consume about 55,440 liters of water per day. This equates to 90.5 metric tons of water per metric ton of food waste.

15.3.5 Summary: Life Cycle Impacts and Assessment of In-Sink Disposal

[11] "Bay State Fertilizer: The Natural Choice for Seasons to Come." Accessed April 1, 2013. http://www.mwra.state.ma.us/publications/fertilizerbrochure.pdf.

Table 15-1: Environmental impacts by process stage, in-sink disposal

Impact category	Unit	Materials for In-Sink	Energy for In-Sink	Materials for Digester	Energy for Digestion	Avoided Impacts	Total
Global warming	kg CO2 eq	0.7834	35.958	0.6405	0.0075	-2.4749	34.915
Carcinogenic	kg benzen eq	0.0262	0.0066	0.0013	0.0000	-0.0878	-0.0537
Ecotoxicity	kg 2,4-D eq	6.6213	2.6594	0.7865	0.0006	-2.6439	7.4239

Table 15-1 summarizes the environmental impacts of diverting 100% of Wellesley's organic waste by in-sink disposal. It includes the disposal mechanisms as well as environmental impacts for the anaerobic digester at Deer Island that will process Wellesley's food waste. The information in the table symbolizes the environmental impacts per metric ton of food waste diverted.

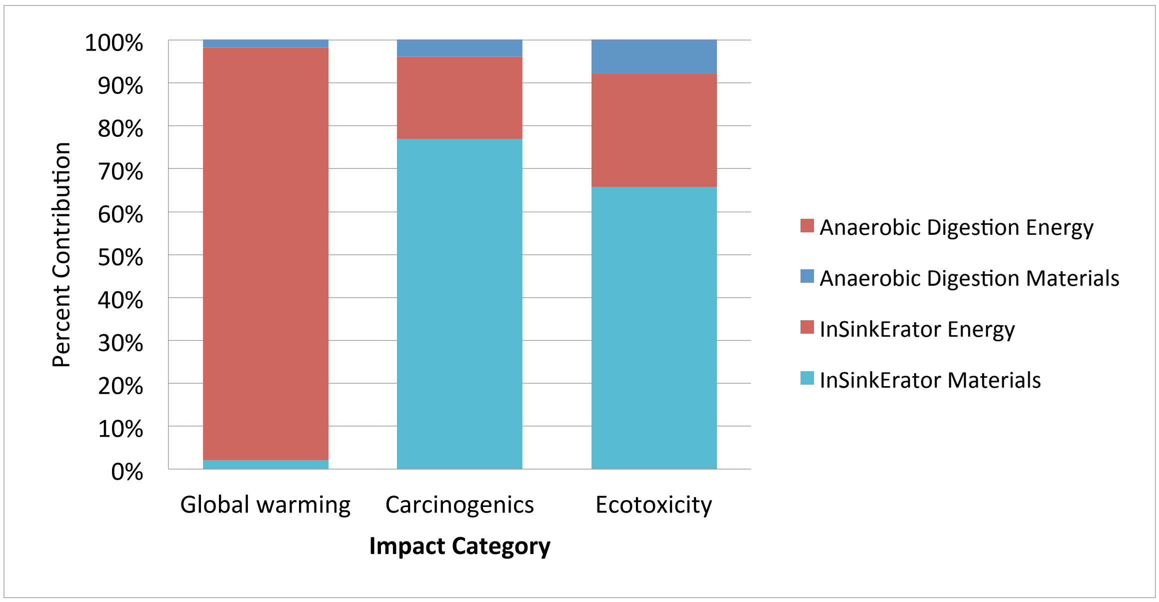

Figure 15-2: Percent contribution of process stages to each impact category, in-sink disposal

Figure 15-2 shows the negative environmental impacts of in-sink disposal, broken down by the percent contribution of each life stage of the process. The avoided impacts are not included in this figure.

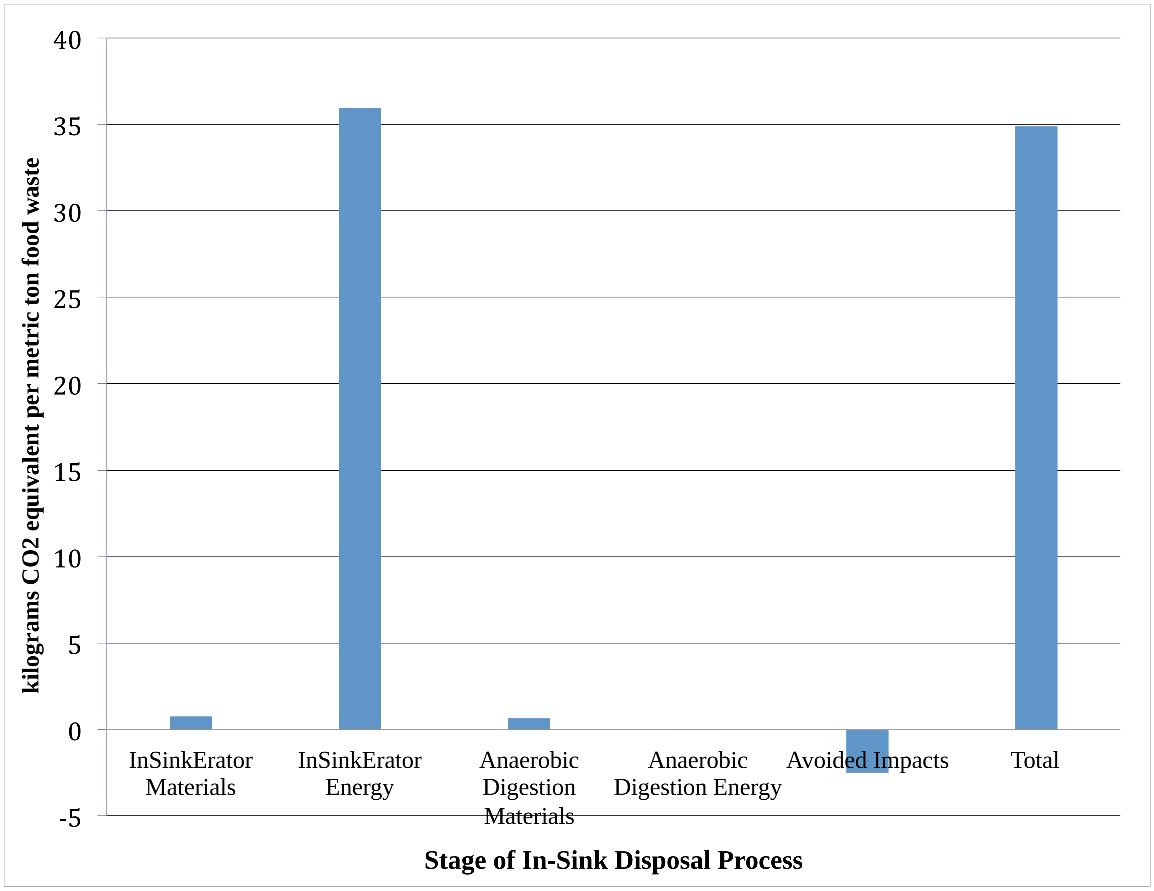

Figure 15-3: Climate change impact of each process stage, in-sink disposal

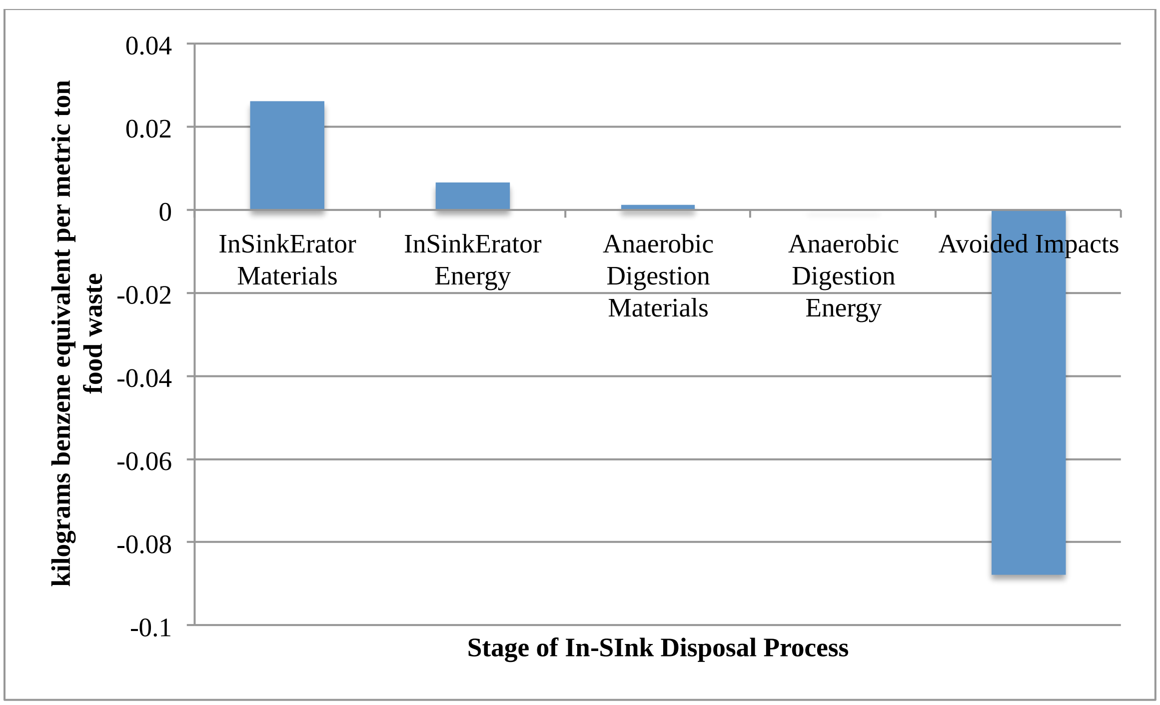

Figure 15-4: Human toxicity impact of each process stage, in-sink disposal

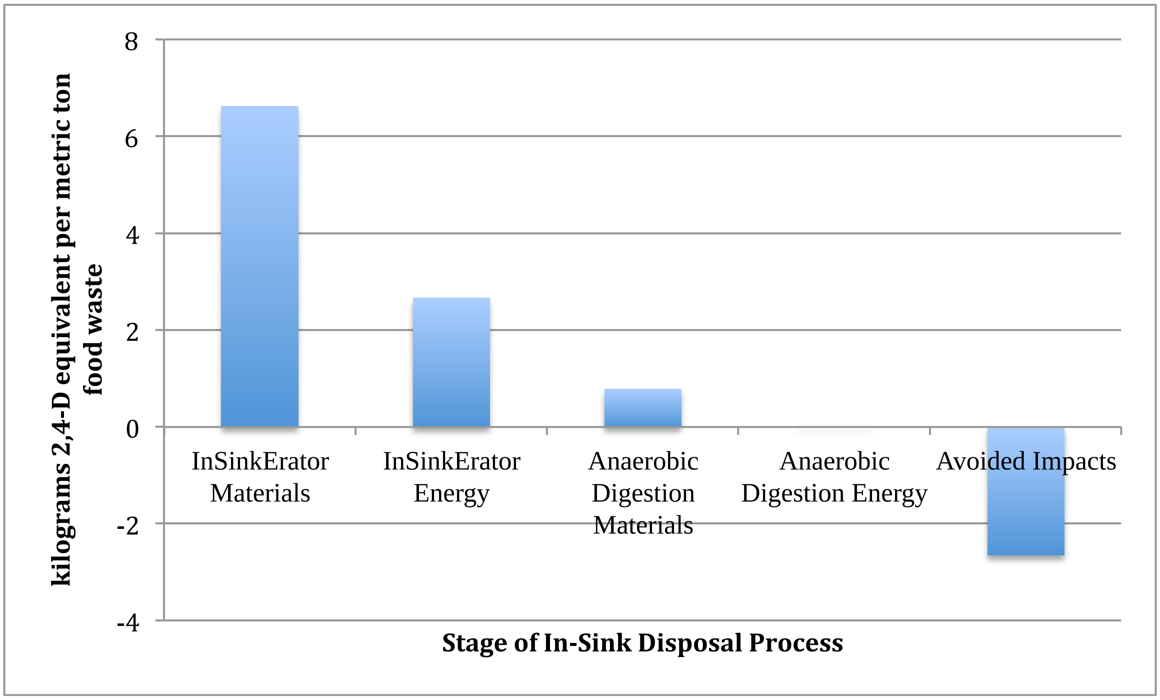

Figure 15-5: Ecosystem toxicity impact of each process stage, in-sink disposal

Figures 15-3, 15-4, and 15-5 show the net environmental impact of in-sink disposal for global warming potential, carcinogenic potential, and ecotoxicity potential (respectively). To find the net impact, we subtract the avoided impacts from the total environmental impacts of the process. In these figures, a negative number represents a positive environmental impact while a positive number represents a negative impact.

As is evident in the environmental impact assessment, the energy and materials for the InSinkErator® are cause of this method's biggest environmental impacts. Wellesley contributes only .008% to the anaerobic digesters on Deer Island and is, therefore, responsible for a small amount of the environmental impact from the digesters.

For both global warming potential and ecotoxicity potential, the negative environmental impacts far outweigh the positive offsets. This effect is probably because of the high energy demand for the InSinkErators®. For carcinogenic potential, the avoided impacts are higher than the combined negative environmental impacts of in-sink disposal because of the benefits from replacing chemical fertilizer with organic fertilizer from the digester.

It is also important to note the high water use for in-sink disposal. Since the sink must be running whenever the InSinkErator® is running, there is an extremely high water demand for this method. In one year, this method of disposal would add a water demand equivalent to 1/18 of Wellesley's current water use. [12]

[12] Calculated with data from: InSinkErator Foodservice. "3-10 H.P. Disposer Models." Accessed April 1, 2013. http://www.InSinkErator.com/en-us/Documents/Foodservice/SS300_to_SS1000_spec_sheet.pdf.

15.4 Costs of In-Sink Disposal

15.4.1 Direct Cost

Tipping Fees
The MWRA charges a fee to dispose of wastewater. For a typical household in Wellesley, the yearly sewer charge is about $940.80 for 90,000 gallons.[13] This equates to $2.76 per metric ton of wastewater. Since 90.5 metric tons of water are required to dispose of one metric ton of food waste with in-sink disposal, the total sewer cost will be about $250 per metric ton of food waste. This cost may be considerably lower than what we estimate if Wellesley College has an institutional discount or some other agreement with the MWRA.

15.4.2 Operational Cost

Transportation Cost
No transportation will be needed for this method, so there will be no transportation cost.

Labor costs
In-sink disposal would require a shift in the primary method that food waste is currently disposed of in dining halls. Instead of placing waste food into the garbage, dining hall employees would have to systematically place the food down the disposal to ensure that the mechanism is not overwhelmed. While there would be a change in where workers are placing waste food, the method would not require any additional labor. Additionally, there would be no additional need for training since several of the dining halls are already doing a smaller version of this approach. While this would be a significant change in how Wellesley treats its food waste, since the institution would be putting such large quantities of food down the drain, it would not require any change in labor.

Energy costs
As described above, the 10 three-horsepower disposals consume a total of 111 KWh of electricity per metric ton of food waste with a cost of $12 per metric ton, assuming 11 cents per KWh.

Other Operational Cost (water)
Wellesley has its own freshwater supply that it does not pay to access, but pays for chemicals needed to make the water potable. The cost of these chemicals is $1.79 per metric ton of food waste.

Cost of Water per Metric Ton of Food Waste Diverted
= 90500 liters per metric ton * $0.00001984 per liter
= $ 1.79/ metric ton

15.4.3 Equipment

[13] "Combined Annual Water and Sewer Charges for Communities Receiving Services from the MWRA 2011." Accessed April 1, 2013. http://mwraadvisoryboard.com/wp-content/uploads/2012/08/MWRA-Retail-Rates-2011.pdf.

Wellesley currently has the required number of in-sink disposals, but this disposal method will be responsible for wear and tear on the equipment, eventually requiring replacement. The expected lifespan for these disposals is 12 years and each costs about $2,500. This equates to a cost of $9.47 per metric ton of food waste.

Cost of InSinkErator®[14]
= number of units * cost per unit / (expected lifespan * amount of food waste diverted/yr)
= 10 units * $2500 / (12 years * 220 metric tons)
= $9.47

15.4.4 Offset Cost

This method would not produce any products that offset costs for the College.

15.4.5 Summary: Cost of In-Sink Disposal

Table 15-2: Cost of in-sink disposal per metric ton of food waste

Cost Category		**Amount ($/metric ton)**
Direct:		
	Facilities	$250.00
.	Transportation	$0.00
Operational:		
	Transportation	$0.00
	Labor	$0.00
	Other (water)	$13.79
Equipment		$9.47
Offset costs		$0.00
Total Cost		$273.29

The cost of this method is dominated by the sewer charge from the MWRA, which contributes 91% of the total amount. It is possible that Wellesley College already has a lower sewer charge rate than typical households in Wellesley. To reduce this cost further, it would be necessary to use less water. The InSinkErator® website shows that the water flow rate can optionally be reduced by about 13% with slight modifications.[15] Though it is not considered in this study, InSinkErator® also sells a retrofit system that reduces water use by up to 70% by reducing the

[14] "InSinkErator Ss 300 Commercial Garbage Disposer." Accessed April 1, 2013. www.sears.com.
[15] "3-10 H.P. Disposer Models." Accessed April 1, 2013. http://www.insinkerator.com/en-us/Documents/Foodservice/SS300_to_SS1000_spec_sheet.pdf.

water flow when food is not being put into the disposal.[16] If the College were concerned about the cost or environmental impacts of the water use, it could install this system.

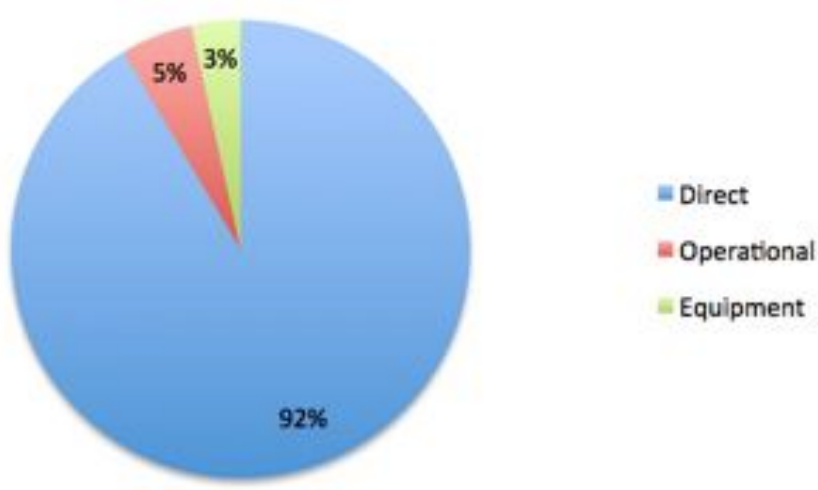

Figure 15-6: Cost of in-sink disposal

15.5 Social Impacts of In-Sink Disposal

15.5.1 Campus Experience - Neutral

Currently, in-sink disposals do not add to or detract from the experience of students or staff at Wellesley College. In-sink disposal units are not visible to the majority of students on campus and for those who do operate them, the units do not create significant amount work, noise or unpleasant odor that would change the way operators feel about the College. Additionally, since in-sink disposal units are already in use at the College, their continued use would not change how students or staff members experience the campus.

15.5.2 Educational Benefit - Negative

The use of in-sink disposals in dining hall kitchens does not provide students with opportunities to be involved or learn about food waste diversion on campus. The use of in-sink units are currently only operated by dining hall staff and they are not visible to most students since they are located in dining hall kitchens. It could be a safety hazard to make the units accessible to students, and the process itself is not particularly educational.

15.5.3 Implementation Difficulty

[16] "AquaSaver System." Accessed April 1, 2013. http://www.insinkerator.com/en-us/Documents/Foodservice/Aquasaver-Brochure.pdf.

Separation - Low
In-sink food disposal units would not require any separation of food. They can process all pre-consumer and post-consumer food waste up to and including small meat bones and vegetable roughage such as pineapple stems and husks.[17]

Permitting and Regulations - Low
The installation and use of in-sink disposal units would not require any permits. Because the College already has the units installed, dining hall staff would not need to learn new rules or regulations regarding the equipment.

Time Until Implementation - Low
In-sink disposal units are already installed in each of the five dining halls at Wellesley College. If the College desires additional units, installation could take place immediately.

Risk - *Low*
In-sink disposal units do not present significant risks to the health or safety of dining hall staff or students who operate them and would not pose a risk to the general student body because they would not be accessible to the public. They only require the flip of a switch to operate and the wastewater produced is sent immediately to an off-campus treatment facility.

15.5.4 Social Justice - Neutral

This method of waste diversion would neither contribute to nor detract from social justice efforts within the on or off campus communities. The disposing of food in the in-sink units would not change the way dining halls operate currently and the end product is sent to an already existing treatment facility.

15.5.5 Summary: Social Impacts of In-Sink Disposal

Given that in-sink disposal units already exist at Wellesley as a way to divert food waste, their continued use would not have a significant social impact, which could be their biggest drawback. This method would not enhance students' awareness of food waste reduction on campus and would not provide notable opportunities for students to get involved in the College's efforts to divert organic waste.

[17] "Food Waste Disposers – Insinkerator." Accessed April 22, 2013. http://www.h2o.co.za/Products/Food-Waste-Disposers-Insinkerator.htm.

Table 15-3: Social impacts of in-sink disposal

Social Impact		Score
Campus experience		Neutral
Educational benefit		Negative
Difficulty:		
	Separation	Low
	Permitting and regulations	Low
	Time until implementation	Low
	Risk	Low
Social justice		Neutral

15.6 Conclusions

In-sink disposal at Wellesley would be easy and cost-effective, but its negative environmental impacts outweigh the benefits, and we do not recommend that it should be a primary method implemented to achieve the College's goals for waste reduction by 2014. The biggest advantage associated with in-sink disposal systems is that this method would not require the purchase or installation of additional equipment, which would both reduce costs and eliminate the need for the implementation of new equipment. From an environmental perspective, in-sink disposal systems have high energy and water demands. Yet, the College does have the advantage of already sending its wastewater to the Deer Island Sewage Treatment Facility, which uses state-of-the-art anaerobic digesters to process food waste. The digestate the facility offsets some of the negative environmental impacts of in-sink systems, but the negatives still outweigh the benefits.

Using in-sink disposal as the primary food waste diversion method would neither offer educational opportunities nor promote the College as a leader in organic waste diversion among colleges. In-sink disposals have a limited capacity to be used as teaching tools for the student body, and would not establish Wellesley as a role model for other colleges or universities looking to divert organic waste using more innovative methods. While in-sink disposal could remain useful in the dining halls for the small amounts of food waste left over on dishes, it would be disappointing to see Wellesley settle for this method as its primary waste diversion method.

16.0 Vermicomposting

Figure 16-1. Redworms are used to process food waste in vermicomposting[1]

16.1 Introduction to Vermicomposting

Vermicomposting uses redworms (*Eisenia fetida*), which process food waste by breaking it down into castings (a high-value compost), and compost tea (a high-quality liquid fertilizer). Redworms can eat almost any organic matter, including vegetative food scraps, paper, and plants. One pound of mature worms can eat up to half a pound of food waste per day. The castings are harvestable three to four months later and can be used as potting soil, while the compost tea can be used for houseplants or gardens.[2] Vermicompost has a high capacity for holding moisture, and contains high levels of microorganisms and plant growth hormones. It also has high levels of humic acid, thus reducing the need for chemical fertilizers.[3] A Cornell University study demonstrates that plants grown in vermicompost have increased germination rates and decreased rates of plant disease.[4]

[1] Pocock, Jennifer. "How Vermicomposting Works." Accessed May 2013. http://home.howstuffworks.com/vermicomposting.htm.
[2] "Wastes - Resource Conservation: Types of Composting." Accessed May 2013. http://www.epa.gov/waste/conserve/composting/types.htm.
[3] Munroe, Glenn. "Manual of On-Farm Vermicomposting and Vermiculture." Accessed February 23, 2013. http://oacc.info/docs/vermiculture_farmersmanual_gm.pdf.
[4] "Vermicompost." Accessed May 2013. http://cwmi.css.cornell.edu/vermicompost.htm.

Typically, vermicomposting takes place on a small scale, with the worms placed in bins full of organic matter. On a larger scale, worms can be placed in a raised bed made out of wood or cinder blocks. Both the bins and the beds should be lined with moistened worm bedding (generally shredded newspaper or cardboard).[5] The worms require adequate moisture, aeration, and protection from extreme temperatures.[6] The ideal temperature range is 13 to 25 degrees Celsius.[7] If the worm bin or bed has too much food waste, it could cause the worms' environment to overheat and potentially kill the worms. Additionally, as surface feeders, redworms cannot function in material greater than a meter in depth.[8]

16.2 Implementing Vermicomposting at Wellesley College

16.2.1 Overview of Implementation at Wellesley

In order to utilize vermicomposting to its fullest extent on-campus, a decentralized system with one worm bin at each of the campus's five dining halls and one worm bin in a central location at the Science Center would be most efficient and educational. The worm bin we recommend, and the one with which we have based our calculations, is the Worm Wigwam, manufactured by Sustainable Agricultural Industries, Inc.[9] The dining hall Worm Wigwams would most likely be located in the basement of the closest residence hall (for the four dining halls attached to residence buildings) or simply in the dining hall itself (for the Campus Center dining hall). The Worm Wigwam at the Science Center would ideally be easily accessible and close to the Leaky Beaker, a small café centrally located in that building.

Every day, workers or student volunteers would bring food waste from the dining halls or the Leaky Beaker to their respective vermicomposting sites. They would then sieve and add the waste, along with fresh bedding, to the Wigwams. These workers or volunteers would also be responsible for checking on the conditions of the worms and helping to keep their environment moist and free of any waste the worms cannot digest. After three to four months of decomposition, the workers would remove the finished compost from the Wigwams and transport it in a college-owned delivery van to the greenhouses and/or any other on-campus site that may use the vermicompost as a soil amendment. We assume that we would use a delivery van that the College already owns. The van most likely runs on diesel and has a fuel efficiency of 10 miles per gallon, or 4.25 km/L (km per L).[10] Every week, the worker would also use the van to pick up a week's worth of recycled newsprint from the *Wellesley News* newsroom and distribute it to each

[5] "Wastes - Resource Conservation: Types of Composting." Accessed May 2013. http://www.epa.gov/waste/conserve/composting/types.htm.
[6] Munroe, Glenn. "Manual of On-Farm Vermicomposting and Vermiculture." Accessed February 23, 2013. http://oacc.info/docs/vermiculture_farmersmanual_gm.pdf.
[7] "Wastes - Resource Conservation: Types of Composting." Accessed May 2013. http://www.epa.gov/waste/conserve/composting/types.htm.
[8] Munroe, Glenn. "Manual of On-Farm Vermicomposting and Vermiculture." Accessed February 23, 2013. http://oacc.info/docs/vermiculture_farmersmanual_gm.pdf.
[9] "The Worm Wigwam." Accessed March 3, 2013. http://www.wormwigwam.com/international_worm_wigwam_manufacturer.html.
[10] "Fuel Economy of 2012 Vans, Cargo Type." Accessed May 2013. http://www.fueleconomy.gov/feg/byclass/Vans__Cargo_Type2012.shtml.

vermicomposting site for that week’s worm bedding. Overall, we assume that the van would travel approximately five kilometers per week.

Operating under our estimate that Wellesley College produces approximately 220 metric tons of food waste annually, the total percentage of food waste diverted annually with the six Worm Wigwams would be 2.61%. Each Worm Wigwam has the capacity to compost seven pounds (3.18 kilograms)[11] of food waste per day for the 225 days of the school year, resulting in approximately 4286.39 kg (4.2864 metric tons) of food waste diverted overall. Because of this low capacity for handling food waste and an inability to handle several types of organic waste (meat, dairy, oil, fatty foods, and compostable dishware), we recommend that the College use vermicomposting primarily for educational purposes and pair it with another waste diversion method capable of processing the bulk of Wellesley’s food waste.

16.2.2 Technology/Equipment

The College would have to purchase six Worm Wigwams in total, along with six gardener’s sieves (one for each of the Wigwams) for sieving the food waste prior to putting it into the Wigwams. Each Wigwam should also be equipped with 10 to 15 lbs. of redworms for a starting population; for our calculations, we assume an average of 12.5 lbs. (5.6699 kg). We assume a lifetime of 10 years each for both the Wigwams and the sieves.[12]

We assume the use of a delivery van that the College already owns, eliminating the need to purchase another vehicle. Paper for the worm bedding should not have to be purchased, as recycled newsprint and possibly computer paper can be used instead. For our calculations, we assumed that solely newsprint would be used.

Collection bins for food waste are common to all methods, and thus are not included in this analysis.

16.2.3 Inputs

Energy
Vermicomposting does not require an energy inputs.

Materials
The Worm Wigwam is made out of UV-stabilized poly resin, with a galvanized steel handle

[11] “The Worm Wigwam.” Accessed March 3, 2013. http://www.wormwigwam.com/international_worm_wigwam_manufacturer.html.

[12] We were unable to find a definite lifetime for the Worm Wigwams. Customer testimonials claim the Wigwams to be long-lasting; WikiHow claims that galvanized tubs can theoretically last forever. Similarly, a galvanized steel sieve would theoretically be able to last for several decades; we account for daily wear by shortening the lifetime to 10 years.
“How to Make Your Own Worm Compost System.” Accessed April 21, 2013. http://www.wikihow.com/Make-Your-Own-Worm-Compost-System.
Langill, Thomas J. “Predicting the service life of galvanized steel.” Last modified May 29, 2003. Accessed April 21, 2013. http://www.thefabricator.com/article/metalsmaterials/predicting-the-service-life-of-galvanized-steel.

crank.[13] We assume that poly resin in this case means polyethylene resin, as it is a commonly used and versatile thermoplastic. The Wigwam weighs 86 lbs., or 39.01 kg;[14] of this, we assume that the galvanized steel crank makes up five kilograms, and that the rest of the weight can be attributed to the polyethylene resin.

To sieve the food, a steel gardener's sieve would work best.[15] We assume that the sieve is made out of galvanized steel, as similar sieves are, but it could also be made out of stainless steel. Assuming the sieve is thirteen inches in diameter, from looking at other sieves of similar sizes, we estimate that one sieve weighs 1.6 lbs., or 0.7258 kg.

For worm bedding, we assume that the recycled newsprint is shredded and moistened. Ideally, there should be a two-to-one ratio of bedding to food waste; for every one kilogram of food waste, we assume two kilograms of newsprint. For moistening the newsprint, we assumed that for every one kilogram of newsprint, one-third of a liter of tap water would be needed; two-thirds liter of water would be used for two kilograms of newsprint.

16.2.4 Outputs

Vermicomposting produces castings and compost tea, both of which can be used as soil amendments. We assume that all vermicompost will be used as a soil amendment on campus. A Worm Wigwam produces about 60 pounds of finished vermicompost per week and has the capacity to process 15 pounds of bedding and waste per day.[16] Taking into account this ratio, one metric ton of food waste, combined with two metric tons of bedding, would produce about 0.6 metric ton of vermicompost.

16.3 Environmental Impacts of Vermicomposting

16.3.1 Collection and Preparation of Food Waste

Energy
No energy is needed for vermicomposting.

Materials
Collection bins are common to all waste diversion methods and have been excluded from this analysis.

Transportation of Food Waste
Every week, we would need to use a delivery van (of less than 3.5 tons) to transport the week's

[13] "Worm Wigwam Advanced Vermiculture System." Accessed March 3, 2013. http://www.compostmania.com/Worm-Wigwam.
[14] "Worm Wigwam Advanced Vermiculture System." Accessed March 3, 2013. http://www.compostmania.com/Worm-Wigwam.
[15] "Steel Compost Sieve." Accessed March 3, 2013. http://www.gardeners.com/Steel-Compost-Sieve/38-995,default,pd.html.
[16] "The Worm Wigwam." Accessed March 3, 2013. http://www.wormwigwam.com/international_worm_wigwam_manufacturer.html.

worth of newsprint bedding to the vermicomposting sites and the finished compost to the greenhouse. We assume a maximum traveling distance of five kilometers.

16.3.2 Process

Materials
We calculated the materials needed to process one metric ton of food waste per day. Vermicomposting would not feasibly be able to process that quantity of food waste on a daily basis, but the unit serves as a measure of comparison across waste diversion methods. Since one Worm Wigwam can take 3.1751 kg (0.003 metric tons) of waste per day, we would need 334 Wigwams for one metric ton of waste. Using 334 Wigwams results in 1670 kg of galvanized steel and 11,359.34 kg of polyethylene resin (since one Wigwam consists of five kilograms of galvanized steel and 34.01 kg of polyethylene resin). Additionally, assuming the lifetime of a Worm Wigwam is 10 years, we divided the materials for 334 bins by 3650 (365 days times 10 years), resulting in 0.46 kg of galvanized steel and 3.11 kg of polyethylene resin per metric ton of food waste per day.

Assuming we need one sieve per Wigwam, we would then need 334 gardener's sieves. Following from this assumption, 242.4172 kg of galvanized steel would be needed for 334 sieves (taking into account our estimate that one sieve weighs approximately 0.7258 kg). We again account for the assumed 10-year lifetime of a sieve by dividing the materials of 334 sieves by 3650 days, resulting in 0.066 kg of galvanized steel.

Because of the two-to-one ratio of bedding to food waste, one metric ton of waste would require two metric tons of newsprint. Two metric tons of bedding would require 666.67 liters of tap water to be adequately moistened.

Energy
No energy is needed for vermicomposting.

16.3.3 Avoided Impacts

Although castings from vermicomposting would be able to be used as a soil amendment on campus, we assume that vermicompost would not offset any fertilizer currently used at Wellesley.

16.3.4 Water Use

This method would require 666.67 liters of tap water to moisten the two metric tons of newsprint bedding required to process one metric ton of food waste. Additional water would also be needed to keep the bedding moistened every day. Due to uncertainty of how much water would be needed due to variable conditions, however, we did not take this water use into account.

16.3.5 Summary: Life Cycle Impacts and Assessment of Vermicomposting

We break down the environmental impacts of vermicomposting into the following process stages: method operation, materials, and transportation. For climate change, human health, and ecosystem toxicity, the method operation stage contributes the greatest impact (Table 16-1, Figures 16-2 to 16-5. Impacts are highest for the method operation stage due to the required daily newspaper input for bedding. The materials category do not have a higher impact because the environmental impacts of the bins are divided by the bins' assumed 10-year lifespan. There is a negligible total environmental impact from transportation. Overall, vermicomposting impacts ecosystem toxicity the most, followed by climate change.

Table 16-1: Environmental impacts by process stage, vermicomposting.

Impact category	Units	Method	Materials	Transportation	Total
Climate Change	kg CO2 eq	1.69E-02	7.39E-05	8.54E-05	1.71E-02
Human Toxicity	kg benzen eq	1.03E-04	9.51E-07	4.33E-07	1.04E-04
Ecosystem Toxicity	kg 2,4-D eq	1.20E-01	-5.65E-07	2.92E-05	1.20E-01

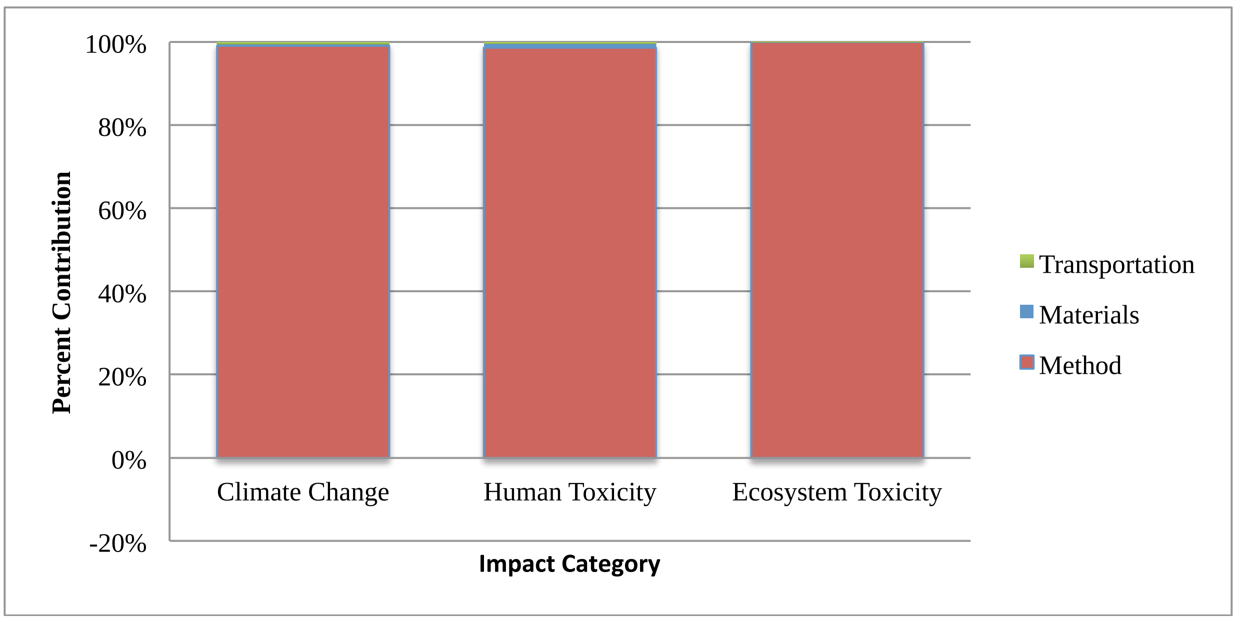

Figure 16-2: Percent contribution of process stages to each impact category

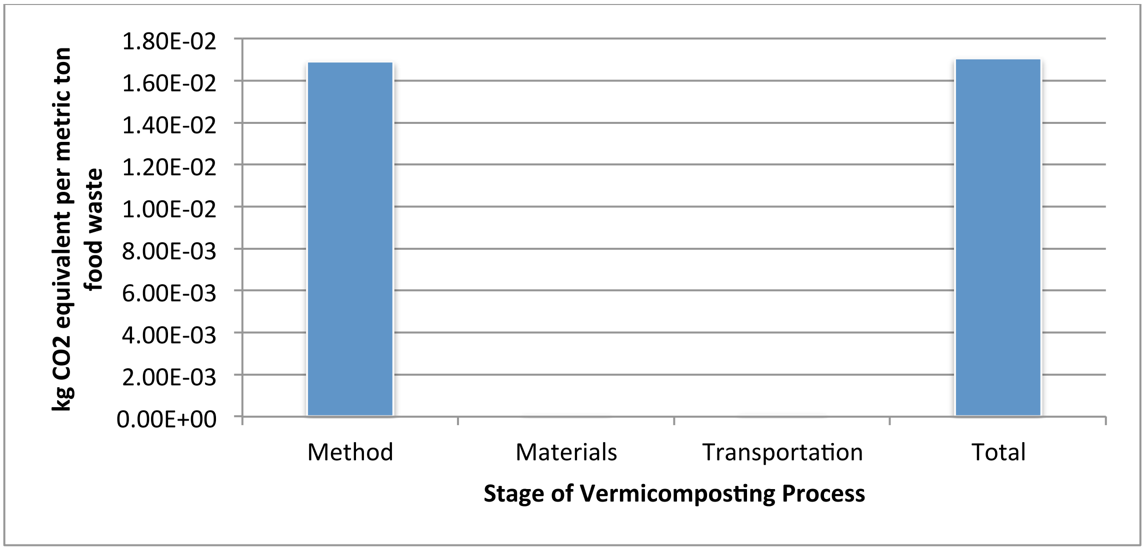

Figure 16-3*:* Climate change impact of each process stage

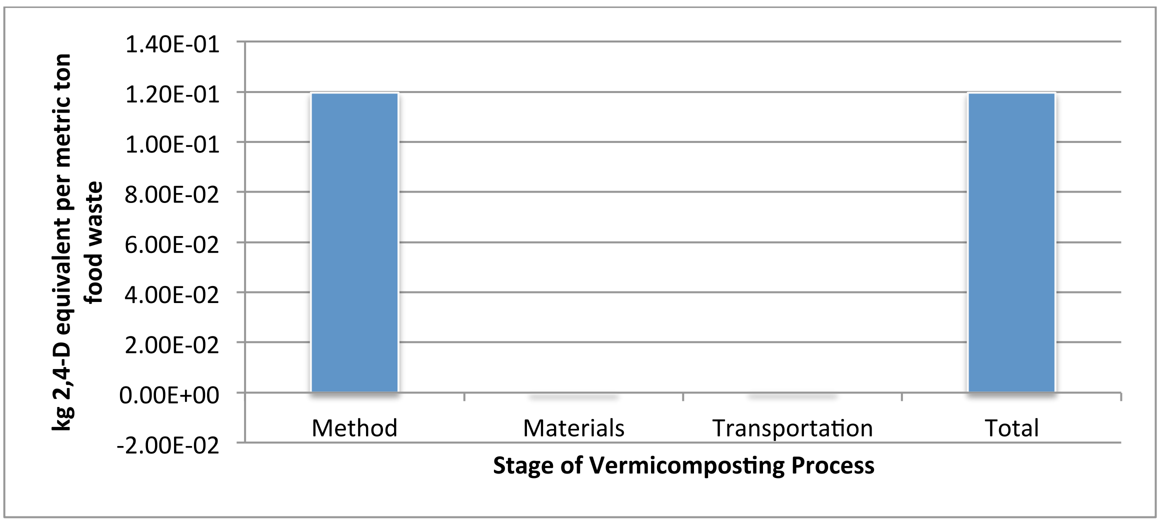

Figure 16-4: Human toxicity impact of each process stage

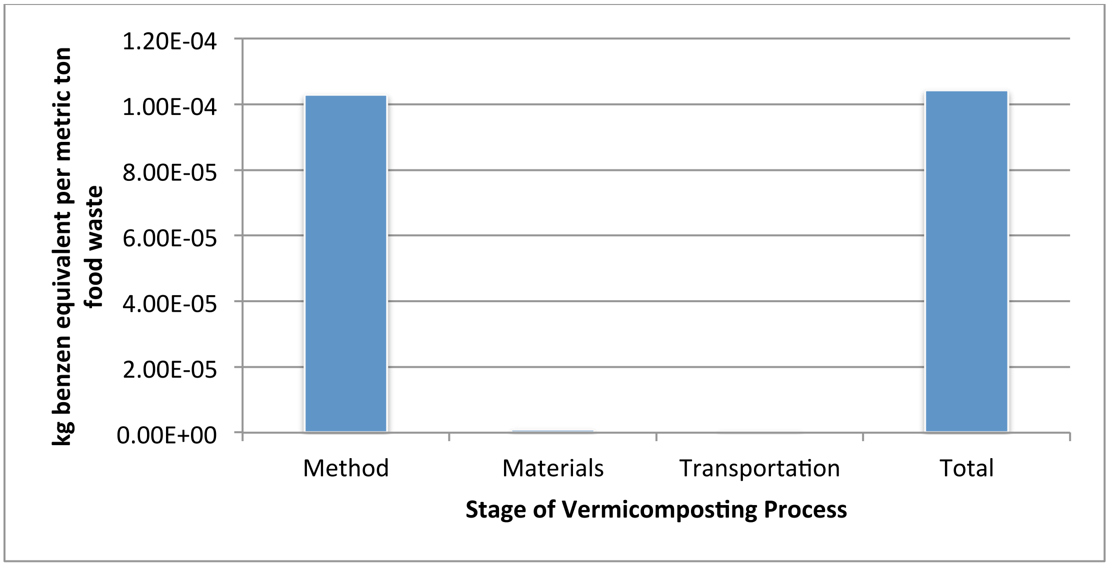

Figure 16-5: Ecosystem toxicity impact of each process stage

Table 16-2: Total environmental impacts,

Impact Category	Unit	Total Impacts
Climate Change	kg ton CO2 eq	1.71E-02
Human Health	kg ton benzen eq	1.04E-04
Ecosystem Toxicity	kg ton 2,4-D eq	1.20E-01

After analyzing the environmental impacts for each life cycle stage, we conclude that the method stage of vermicomposting has the most significant environmental impact. This analysis accounts for most of the climate change, ecosystem toxicity, and human toxicity impacts. The transportation and the materials needed for vermicomposting show overall minimal environmental impact. The effect vermicomposting has on human toxicity is considerably minimal.

Environmental impacts are abnormally low because we assume a lifetime of 10 years for both the vermicomposting bins and sieves. The newspapers and amount of gasoline used to travel a maximum distance of five kilometers also have relatively low environmental impacts.

The environmental impacts of vermicomposting at a scale that is most feasible for the College would be even lower, since the vermicomposting method is not intended to process one metric ton of Wellesley's food waste per day. In summary, the calculations, although relatively low, are standardized and do not reflect the actual implementation impacts on Wellesley College campus. Table 16-2 sums the total environmental impacts for each environmental impact category.

16.4 Costs of Vermicomposting

16.4.1 Direct Cost

Tipping Fees

Vermicomposting would be conducted entirely on campus, so there would be no tipping fees.

Trucking Fees
Vermicomposting would be conducted entirely on campus, so there would be no trucking fees.

16.4.2 Operational Cost

Summing the transportation, labor, energy, and other operational costs, the total operational cost for one metric ton of food waste per day would be $4,477.59. For one bin (0.003 metric ton of food waste per day), the operational cost would be $79.70.

Transportation Cost
A Wellesley College facilities delivery van would travel an average of five kilometers per week to transport the two metric tons of recycled newsprint and the 0.6 metric ton finished compost. We assume that the delivery van runs on diesel gas, which costs $4.00 per gallon, or $1.06 per liter.[17] We estimate that the van has a fuel efficiency of 10 miles per gallon, or 4.25 km per liter.[18] Therefore, it would cost $1.25 to travel five kilometers per week.

Transportation cost per week
= 5 km/week * (L/4.25 km) * ($1.06/L) = $1.25/week

This comes to $0.18 per 0.003 metric tons of food waste per day, or $60.12 per metric ton of food waste per day.

Labor Costs
We assume that six workers would be hired to oversee the vermicomposting process: one in each of the five dining halls, and one at the Science Center. At the end of a work day, a worker in each of these areas would take one hour to separate a portion of food waste from the dining hall or Leaky Beaker's daily waste, sieve the waste into the worm bin, prepare and add new worm bedding if needed, and check the worm bin for proper soil temperature, moisture, and aeration. Every week, one worker would take an additional three hours to remove the finished vermicompost from the six locations, transport it to the greenhouses or grounds department, collect a week's worth of recycled newsprint from the *Wellesley News* newsroom, and deliver the newsprint to the six worm bin sites.

The workers could be dining hall delivery workers specifically assigned to vermicomposting, or student dining hall workers. Ideally, academic classes and student organizations would regularly monitor the vermicomposting process. The hourly wage for dining hall delivery workers is $24.16, and $9.00 per hour for student dining hall workers.[19] To reduce labor costs, we assume five student dining hall workers and one delivery dining hall worker would be employed. The delivery dining hall worker would transport the finished compost, collect the worm bedding, and oversee the six vermicompost sites. Operating six Worm Wigwam worm bins every week would

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[17] Willoughly, Patrick, Wellesley College Director of Sustainability. ES 300, 2013. March 6, 2013.
[18] "Fuel Economy of 2012 Vans, Cargo Type." Accessed May 2013. http://www.fueleconomy.gov/feg/byclass/Vans__Cargo_Type2012.shtml.
[19] Willoughly, Patrick, Wellesley College Director of Sustainability. ES 300, 2013. March 6, 2013.

cost $63.00 for each of the five student dining hall workers and $169.12 + 72.48 (for collection and delivery) = $241.60 for a delivery dining hall worker. This totals $556.60 in payment to workers per 0.126 metric tons of food waste per week. Per day, the average payment is $13.25 per 0.003 metric tons of food waste, or $4,417.46 per metric ton.

Energy Costs
There are no energy costs associated with vermicomposting.

Other Operational Cost
The only other operational cost associated with vermicomposting is water use. For one metric ton of food waste, 666.67 liters per metric tons of water would be used to moisten worm bedding. Water treatment costs $0.00001984 per liter of water for Wellesley College.[20] Therefore, for one metric ton of food waste, the water cost is $0.01. The water cost is negligible for 0.003 metric tons of waste.

16.4.3 Equipment

The product price of one Worm Wigwam worm bin (with a one-year warranty) is $635.00. The shipping fee for the Worm Wigwam is $99.00.[21] The total equipment cost would be $734.00. The implementation cost of six Worm Wigwams would be $4,404. Implementation of the 334 Wigwams needed to compost one metric ton of food waste per day would cost $245,146. Taking into account an assumed lifetime of 10 years for a Worm Wigwam, the final cost for these 334 Wigwams per metric ton of waste per day would be $67.16.

One steel gardener's sieve would be purchased for every one Worm Wigwam bin. The product price of a steel gardener's sieve is $19.95 and the shipping price is $7.95, totaling $27.90.[22] Six worm bins need six sieves, totaling $167.40. Processing one metric ton of food waste per day would require 334 sieves, totaling $9318.60. Factoring in a lifetime of 10 years per sieve, the final cost for these 334 sieves would be $2.55 per metric ton of food waste per day.

Redworms can be purchased at the bulk price of $26.50 for 0.45 kg of worms, with $11.00 for shipping, totaling $37.50.[23] The recommended starting population for one Wigwam is 12.5 lbs. (5.6699 kg); 13 bags of worms would be needed per bin, at a cost of $487.50. For one metric ton of food waste per day, the total redworm cost would be $162,825. A population of red worms doubles every three to four months.[24] If we were to choose the most cost-efficient method, we would implement a new worm bin every three to four months after a worm population doubles, such that the cost for worms for six bins would still be $487.50. With this assumption, processing one metric ton of food waste would cost only $487.50 for worms.

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[20] Willoughly, Patrick, Wellesley College Director of Sustainability. ES 300, 2013. March 6, 2013.
[21] "Worm Wigwam Advanced Vermiculture System." Accessed March 3, 2013. http://www.compostmania.com/Worm-Wigwam.
[22] "Steel Compost Sieve." Accessed March 3, 2013. http://www.gardeners.com/Steel-Compost-Sieve/38-995,default,pd.html.
[23] "Composting Redworms." Accessed March 24, 2013. http://www.compostmania.com/Composting-Redworms-Eisenia-fetida-1-lb.
[24] "Composting Redworms." Accessed March 24, 2013. http://www.compostmania.com/Composting-Redworms-Eisenia-fetida-1-lb.

The total equipment cost for the operation of one bin (with 0.003 metric ton of food waste per day) would be $488.68, and the total equipment cost for one metric ton of food waste per day would be $162,894.71.

16.4.4 Offset Cost

There are no offset costs associated with vermicomposting.

16.4.5 Summary: Cost of Vermicomposting

Table 16-3: Cost of vermicomposting for one metric ton of food waste.

Cost Category		Amount ($/metric ton)
Direct:		
	Facilities	$0.00
	Transportation	$0.00
Operational:		
	Transportation	$60.12
	Labor	$4417.46
	Energy	$0.00
	Other	$0.01
Equipment		$162,894.71
Total Cost		$167,372.29

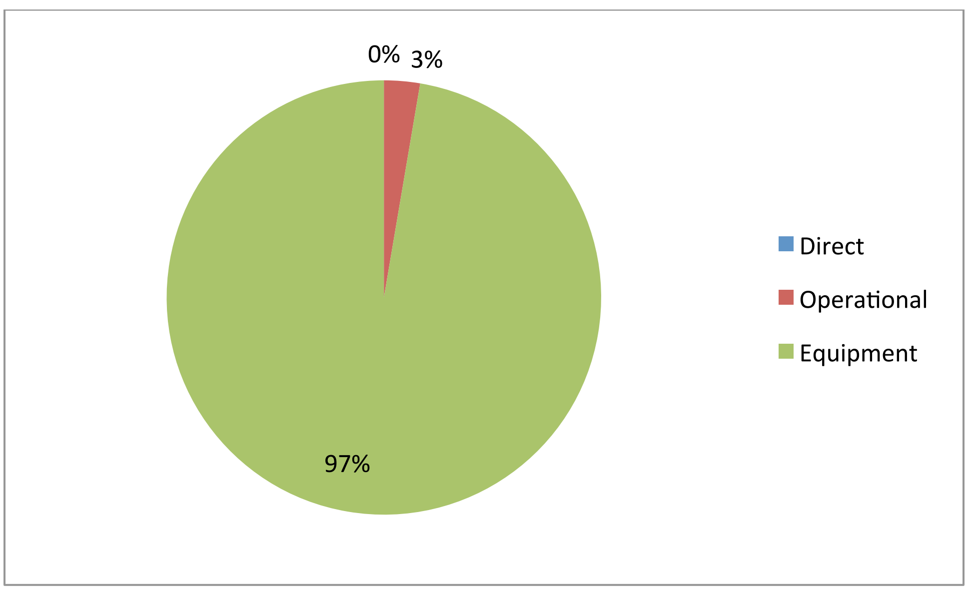

Figure 16-6: Cost of vermicomposting.

As shown in Table 16-3, the total cost of processing one metric ton of food waste per day with vermicomposting would be $167,372.29. As shown in Figure 16-6, direct costs account for 0%, operational costs for 3%, and equipment costs for 97% of total costs.

The equipment cost is the highest because we take into account shipping fees and because we calculate the processing of one metric ton of food waste per day. If we were to process one metric ton of food waste over a period of time, the equipment could be reused so that the cost would be substantially lower. Again, the vermicomposting method is not intended to process one metric ton of food waste per day, or even divert a significant portion of Wellesley's organic waste. For actual implementation (in which we would use six worm bins instead of 334), equipment costs would be significantly lower.

16.5 Social Impacts of Vermicomposting

16.5.1 Campus Experience - Positive

Vermicomposting would contribute to a positive campus experience. Although the Worm Wigwam may not necessarily be visually appealing, it can serve as a source of pride. If placed in the Science Center, it would be easily visible and accessible, providing a concrete example of composting on-campus. The end product (the castings and compost tea) would help contribute to the campus's landscape.

Additionally, because the composting process is contained entirely within the Worm Wigwam, there would be no odor or pest problems. Odor would only arise due to human error within the vermicomposting process, such as through the use of overly wet bedding, the addition of meat or dairy waste, the addition of too much food waste, or the occurrence of acidic or anaerobic conditions. Regardless of these problems, the odor would still be contained within the bin. Placing the Wigwams indoors further protects their contents from pests such as centipedes, ants, and earthworm mites; if the food waste and bedding are layered as instructed, then flies, including fruit flies, should not pose a problem.[25]

16.5.2 Educational Benefit - Positive

Vermicomposting on campus would offer new academic opportunities and visibility, giving it a high educational rating. Placing a Worm Wigwam in the Science Center would allow science classes, especially environmental studies and biology classes, to easily access it and integrate it into their classroom experience. Vermicomposting is a common project in schools that want to educate their students about sustainable initiatives.[26]

Ideally, students would have the opportunity to interact with the Worm Wigwams outside of class as well. Although trained workers would be responsible for sieving and adding food to the Wigwams and maintaining them daily for the sake of consistent care, we recommend that other students, especially those involved with environmental organizations on-campus, will also volunteer to help with the process. It would be easy for students to participate in any stage of the process, from separating the food waste to cranking out the castings when ready.

[25] "Troubleshooting Problems with Worm Bins." Accessed March 10, 2013. http://compostmania.com/blog/troubleshooting-problems-with-worm-bins/.
[26] Water Quality & Waste Management." Accessed March 10, 2013. https://www.bae.ncsu.edu/topic/vermicomposting/pubs/worms.html.

16.5.3 Implementation Difficulty

Separation - High
Redworms should not be fed meat (including fish), dairy products, bones, or fatty or oily foods. These restrictions make food separation for vermicomposting a stringent process.[27]

Permitting and Regulations - Medium
No permits are required for vermicomposting in the state of Massachusetts, although, as with all composting methods, the Massachusetts Department of Environmental Protection (MassDEP) requires an annual compost site report.[28] It is possible that the College may experience health regulation issues if mistakes are made during the vermicomposting process: food contamination or too much food waste can cause the worms to die and odor to arise (although both situations would still be contained within the Wigwam and would not spread). Flies may be attracted to the Wigwam if it is not shut and if the bedding is not layered on top of the food waste properly.[29]

Time Until Implementation - Medium
Although vermicomposting would be relatively easy and quick to implement, it would not be immediate. The Worm Wigwams need to be purchased, delivered, and set up, and workers need to be trained on food separation and the vermicomposting process.

Risk - Low
The risk of contamination of worm-friendly food waste by other food wastes is low. The food waste will be sorted prior to being transported to the worm bins, such that the probability of contamination will be little to no frequency. In the case that contamination does occur, the daily maintenance checks will lower the risk of any severe negative impacts (such as the death of the redworms).

16.5.4 Social Justice - Neutral

Ideally, a vermicomposting system should pose no labor problems; if the workers do as instructed, then there is little human risk. Having the bins indoors as opposed to outdoors minimizes the chance of invasion by outside pests and insects. People who are allergic to mold spores or fungi should avoid working with the Worm Wigwams, or contact their physician for further instructions.[30]

16.5.5 Summary: Social Impacts of Vermicomposting

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[27] North Carolina State University Department of Biological and Agricultural Engineering. "Water Quality & Waste Management." Accessed March 10, 2013. https://www.bae.ncsu.edu/topic/vermicomposting/pubs/worms.html.
[28] MassDEP. "Composting & Recycling Facility Annual Reporting." Accessed March 10, 2013. http://www.mass.gov/dep/recycle/approvals/dswmpu03.htm.
[29] CompostMania. "Troubleshooting Problems with Worm Bins." Accessed March 10, 2013. http://compostmania.com/blog/troubleshooting-problems-with-worm-bins/.
[30] CompostMania. "Troubleshooting Problems with Worm Bins." Accessed March 10, 2013. http://compostmania.com/blog/troubleshooting-problems-with-worm-bins/.

Table 16-4: Social impacts of vermicomposting.

Social Impact		Score
Campus experience		Positive
Educational benefit		Positive
Difficulty:		
	Separation	High
	Permitting and regulations	Medium
	Time until implementation	Medium
	Risk	Low
Social justice		Neutral

As seen in Table 16-4, the highest social cost comes from the food separation process. Worms cannot digest meat and dairy, fats and oil, and compostable dishware, so separating these things out is vital. Sorting out the vegetative food scraps is not inherently difficult, but is difficult due to the wide range in food scraps. Food separation may be significantly easier at the vegetarian-only dining hall, Pomeroy.

16.6 Conclusions

Although it is a relatively quick, low-cost, low-risk, and uncomplicated method of composting, vermicomposting would be best implemented as an educational method at a small scale. The worms are not able to process certain categories of food (meat and dairy, bones, oil, and fatty foods). Our Life Cycle Assessment shows the processes associated with operating the vermicomposting units have the greatest negative environmental impacts.

Vermicomposting would allow students to get involved with all stages of the composting process: food separation, sieving the food waste for the worms, preparing and layering bedding, and separating the finished compost from the worms and the waste. When implemented on-campus, vermicomposting presents a concrete, educational, and accessible example of Wellesley's dedication to food waste diversion.

17.0 Methods Conclusions

We take a holistic approach to evaluate the impacts of the twelve food waste diversions methods examined in this report. We compare all of the methods across the three impact categories: environmental, cost, and social impacts. We study each method to determine the range of environmental impacts, the costs per metric ton of food waste processed with each of the methods, and the amount of social impacts. We determine the best and the worst method options in each of the three categories.

We highlight the best options when considering combined environmental, cost, and social impacts, as this the College decisionmaking process (Figure 17.1). It is likely that the College will implement food waste diversion options that balance environmental with cost and social impacts. Determining the diversion methods that are best in all three categories is in line with a broad consideration of sustainability. In order to compare our methods across all evaluated metrics, we create a system of aggregating the results from our three impact category analyses.

Figure 17-1: Balance of cost, environmental, and social impact category evaluations. Our meta-conclusions across methods will look for the best options that lie at the center of this diagram, and balance impacts in all three categories.

17.1 Environmental Impacts

This section assesses the environmental impacts of the twelve food waste diversion methods evaluated in this report. For each of the environmental impacts considered – climate change, human health, and ecotoxicity – we identify the most environmentally sound methods, the source of the environmental impact, and methods to mitigate these impacts. Though not included in our Life Cycle Assessment results from SimaPro, we also compare the water use requirements per metric ton of food waste processed with each method. The assessment of such impacts is a critical component of decisionmaking.

The cost and social impacts of each method also require evaluation, yet we do not recommend a method that causes environmental harm at a low financial cost. Wellesley College's

Sustainability Statement, adopted in 2007, additionally asserts a commitment to the consideration of sustainability in its decisionmaking processes.

17.1.1 Methodology

For each method, we assessed the environmental impact on climate change, human health, and ecosystem health (ecotoxicity) per metric ton of food waste diverted. These impacts are measured in kilograms of carbon dioxide equivalents, kilograms of benzene equivalents, and kilograms of 2,4-Dichlorophenoxyacetic acid (2,4-D) equivalents, respectively. We conducted three analyses in order to assess which methods had the lowest environmental impact in each category.

Since climate change, human health, and ecotoxicity are all measured in different units, we first created a point system in order to analyze the three impacts with a common unit of measurement. This point system was used to aggregate the three environmental impact categories, and compare overall impact scores across methods. The process of creating a point system involved dividing each of the values in each impact category (climate change, human health, and ecotoxicity) by the United States' total impact in that category over one year.[1] We multiplied these very small values by one trillion so that the values of the resulting "points" were comprehensible. This system, known as normalizing, is standard practice in Life Cycle Assessments.

For the second environmental impact comparison, we add the points from each category (climate change, human health, and ecotoxicity), weighting each of the three factors equally. We used this environmental impact point comparison to draw preliminary conclusions about the methods and form initial recommendations for Wellesley College.

Finally, for all methods considered that require freshwater inputs, we compared the water required to process one metric ton of food waste. It is important to note that we compared the water requirements of these methods on a log scale.

17.1.2 Environmental Impacts Comparisons

Climate Change

Greenhouse gas (GHG) emissions contribute to and increase the rate of global climate change. Greenhouse gas emissions are a global environmental concern, and have received increased attention in recent decades. A waste diversion method with high CO_2 equivalents will force negative environmental impacts and produce effects that would be felt by ecosystems and individuals beyond the scope of the college. We strongly urge Wellesley College to limit its carbon footprint by implementing a method with a low environmental impact on climate change.

[1] Product Ecology Consultants, "SimaPro Database Manual, Methods Library," Accessed April 2013 http://www.pre-sustainability.com/download/manuals/DatabaseManualMethods.pdf.

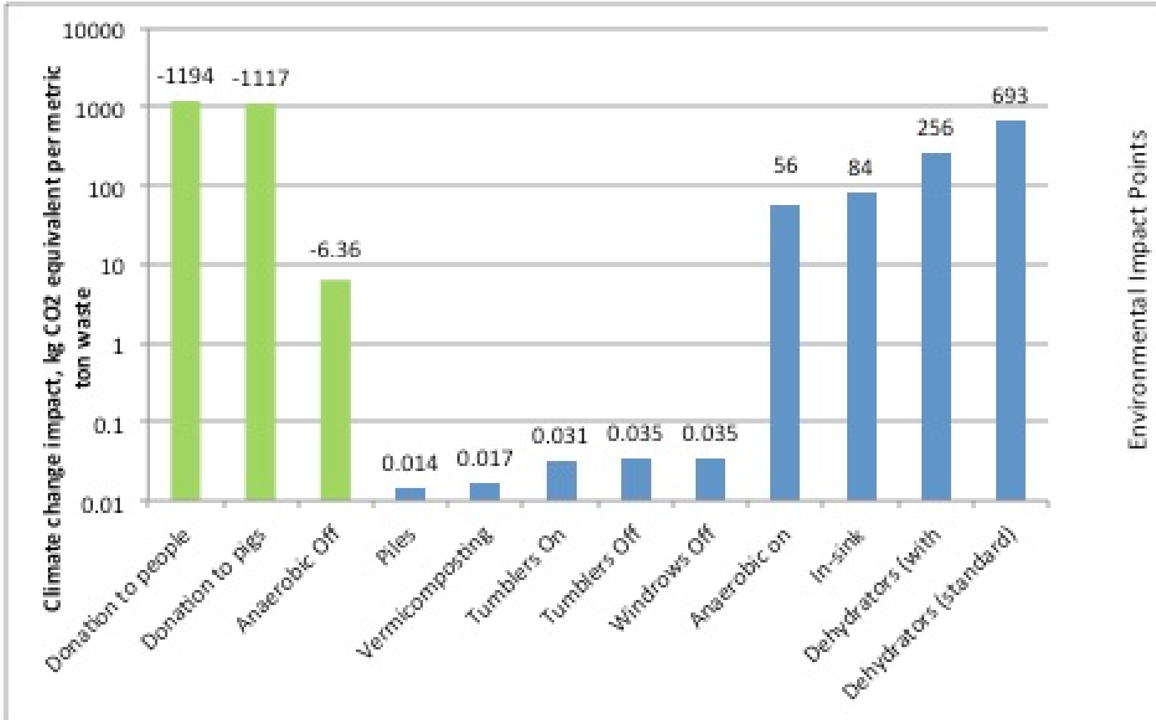

Figure 17-2: Environmental impact on climate change (in kg CO_2 equivalent), per metric ton of food waste processed by each waste diversion method. The graph also indicates the environmental impact point scoring for each method.

Figure 17-2 shows the climate change impact in kilogram of carbon dioxide equivalent per metric ton of food waste. The primary source of greenhouse gas emissions in the waste diversion methods we considered results from transportation and disposal methods. All of the proposed methods of organic waste diversion at Wellesley College have negative environmental impacts on climate change, except for donation to pigs, donation to humans, and anaerobic digestion off campus. The net positive climate change impact from donation may come as a surprise. While there are GHG emissions from the transportation of food to donation sites, these emissions are offset by the avoided impacts that would have resulted from food production if this food were not sourced via donation. Anaerobic digesters off campus have a beneficial impact due to the associated production of biogas. The biogas is used to produce electricity, which offsets GHG emissions that from burning fossil fuels. Piles off campus, tumblers off campus, and windrows off campus all have a relatively low impact on climate change.

There are strategies to decrease the climate change impacts of the methods considered in the repot. Reductions are primarily possible through changes in transportation for each method, which results in the greatest contribution of GHG emissions for most methods. Currently, the trucks used to divert food waste or transport food donations have a very low gas mileage – assumed at a fuel efficiency of nine miles per gallon, across most methods. Finding a more fuel-efficient method of transportation would drastically reduce climate change impacts for all off-campus diversion methods. Reductions through on-campus efficiency increases would be smaller than increasing off-campus efficiency because transportation for on-campus methods is limited to pick-up of waste from collection sites.

Human Health

Each diversion method can impact human health through the exposure to carcinogens during equipment manufacture, transportation, and operation. Figure 17-3 shows the environmental impact to human health in kilograms of benzene equivalent per metric ton of food waste diverted. In addition to causing cancer, long-term exposure to benzene can cause significant reproductive and developmental damage.[2]

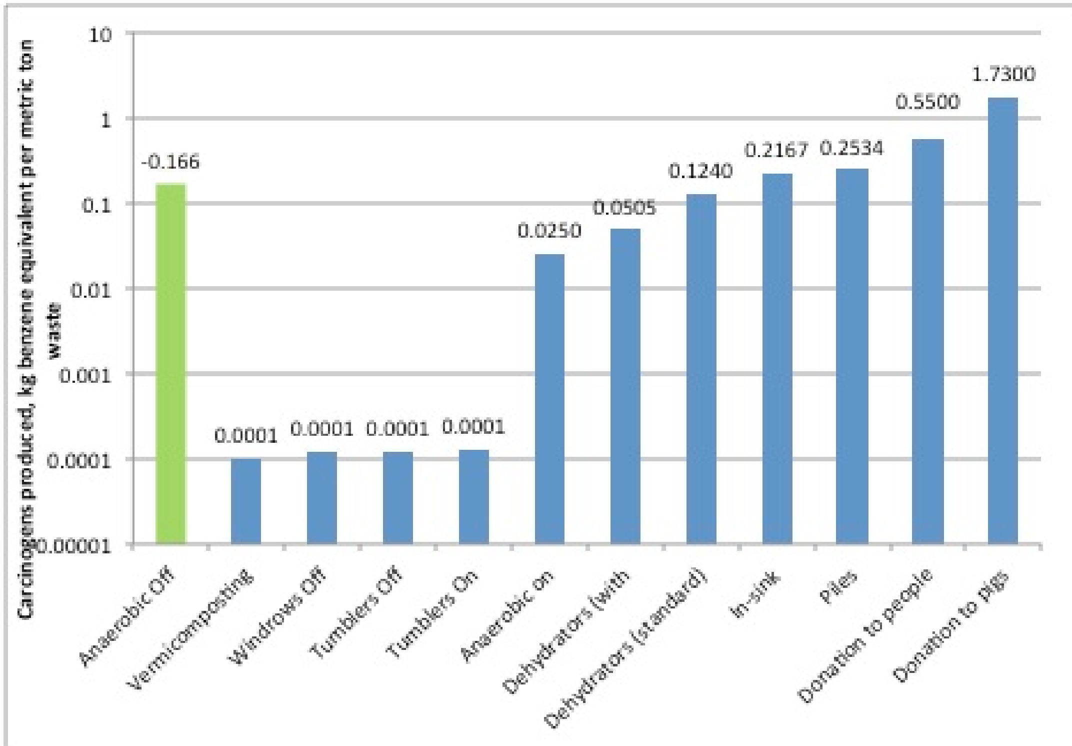

Figure 17-3: Environmental impact per metric ton of food waste on human health (in kg benzene equivalent) by organic waste diversion method.

The method with the highest contribution of carcinogens is donation to pigs. The pig farm that we evaluated in the report burns wood to boil food waste prior to feeding it to their pigs. This process releases harmful carcinogens and other toxins. Donation to people has the second largest impact on human health. In this method, aluminum pans are required to package the donated food. Significant levels of carcinogens are released when the aluminum for the production of these pans is produced. Methods with the least negative impacts to human health include vermicompostng, windrows off campus, and tumblers off and on campus.

If the primary concern for the college were human health, we recommend that Wellesley College implement anaerobic digestion off campus as its primary waste diversion method. Off-campus anaerobic digestion is the only method with a beneficial environmental impact in the human health impact category. While carcinogens are released during the construction of the digester and during its operation, this environmental impact is offset by the production of fertilizer and

[2] EPA, "Benzene," *Toxic Transfer Network*, accessed April 10, 2013. http://www.epa.gov/ttnatw01/hlthef/benzene.html.

biogas. The release of carcinogens to produce an equal volume of chemical fertilizer and electricity is higher than the environmental impact of the method.

Since carcinogens frequently stem from the equipment manufacturing processes for these methods, it would be difficult to reduce the environmental impacts to human health. Alternative options could be explored, such as different boiling methods with the donation to pigs method, or substitutes for problematic materials, such as with the donation to people method.

Ecotoxicity

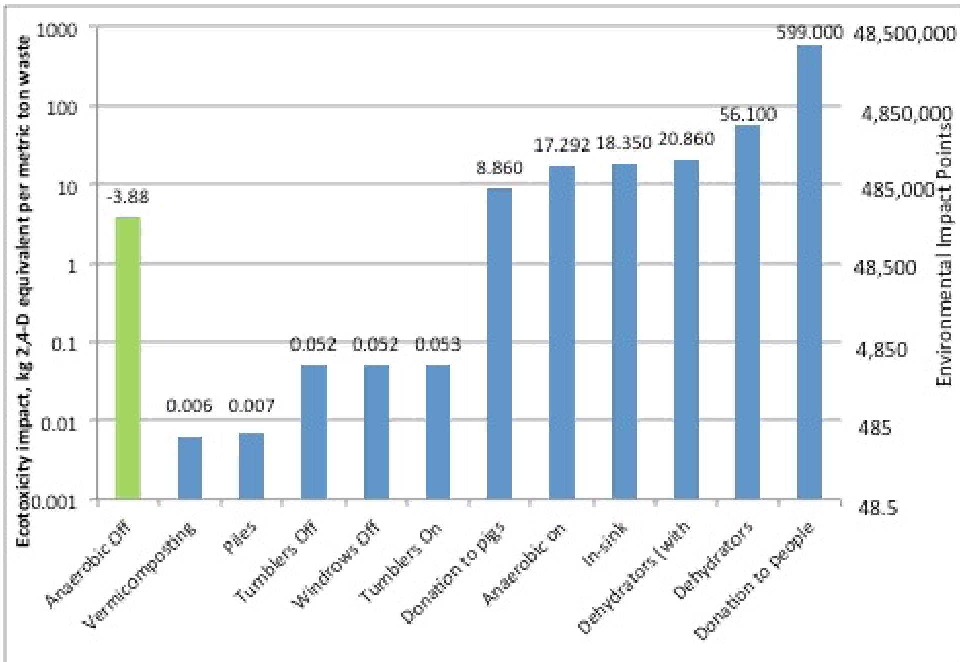

Figure 17-4: Environmental impact on ecotoxicity (in kg 2,4-D) per metric ton of food waste diverted, by organic waste diversion method.

All the proposed methods of organic waste diversion have an impact on ecosystem toxicity, or ecotoxicity. These impacts are measured and reported in kilograms of 2,4-Dichlorophenoxyacetic acid (2,4-D) equivalent. 2,4-D is an ingredient commonly found in pesticides and herbicides. Studies have shown that exposure to 2,4 D can result in blood, liver, and kidney toxicity. Chronic exposure to this compound can adversely affect the eyes, thyroid, kidney, adrenal gland, and ovaries or testes. Studies indicate that chronic exposure can lead to delayed neurobehavioral development and prolonged exposure can be extremely harmful to children.[3]

Figure 17-4 shows the ecotoxicity impact in kilograms of 2,4-D equivalent. The processes within each method that have the highest impacts on ecosystem health often include transportation and energy generation, though other contributions to ecotoxicity may include groundwater

[3] EPA, "2,4-Dichlorophenoxyacetic acid (2,4-D) Chemical Summary," *Toxicity and Exposure Assessment for Children's Health*, EPA, Accessed May 2013, http://www.epa.gov/teach/chem_summ/24D_summary.pdf.

contamination by leachates, emissions from energy generation, and land use changes from resource extraction.

The methods with the highest contribution to ecotoxicity include donation to people and dehydration. Methods with the lowest impacts include anaerobic digestion off campus, vermicomposting, piles off campus, tumblers on and off campus, and windrows off campus. Anaerobic digestion off campus is the only method with an ecotoxicity impact below zero, as the ecotoxicity impact of equipment manufacturing and powering the digester is offset by biogas production.

Transportation and energy generation are the processes that contribute the most to ecosystem toxicity. We suggest modifying these processes to decrease overall impacts in ecotoxicity. Changing energy generation from non-renewable energy to renewable energy sources for off-campus methods would greatly reduce the associated impacts. For off-campus methods, using alternate transportation options could lower the ecosystem toxicity impact. Decreasing the distance traveled during collection and travel time to off-campus facilities would also improve ecosystem impacts.

Water Use

Some of our proposed waste diversion methods use large volumes of water. Generally, the environmental impacts of water use are not as high a priority as other environmental impacts, given the ease of access and the availability of clean water in Massachusetts. The College would face a low risk of aquifer depletion even if an organic waste diversion method requires high water use, but water conservation is currently one of Wellesley's primary sustainability goals.[4] Choosing a diversion method with low water requirements will help the College comply with this goal. Though we generally advocate following the ethic of conservation, we recognize that this environmental factor is not as important as the other three.

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[4] Office of Sustainability, Wellesley College "Current Goals," Accessed April 22, 2013. http://web.wellesley.edu/adminandplanning/Sustainability/.

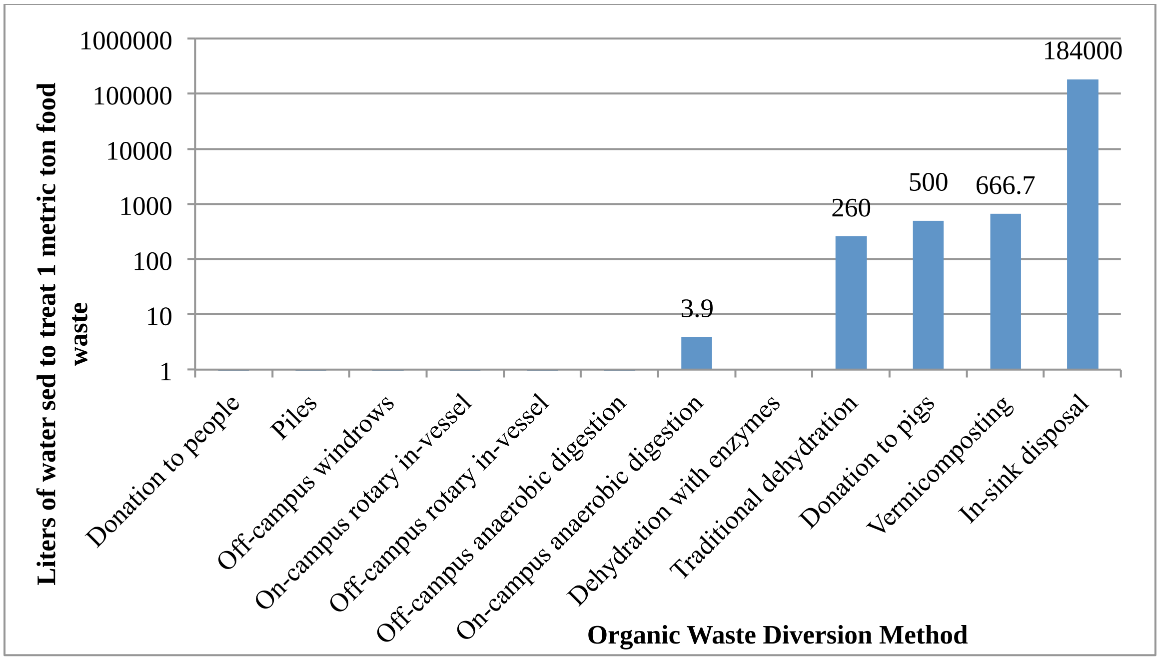

Figure 17-5: Water use (in liters) per metric ton of food waste diverted

Figure 17-5 shows the liters of water used to process one metric ton of food waste, across all diversion methods. The waste diversion with the highest water use is in-sink disposal, as the process involves flushing food scraps down the sink and blending them with enough water that they can be sent with the rest of the College's wastewater to the MWRA treatment plant at Deer Island, Massachusetts.

If the College cares primarily about the environmental impacts of water use, the College would pursue diversion methods that have negligible water use. These methods include donation to people, piles off campus, windrows off campus, tumblers on and off campus, anaerobic digesters on and off campus, and dehydrators with enzymes. Donation to people, piles off campus, windrows off campus, and tumblers on and off campus require no freshwater inputs.

Anaerobic digestion requires freshwater inputs to dilute the food waste, such that the mixture is comprised of approximately 12% solids. At the end of the digestion process, this water is separated from the sludge and circulated back into the tank. The environmental impact for water use is negligible for off-campus anaerobic digestion. For on-campus anaerobic digestion, the digester would be filled with the requisite volume of water following construction. This water would then be cycled through the system continually.

For methods that do not require water inputs or require a negligible amount, water use reduction strategies are not needed. It would be difficult to reduce water use for the methods that require high water inputs. Donation to pigs, for example, requires a high water input in order to boil the food scraps. For large-scale vermicomposting, water is necessary to keep the newsprint worm bedding moist. In-sink disposal is the only method where water reductions are feasible. The machine could be run only at the end of mealtimes instead of throughout mealtimes, ensuring that a minimum amount of water is used to process via in-sink disposal.

17.1.3 Environmental Impacts Conclusions

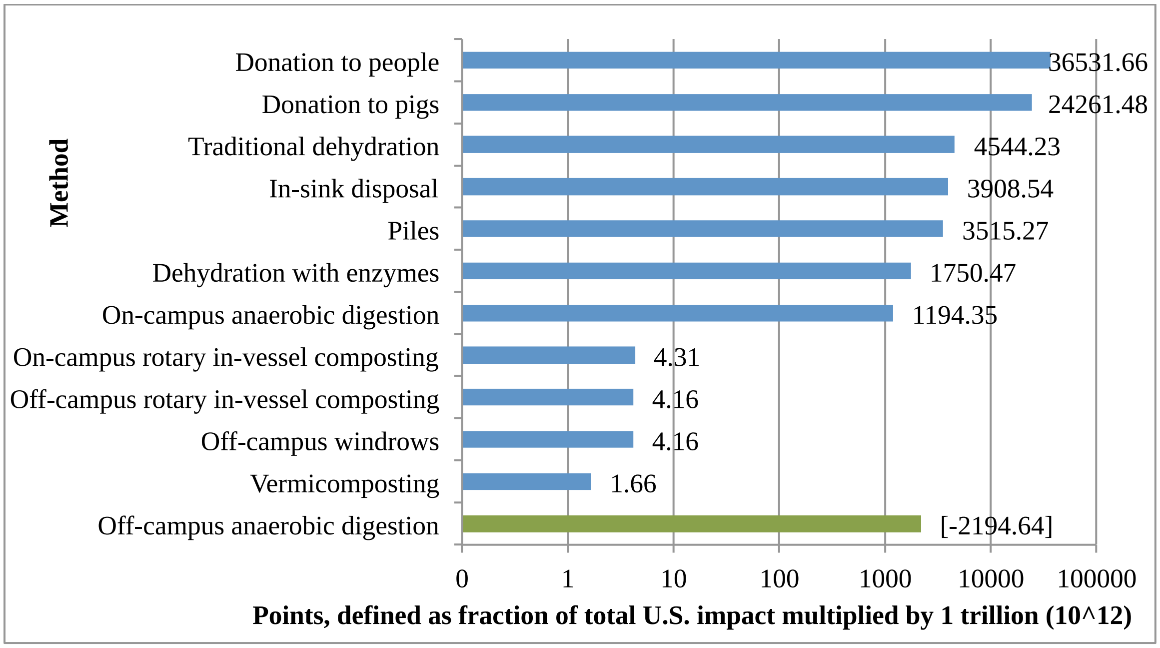

Figure 17-6: Normalized Comparison of Waste Diversion Methods, in point system

To assess the combined environmental impacts, we assemble a graph that gathers each set of impacts into one comprehensive, normalized display (Figure 17-6). This graph assumes that all environmental impacts are valued equally, which may not be the case. Donation to pigs and donation to people have significant environmental impacts due to their ecotoxicity, human health, and water use implications. Tumblers and windrows perform particularly well across all environmental categories. Anaerobic digesters off campus have a positive impact on the environment.

If environmental impacts were Wellesley's primary consideration, we would recommend anaerobic digestion off campus, vermicomposting, windrows off campus, and tumblers off campus. It is important to note that there are two other impact categories – cost and social cost – that are significant factors in our recommendations. Thus, while we can identify methods with minimum environmental impact, we cannot make a conclusive recommendation until all three categories have been carefully weighed.

17.2 Cost Analysis

Financial impacts will be a factor in Wellesley College's choice of food waste diversion method. In addition to the initial implementation investment, Wellesley must consider the long-term costs of each method. The College must ensure that the method is financial sustainability and will not jeopardize the phenomenal educational and financial assistance that it offers women from around the world.

The costs to Wellesley for diverting one metric ton of food waste range from $85 (off-campus anaerobic digestion) to $167,372 (vermicomposting). For the purpose of this study, we assume that vermicomposting and donation to people would not be able to account for 100% of Wellesley's organic waste and would need to be implemented in combination with other programs. Figure 17-7 shows the comparative costs of all organic waste diversion methods (excluding vermicomposting). The average cost across all of organic waste diversion methods included is $712.

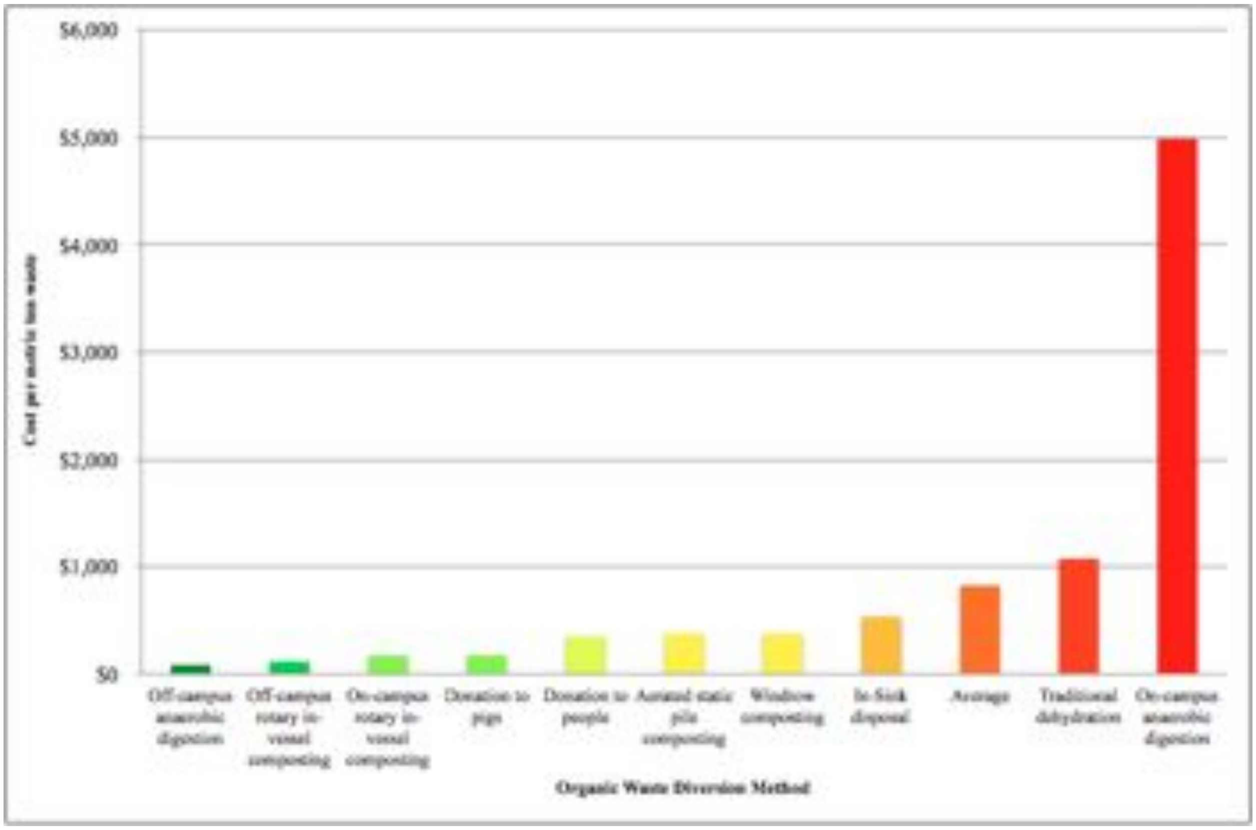

Figure 17-7: Comparison of costs by waste diversion method. Note: This graph does not include vermicomposting.

When analyzing the cost of food waste diversion methods, we assume that the college would implement vermicomposting as an educational project and not as a large-scale method of organic waste diversion. We opted to not include vermicomposting in the figures because equipment costs are extremely high for small-scale vermicomposting, accounting for 95% of the total cost ($167,372 /metric ton), as calculated in Chapter 16: Vermicomposting. Equipment costs are high because the report is calculating the processing of one metric ton of organic waste *per day*, which would require the use of 334 worm bins. If the college were to use vermicomposting as a supplemental educational method, the cost per day would be substantially lower since Wellesley would only have to buy a few composting bins. Since the cost per metric ton would be extremely disproportionate to the actual cost of this method, we did not include vermicomposting in the figures.

As seen in Figure 17-7, on-campus anaerobic digestion is extremely costly. Operational costs, particularly for labor, make up 80% of the total cost ($4,988/metric ton). There is no way to minimize this cost since labor laws require that the anaerobic digester be staffed 24 hours/day.

In addition to its high costs, on-campus anaerobic digestion has a very long payback period. Figure 17-8 shows the comparative costs of all organic waste diversion methods except on-campus anaerobic digestion and vermicomposting (the two financial outliers). The average cost across the methods included in Figure 17-8 is $364/metric ton.

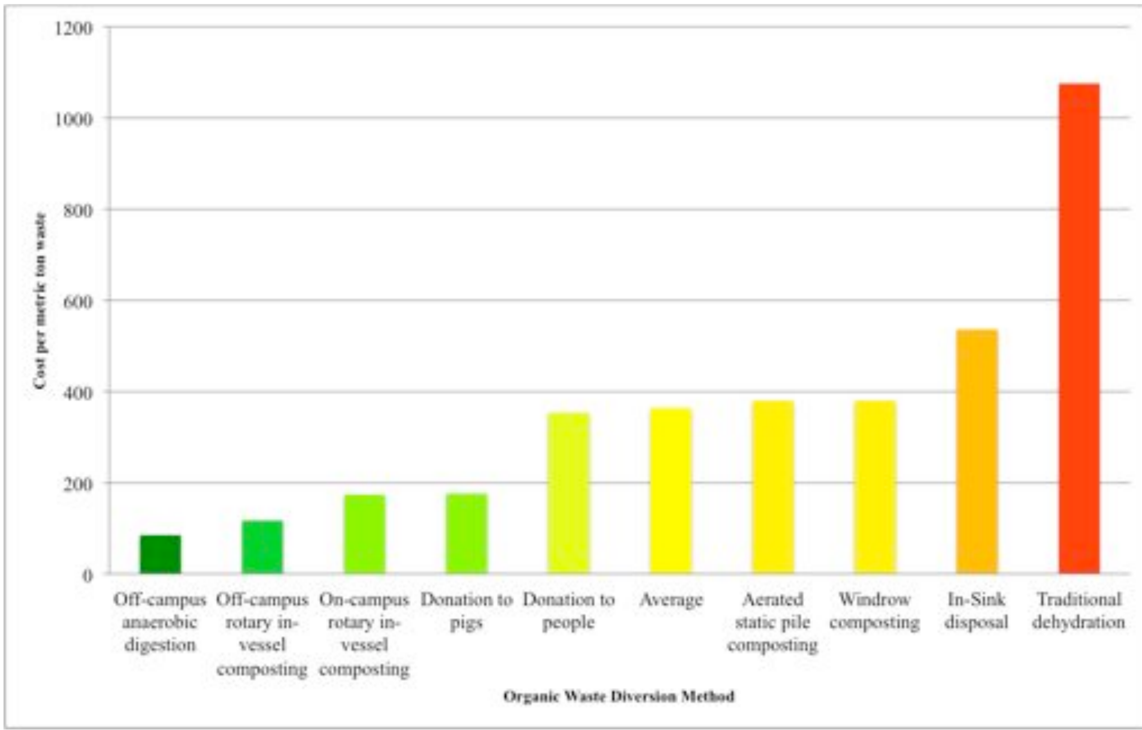

Figure 17-8: Comparison of costs by waste diversion method. This graph does not include the two highest costs, vermicomposting and on-campus anaerobic digestion.

The source of the cost varies by method type. For donation to pigs and people, a majority of the costs come from the containers. The cheapest container option for donation to people – aluminum trays – accounts for 99% of the total cost of ($354/metric ton). The college could look into reusable containers to further reduce costs, but would need to find a food recovery organization that could return containers.[5] There is also a high equipment cost associated with donating to pigs. The necessary containers – standard five gallon buckets – account for 73% of the total cost ($176/metric ton). These containers are reusable and only need to be purchased once.

When considering off-campus options, a large portion of the costs for each method comes from tipping fees, or the fees paid to the facilities for taking our waste. For piles and windrows, the

[5] Lovin' Spoonfuls, "Food Donation Guidelines," 2013. Obtained from Emma McCarthy Emma, email correspondence. March 25, 2013.

pickup fee charged by the facility is the only cost incurred ($380/metric ton). The College could lower this cost by organizing for one pickup location and letting the food waste accumulate longer. Scheduling for one pickup per visit could drop facilities costs for piles and windrows to $220/metric ton.

Similarly, direct costs (tipping fees and off-campus transportation costs) are the only expenses associated with anaerobic digestion and tumblers off campus. For off-campus tumblers, the facilities cost accounts for 61% of the total cost ($117/metric ton) while facilities account for 47% of off-campus anaerobic digestion ($40/metric ton). To reduce the cost of either of these methods, the college could research cheaper off-campus facilities. The cheaper facilities may be farther from Wellesley, mandating a higher transportation cost. Wellesley could reduce the price of transportation by selecting a cheaper organic waste hauling company.

For the on-campus food diversion methods, labor and equipment costs are generally high. For on-campus tumblers and standard dehydrators, operational costs incur the highest expense, accounting for 64% and 30% of the total cost, respectively. Hiring students through work-study programs, creating volunteer positions for easier tasks, and increasing the level of automation could lower labor cost.

In-sink disposal has a particularly high facilities cost, contributing to 93% of the total cost ($536/metric ton). The fee is paid to the MWRA to help maintain the Deer Island Sewage Treatment Facility. This sewer charge could be significantly lower if Wellesley College has an institutional discount or some other agreement with the MWRA, as this cost is calculated from the sewage costs of typical households in Wellesley, MA. The college could further reduce its facilities cost by buying a retrofitted in-sink disposal that can reduce water use by up to 70%.

If the cost of the method were Wellesley's only concern, then the college would implement off-campus anaerobic digestion, the cheapest option ($85/metric ton). If the college wanted to divert its organic waste on campus, then it would implement on-campus rotary in-vessel composting ($174/metric ton).

17.3 Social Impacts

An important component of this Life Cycle Assessment is an analysis and evaluation of the social impacts of food waste diversion methods. If we only evaluate the methods from environmental and cost impacts, the College could potentially adopt a waste diversion method that does not meld with important social factors. It is likely that the College will want to choose the food diversion methods with positive or neutral social impacts. In this report, we define four social impact categories: campus experience, education, difficulty, and social justice.

17.3.1 Methodology

The first impact category, *campus experience*, evaluates both the physical effects of a given method on the College's campus and the more general effects on the College's image. This category evaluates whether the food diversion method, for example, would smell poorly or would enhance or detract from the physical campus appearance. For consistency across the social impact analysis, we rank the impact on Wellesley's campus experience from negative one (detrimental) to one (positive)

The second impact category, *education,* evaluates whether a food waste diversion method would provide academic opportunities and be visible to the student body. We assess whether the method could be integrated into classroom experiences, whether students could easily visit and learn from the diversion method, and whether method is centrally located. For consistency in ranking, we present the education as educational benefit and rank as with negative one (none), netural (possible), or one (likely).

The third impact category, *difficulty of implementation*, includes an evaluation of four sub-categories: *separation, permitting and regulations, time until implementation, and risk*. A comparison of separation is important; if the diversion method requires that the food waste be thoroughly sorted, there is a possibility for more contamination. If the waste diversion method requires several years to implement, the college will not be able to divert sufficient quantities of its food waste by the 2014 Organic Waste Ban deadline. Risk is assessed as risk posed directly to members of the Wellesley College community.

Besides the logistical and practical social components of each method, we believe it is important to evaluate the methods from a *social justice* perspective. A sustainable waste diversion system will account for possible impingements on workers' labor rights, or notable improvements in people's access to resources that are socially, physically, or economically inaccessible prior to the implementation of a method.

Social factors will influence the means and success of the chosen food waste diversion methods. If a component of the diversion method takes significant time to permit or a lot of behavioral adjustment, it will be harder to implement. It is likely that the College will weigh social aspects in decisionmaking and adopt a method that is easy to implement, provides educational opportunities, adds to campus aesthetics, gives the college good publicity, and for which there is a low likelihood of contamination and few to no negative impacts on social justice.

17.3.2 Waste Diversion Methods Within Social Impact Categories

The individual rankings for all organic waste diversion methods considered in our report are shown in Table 17-1. It is important to note that all of the methods included in this report are feasible at Wellesley College and have been successfully implemented at other institutions. In th table, methods ranked "low" are the most beneficial and those ranked "high" are the most problematic. This table will be most useful for comparing the social impacts of a method against all other methods since all scores are relative.

Table 17-1: Comparison of Social Impact Category Results, across organic waste diversion methods. A score of “Medium” or “Neutral” signifies that there is not a significant impact of this method in the relative category or subcategory. A score of “Low” or “Positive” indicates a beneficial contribution, while a score of “High” or “Negative” indicates a detrimental or problematic contribution.

	Donation to People	Donation to Pigs	Piles (Off Campus)	Windrows (Off Campus)	Tumblers (On Campus)	Tumblers (Off Campus)	Anaerobic Digester (On Campus)	Anaerobic Digester (Off Campus)	Dehydrator (Traditional)	Dehydrator (Enzyme)	Vermi-composting	In-Sink Disposal
CAMPUS EXPERIENCE	Neutral	Neutral	Neutral	Neutral	Positive	Neutral	Neutral	Neutral	Neutral	Neutral	Positive	Neutral
EDUCATIONAL BENEFIT	Neutral	Negative	Negative	Neutral	Neutral	Negative	Positive	Negative	Negative	Negative	Positive	Negative
DIFFICULTY (Separation)	High	Medium	Medium	Low	Low	Low	High	Low	High	Medium	High	Low
DIFFICULTY (Permitting and Regulations)	Low	Low	Low	Low	Medium	Low	High	Low	Medium	Medium	Medium	Low
DIFFICULTY (Time Until Implementation)	Low	Low	Low	Low	Medium	Low	High	Medium	Medium	Medium	Medium	Low
DIFFICULTY (Risk)	Medium	Medium	Low	Low	Medium	Low	High	Medium	Medium	High	Low	Low
Social Justice	Positive	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral

Campus Experience
Wellesley College is known for its aesthetic beauty. Indeed, alumnae often speak of the impact that the campus’s natural landscape had on their college experience. It was important to consider the ways diversion methods may negatively or positively affect the campus experience. None of our methods received negative scores, demonstrating that no food waste diversion method will be detrimental to the campus experience. All off-campus methods (piles, windrows, tumblers, anaerobic digestion) and several on-campus methods (donation to people, donation to pigs, anaerobic digestion, both types of dehydration, and in-sink disposal) received neutral scores because their daily operation and infrastructure does not affect the campus aesthetic. Two on-campus methods, tumbling and vermicomposting, received positive scores because both would bestow a sense of pride and provide Wellesley College with good publicity.

Educational Benefit
It is important to consider the educational opportunities that will come with the implementation of certain diversion methods. Wellesley College may choose to implement a waste diversion method that offers this added benefit of educational opportunities. Methods with negative scores are donation to pigs, piles, tumblers off campus, anaerobic digesters off campus, both types of dehydration, and in-sink disposal. These methods rank negatively because there is no potential for educational benefit. Methods with positive scores are anaerobic digester on campus and vermicomposting. These methods are both visible and offer ample educational opportunities for students.

Difficulty of Implementation
Separation

The difficulty of separation considers how much time and care will go into preparing food waste for diversion. The methods with the lowest separation difficulty (windrows off campus, tumblers, and anaerobic digesters) require no separation since they are able to handle all food wastes including animal products. The methods with medium separation difficulty (piles, donation to pigs, and enzyme dehydrators) require that one or two types of organic waste, such as animal products and bones, oils, greases, and compostable containers be separated. The methods with highest level of difficulty (traditional dehydrator, and vermicomposting) require that more than two types of the aforementioned waste products be separated out of the stream. A different type of high level separation difficulty is “donation to people,” the separation required for this diversion method would require that those separating have a clear understanding of what quality of food can be reused for human consumption.

Permitting and Regulations

It is important to consider the permitting requirements and the regulatory structures that govern implementation of each method. Permitting and regulatory procedures will determine the necessary paperwork the College or AVI need to complete. Methods that receive a low score include donation to people, donation to pigs, piles off campus, windrows off campus, tumblers off campus, anaerobic digestion off campus, and in-sink disposal. These methods would predominantly occur at off-campus facilities and would not require the College to be involved in any additional permitting. In-sink disposal is already used by the College, and would not require additional permits to handle a larger volume of the College’s food waste.

Methods that receive medium scores include tumblers on campus, dehydrators (traditional and enzyme), and vermicomposting. Tumblers on campus would likely require permitting for the use of new machinery to process food waste. The College may require a building and renovations permit from the Town of Wellesley in order to restructure dining halls to accommodate the dehydration machinery. Vermicomposting would require special permits because it involves the use of live worms and requires regular health inspections. Anaerobic digestion on campus receives a high score because of the construction process.

Time Until Implementation

The time required for a given method to be implemented and divert Wellesley’s food waste is of utmost importance given the need for compliance with the 2014 Organic Waste Ban. The information provided in this section both informs Wellesley’s compliance with the Ban and suggests the best options over the next several years.

The following methods can be implemented immediately and receive a low score: donation to people, donation to pigs, piles, windrows, tumblers off campus, and in-sink disposal. For donation to people and pigs, piles, windrows, and tumblers off-campus, outside companies and contractors would be able to take our waste immediately, and for in-sink disposal, the on-campus operations in dining halls could immediately scaled up to accommodate all of our waste.

Tumblers on campus, anaerobic digestion off campus, and both types of dehydration rank medium for time until implementation, as they can all be implemented before the 2014 Organic Waste Ban but require some phase-in time. Building a tumbler on campus will take at least a year. Anaerobic digesters off-campus are still being built by local farms and will be online within the year to accommodate institutions such as Wellesley that need to divert food waste. Traditional dehydration will also require some renovation and the installation of machinery in dining halls. The only method receiving a high score is anaerobic digestion on campus, since building an anaerobic digester will take at least 2 years.

Risk

The risk for each method indicates the potential threat to the Wellesley College community from implementing each waste diversion method. The methods with a low score include piles off campus, windrows off campus, tumblers off campus, vermicomposting, and in-sink disposal. These methods are predominantly done off-campus with the exception of vermicomposting and in-sink disposal that have no associated risk to humans. Methods with a medium score include donation to people, donation to pigs, tumblers on campus, anaerobic digestion off campus, and traditional dehydration. There would be a low probability but high severity of harm from contamination with donation to people, and donation to pigs. For tumblers on campus, anaerobic digestion off campus, and traditional dehydration, there would likely be a high probability but low severity of harm from contamination.

Methods that have a high score include anaerobic digestion on campus and dehydration with enzymes. The anaerobic digestion equipment could be potentially dangerous to employees and could pose a potential risk of soil contamination or odor pollution if leakage occurs from the facility. There is also a high probability and high severity of harm from contamination with anaerobic digestion. There is a similarly high probability and high severity of contamination for enzyme dehydrators. Contamination from high levels of oils or compostable dishware could kill the microorganisms; any contamination from textile materials or metal utensils could easily break the machine.

Social Justice

Social justice was assessed for each method to ensure that the potential negative social justice impacts of any method could be known and incorporated into the decisionmaking process. No methods rank negative for social justice impacts. All methods besides donation to people rank neutral, showing that they have neither positive nor negative social justice impacts. The only method with a positive social justice impact is donation to people, since this method would help feed hungry people in the Greater Boston Area.

17.3.3 Summary of Social Impacts for all Methods Across Categories

In order to compare the overall social impacts of each diversion method, we aggregated the rankings from each category in Table 17-1 to get a total social impacts score. The result of the aggregated ranking is shown in Figure 17-9. In order to sum the rankings for each category, we quantified the qualitative results, such that a “high” ranking, that has a negative effect, would get a low number score, and a “low” ranking, that has a beneficial effect, would get a high number score and show up positively on a graph. A ranking of high = 0, medium = 1, and low = 2.

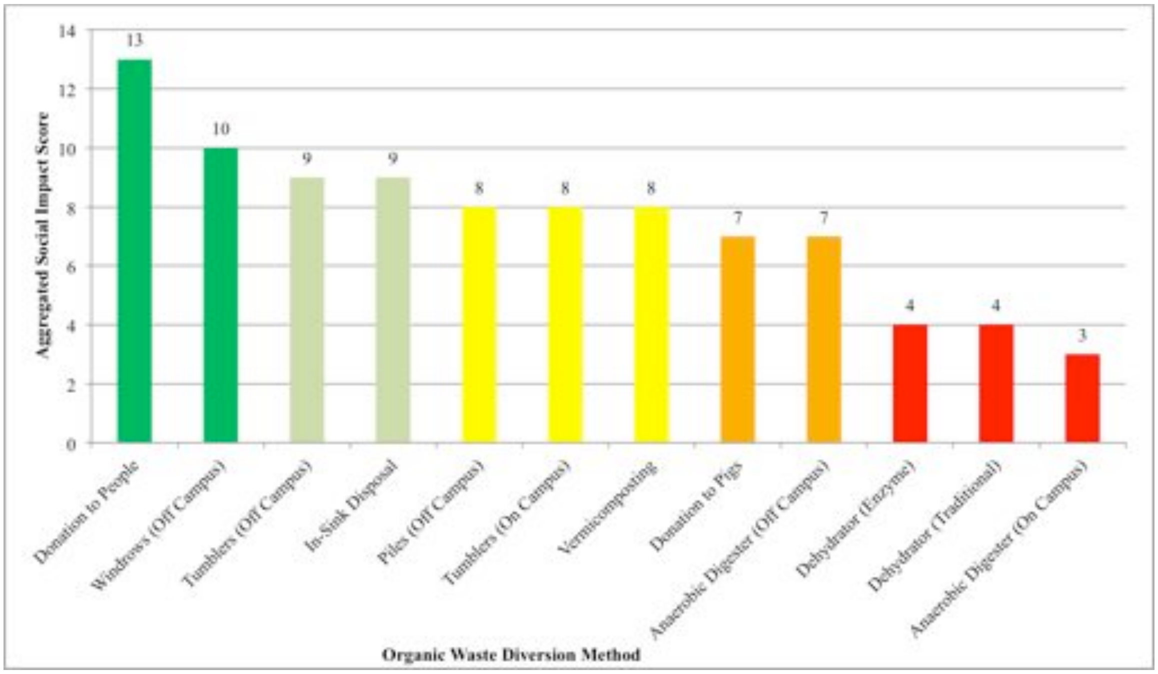

Figure 17-9: Aggregated ranking for social impacts across all impact categories.

17.3.4 Recommendations for Selection of Composting Methods based on Social Impacts

Most of the diversion methods considered are relatively beneficial and are minimally problematic in terms of the social impact categories considered. Anaerobic digestion on campus, and both dehydration methods are the most problematic overall in relation to social impacts. Permitting and regulations and time until implementation are low across donation to people, donation to pigs, piles off-campus, windrows off-campus, and tumblers off-campus. These methods provide the College with diversion options that are quick to put in place.

Across all methods, the categories that are most problematic are lack of educational opportunities and difficulty of separation. This indicates that strategies to increase the educational aspects of the diversion program and increase the ease of separating food waste materials would significantly improve the social impacts of the diversion methods considered.

If Wellesley College's primary concern is social impacts, we suggest that the college choose to donate our leftover food to people. Although the method requires high separation and would not provide educational opportunities or improve the campus experience, donation to people is the only method that tangibly contributes to the community in a positive way, making it the only method to have a positive social justice impact.

The analysis of these social factors suggests that no single method will allow Wellesley ease of implementation in conjunction with social benefits. Opportunities for positive social outcomes, such as donation to food-banks and active student involvement, may call for the implementation of an additional method. Combining off-campus methods such as windrowing or tumbling, that are easy to implement but would offer the college little in the way of positive image, with methods that have positive social benefits, such as donation to people and vermicomposting, could give the College good publicity and cultivate a positive student consciousness.

17.4 Meta-Conclusions Across Methods

Having seen how the twelve methods compare within the three impact categories - environmental, cost, and social - we look to see how each method performs across them. It is difficult to compare scores from these three impact categories since they are measurements of very different metrics. We are not familiar with any standardized way of doing a comparison like this. One very basic way is to rank each method from 1 to 12 in each of the three categories and then sum the three rankings for each method. In this comparison, a lower score is better, with the best possible score being a 3, and the worst possible score being a 36. Figure 17-10 shows the results of such ranking.

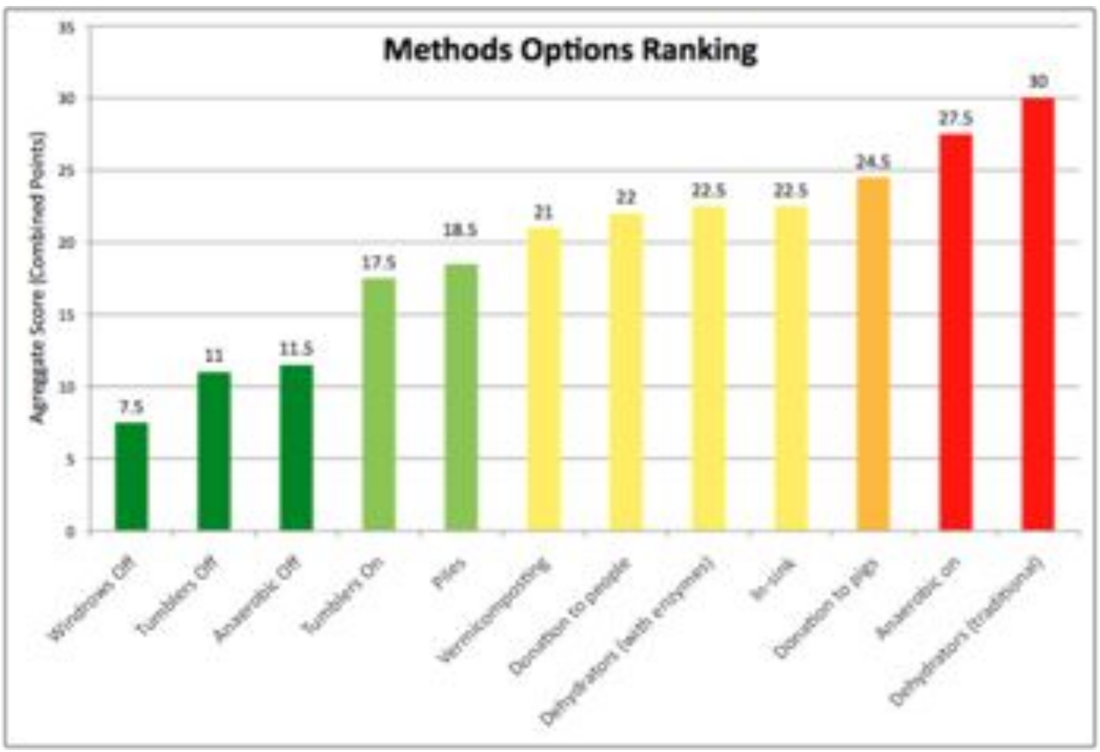

FIGURE 17-10: Ranking-based scores for comparing methods

The methods that scored the best are all off-campus: windrows, tumblers, and anaerobic digestion. The worst ranked methods across all three impact categories are both on-campus: anaerobic digestion and traditional dehydrators.

An alternative method of comparison is to graph the impact from cost, environment, and social factors on the same plot as shown in Figure 17-11. On this plot, we are looking for methods with low environmental impacts, low cost, and positive social impacts. The ideal options will be close to the origin (where the X- and Y-axes meet), and will be dark green.

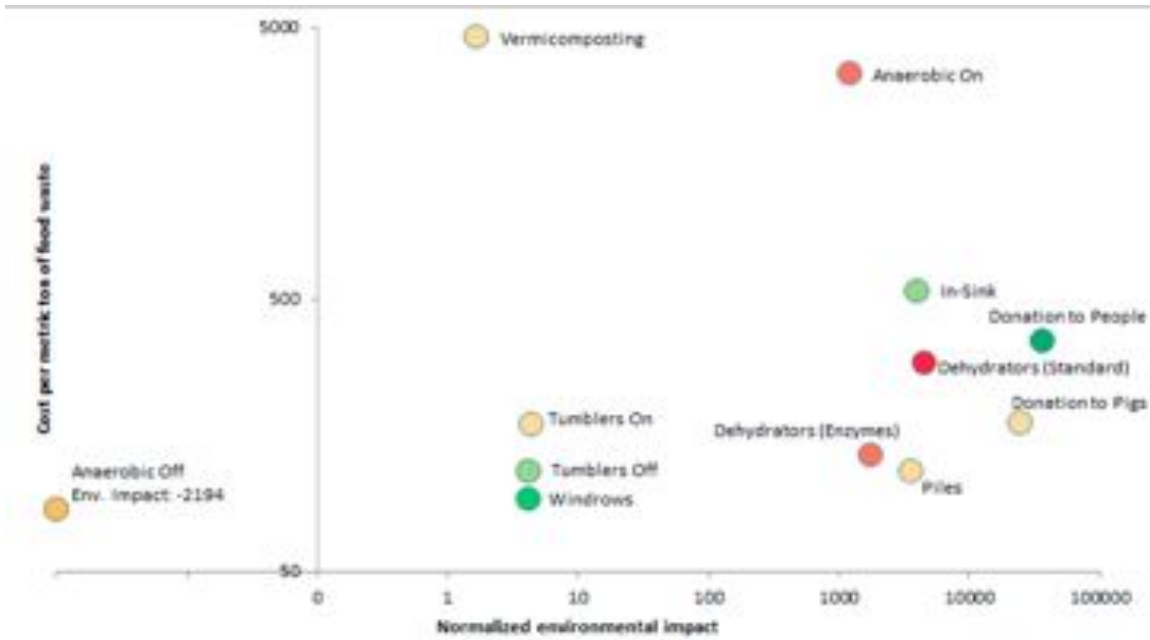

Figure 17-11: Plot of Impacts for Environment, Cost and Social Factors

In Figure 17-11, the best options are the same as those in Figure 17-10: anaerobic digestion off campus, windrows off campus, and tumblers off campus. Additionally, this plot shows that tumblers on campus are a good option to consider. Vermicomposting, both types of dehydrators, and anaerobic digestion on campus are the worst options shown in Figure 17-11.

Off-campus anaerobic digestion would have the lowest price and would have a net benefit to the environment, making it the best choice from an environmental and cost perspective. However, it has a much lower social value than the other low-scoring options. This is mainly due to the fact that it cannot handle significant amounts of contamination in our food waste and that it may not be able to be implemented immediately, due to the limit in anaerobic digesters that are currently available in Massachusetts.

Vermicomposting has the highest cost and would not be able to reasonably process large volumes of food waste. Yet vermicomposting may be useful for Wellesley to implement on a small-scale as an educational initiative, alongside a large-scale method that will process the majority of the College's food waste.

Donation to people may be an excellent option for a portion of our food waste, especially if we prioritize Wellesley's social impact goals over other factors. Donation to people is the only method that has a positive social justice impact, because it would help reduce hunger in the Greater Boston Area. Donation to people could be implemented on a small scale, in tandem with one of the best diversion options outlined above.

Taking into account that there is no panacea of food waste diversion at Wellesley College, we present a range of methods in Chapter 18 that we take to be the College's best options going forward.

III. Conclusion

18.0 Final Conclusions

18.1 Motivations

Wellesley does not yet have an institutionalized system for managing its food waste. The MassDEP's 2014 Organics Waste Ban will require all institutions in the state that produce over one metric ton of organic waste per week to divert 100% of its waste from the traditional waste stream. This waste law provides Wellesley with the opportunity to imagine new possibilities for successful organic waste reduction and diversion programs. We see this as a chance for Wellesley to show leadership and innovation in food waste diversion at an institutional level. Such actions are becoming a growing trend among peer institutions and are gaining momentum throughout the United States and the world.

This project is a student-driven initiative, undertaken by Environmental Studies majors who are passionate about contributing to a program that will create real change on campus and in the surrounding area. The 2014 Organics Waste Ban provides our class with the opportunity to analyze organic waste diversion on campus not only through a typical cost analysis, but also through a study of environmental and social impacts. While the ban provided the stimulus for creating our report, we have gone beyond mere compliance to promote a paradigm shift of sustainability. We recommend an institution-wide framework that will become ingrained in the campus culture and serve as a model for peer institutions.

We strongly recommend that the College take into account environmental, cost, and social impacts when assessing the various reduction and diversion options. Implementing an organic waste diversion program on campus is a significant investment. Thus, choosing a sustainable option that is suited for our campus culture is important to the program's long-term success. The success of any method depends on the responsiveness of staff and students to the changes. By considering social impacts, we provide a realistic picture of how well each reduction and diversion option would fit into our campus culture. Additionally, any option that significantly disrupts the academic or social experience or involves restructuring of the campus is not realistic.

Diverting food waste from the traditional waste stream reflects Wellesley College's 2007 Sustainability Statement. The College pledges a commitment to the consideration of sustainability in its decisionmaking processes. Altering Wellesley's current food management system goes beyond complying with local regulations; Wellesley now has the opportunity to become a leader in sustainability among peer institutions. Therefore, ensuring that the diversion methods minimize adverse environmental impacts on and off campus is an essential component of the decisionmaking process.

18.2 Report Summary

18.2.1 Methodology

In this report, we used the broad categories of environmental, cost, and social impacts to assess food waste reduction and diversion programs that we considered reasonable to implement at Wellesley. We analyzed twelve food waste diversion methods: donation to people, donation to pigs, piles (off campus), windrows (off campus), tumblers (on and off campus), anaerobic digestion (on and off campus), dehydrators (standard and with enzymes), vermicomposting, and in-sink disposal.

We conducted a Life Cycle Assessment (LCA) for each of the twelve food waste diversion methods to examine the effects that each method would have on the environment throughout its lifetime. We assessed three environmental impacts: global warming potential, human toxicity, and ecosystem toxicity. This analysis allowed us to compare the environmental impacts across methods. As cost will be an important factor in the College's decision-making process, we also took into consideration the financial burden of each method. Our analysis included direct costs (fees to facilities, transportation costs to third parties), operational costs (transportation costs on campus, labor costs), equipment costs (equipment installation, construction of new facilities), and avoided costs. Avoided costs are those that the College currently pays that it would cease paying when using the method. For example, the College would have to produce and buy less natural gas if an anaerobic digester system were installed on campus. Finally, we considered the social impacts that methods would have both on and off campus. Social factors included the difficulty of implementation, as well as how a new program might change students' dining experience, provide educational opportunities for students, and contribute to social justice. Whatever method the College chooses to implement, we hope that it will be a positive change for students, staff, the greater Town of Wellesley, and the Boston community.

18.2.2 Reduction

The first step to sustainable organic waste management at Wellesley is reducing the amount of food that goes to the traditional waste stream. We analyzed six waste reduction strategies: restructuring the meal plan, changing how food is served or presented, providing opportunities for students to take leftovers, reducing leftover waste at catered events, raising awareness of waste management, and implementing an institution-wide food monitoring system.

A change in the meal plan would mean allowing students an allotted number of meals to monitor dining hall use, paying according to the weight of their food or per individual food item, or a ticketing system where students exchange a ticket for each dish. Changing the meal plan would significantly change dining hall culture on campus. In contrast, serving smaller pre-plated portions and using smaller plates, bowls, cups, and utensils in the dining hall would be more easily accepted by the student body. Another strategy for reduction is to leave food outside of dining halls at the end of the day for students to take or to allow Tupperware containers during the last ten minutes that the dining halls are open. We could also aim to reduce leftover food waste from catered events on campus by requiring attending students to RSVP.

The two reduction methods we see holding the most promise are education and awareness initiatives and a food monitoring system. Due to their ease of implementation and effectiveness, we recommend these two reduction strategies as the primary means of food waste reduction on campus. Literature shows that the most successful food waste reduction plans include education and awareness campaigns targeting students, but that education and awareness campaigns alone do not reduce food waste significantly. Thus, education and awareness will supplement any other reduction method we choose. This educational component could be run by the Office of Sustainability at Wellesley or by student organizations such as Wellesley Energy and Environmental Defense (WEED).

Food waste monitoring systems at other colleges have reduced food waste by 30 to 50%. The systems are expensive, with an initial cost of $21,650 and an upkeep cost of $3,000 per year. Despite the cost, we recommend food waste monitoring as a primary reduction method due to its effectiveness. A food waste monitoring system will be useful for promoting awareness of food waste on campus, especially if weekly or monthly food waste amounts are prominently displayed in each dining hall. Even if other reduction options pursued, we still recommend incorporating a food monitoring system to assess whether these other reduction methods are effective.

18.2.3 Food Waste Diversion

Our analysis of food waste diversion options at Wellesley College shows that there are many great options for diverting our food waste. There are several methods that would best suit Wellesley's specific institutional needs depending on how the College prioritizes environmental, cost, and social impacts in the decisionmaking process.

Environmental Impact

We assessed the overall environmental impact of each method based on their contributions to climate change, human health (measured in carcinogens), ecotoxicity, and water use. If environmental impacts were our primary consideration for a disposal method, we would recommend anaerobic digestion off campus, windrows off campus, and tumblers off campus. Tumblers and windrows perform particularly well across all environmental categories; anaerobic digesters off-campus have a net positive impact on the environment since the digestion process produces energy in the form of biogas.

Our analysis shows that both donation to pigs and donation to people would have the highest environmental impacts of all methods. These environmental impacts are a result of the production and use of aluminum trays for donation to people and the high quantity of water needed to boil the food waste for pigs.

Cost

In terms of monetary cost, the least expensive methods include anaerobic digestion off campus, windrows off campus, tumblers off campus, and piles off campus. These methods range in cost from $85-117 per metric ton of food waste. Since these methods involve a contracted off-campus composting facility, the College would not have to purchase any equipment or build additional infrastructure. Transportation makes up the bulk of the cost for these methods.

The most expensive methods are vermicomposting, anaerobic digestion on campus, in-sink disposal, and donation to people. Vermicomposting, in-sink disposal, and on-campus anaerobic digestion require purchasing expensive equipment. Donation to people mandates the purchase of large quantities of disposable containers. It is important to note that neither vermicomposting nor donation to people would be able to handle the majority of the College's food waste.

Social Impact
The last category we used to examine diversion methods was social impact. We considered whether each method would offer educational opportunities, contribute positively or negatively to the campus experience, be difficult to implement and maintain, and address social justice issues. The methods with the best combination of social factors include donation of food to people, windrows off campus, and tumblers off campus. Donation to people is the only method with a positive social justice component, as it addresses unequal access to healthy food in the greater Boston area. Windrows and tumblers off campus perform well due to their ease of implementation.

The method that performed worst in our social impact assessment were dehydration (both standard and with enzymes). Dehydrators would require a high degree of food waste separation and thus have a medium risk of contamination.

18.3 Recommended Implementation Plan for Wellesley College

Choosing a method that can be implemented before the 2014 Organic Waste Ban is critical for meeting the state criteria. But the development of our food waste diversion plan is motivated by more than just compliance with the law; options that may have a longer implementation time must still be considered for long-term sustainability. In this section we present three phases of food waste management that can be implemented over the next five to ten years.

We recommend that the College first choose an inexpensive off-campus option that can handle all of our food waste. Once Wellesley diverts its food waste to one of these systems to ensure its compliance with the law, we recommend that the College start a partnership with a food recovery organization to donate edible pre-consumer food to shelters. We also advise the use of small-scale educational vermicomposting sites throughout campus. Within the next five years, we recommend that Wellesley take responsibility for its waste by creating a system to process all food waste on campus. We recommend installing compost tumblers on campus.

18.3.1 Options with an Immediate Start Date

Two of our highest-ranked options across all impact categories - windrows off campus and tumblers off campus - would be able to accept our food waste immediately. Anaerobic digestion off-campus will also most likely be available by Fall 2013. These methods can each handle 100% of our organic waste, and tumblers and windrows can tolerate contamination of up to 10% non-food waste materials, the highest of all methods. All three are attractive short- and/or long-term solutions.

We Care Environmental in Marlborough, 14 miles west of Wellesley, operates compost tumblers. In Wellesley's composting pilot project (launched in April 2013), pre-consumer food scraps from all of the dining halls have been sent to We Care. This established relationship with the facility would make it easy for the College to increase the volume of food waste sent with minimal hassle. The estimated cost of pickup is $117 per metric ton of food waste, amounting to $26,000 per year.

A local composting facility that uses windrows is another promising option. Agresource Inc. processes compost at the Needham Recycling and Transfer Station, four miles southeast of Wellesley. The company has demonstrated a desire to build a relationship with the College. During a site visit, the vice president personally gave the ES 300 class a tour of the facility; Agresource has also supplied compost to Regeneration, Wellesley's student farm, at a discount. We were impressed by the company's good communication and active desire to engage with students; the potential for educational value from the partnership contributed to its placement as the highest-ranked method in the social factors metric after donation to people. The estimated cost of pickup is $93 per ton of food waste, amounting to $20,500 per year.

Off-campus anaerobic digesters will become another option for the bulk of our food waste. Jordan Dairy Farms, the only local anaerobic digester currently available for processing food waste, is already at capacity. Fortunately, four other digesters are currently being built on the farms and will be available for use by the August 2013. At an estimated cost of $85 per metric ton of food waste (or $18,700 per year) and with a net beneficial environmental impact (due to the fertilizer and biogas produced), off-campus anaerobic digestion is the most environmentally friendly and lowest-cost method of all those surveyed.

The feasibility of sending food waste to a digester depends on the College's ability to limit contamination in the waste. Anaerobic digesters are very sensitive to contamination, particularly by metal objects; several forks in a load of food waste could disturb the system's microorganisms significantly and lower its efficiency. Within the next year, the company will finish construction of a waste separation facility to remove contaminants from the organic material, making this problem less pressing. In addition, contamination will undoubtedly decrease over time as composting is assimilated into Wellesley's campus culture. Thus, despite the risk of contamination, we recommend keeping anaerobic digestion off campus on our list of options for immediate implementation.

18.3.2 Programs to Establish over the Next Year

Composting with windrows, off-campus tumblers, or an off-campus anaerobic digester has the benefits of low hassle and fast implementation. Within the next year, we recommend that Wellesley supplement these options with small-scale vermicomposting and the donation of edible food to people. Although far more expensive than other methods, vermicomposting will prove valuable for educating students about compost and possibly handling low-level dispersed food waste such as that in residence halls. We also highly recommend donation of healthy, pre-consumer food to people in need, as it is an opportunity for the College to address the inequality of access to healthy food in the Greater Boston Area.

At $3,377 per metric ton, vermicomposting systems would be expensive and difficult to implement on a large scale. Used as small demonstration projects, however, they can help connect students to the decomposition process and invoke an appreciation of the potential of food “waste” to become high-quality, nutrient-rich soil. The worms would live in self-contained bins into which students deposit food scraps, excluding meat, dairy and citrus. Every month or so, staff or student volunteers would sort the compost from the worms and put it to use. We recommend placing bins in the Science Center’s Leaky Beaker area, as well as the Sustainability Cooperative and the Sustainability Hallway in Bates Residence Hall. Vermicomposting could also work well for summer residents. Students in a smaller community during a more relaxed time of year are more likely to compost properly; the Regeneration student farm has successfully collected compost from summer residents for the past few summers.

Including donation to people in the mix of solutions is a priority for our class. Edible food is much more valuable in its intact state than as compost. Approximately 10% of households in Massachusetts (over 700,000 residents) are food insecure, meaning that they lack consistent access to healthy food.[1] Meanwhile, residents and institutions in Massachusetts discard thousands of pounds of edible, healthy food every day.[2] Wellesley can easily help to connect unwanted food with those who need it by donating its edible pre-consumer food, which accounts for an estimated 15% of all food waste on campus. A food waste donation program would require staff to qualitatively judge which pre-consumer dishes are healthy and would remain tasty when reheated. They would then package this food in disposable containers and put it into the refrigerator. A food recovery organization or shelter would pick up food once per day at no cost. Regular communication with the shelter on which types of foods are fit to donate would be an essential part of building this relationship. The environmental impact, as well as the cost ($396 per ton), is greater than those of most other methods, largely because of the disposable containers needed to carry the food to the shelter. But the ability to make a positive contribution to social justice in the Greater Boston Area leads us to heartily recommend donating all safe, healthy, and edible food to people in need.

18.3.3 On-Campus Options for the Next 5-10 Years

In the long term, we recommend that Wellesley take responsibility for its food waste by creating an on-campus program to process it. We recommend the implementation of tumblers and the consideration of an anaerobic digester on campus within the next ten years.

We recommend that the college look into the feasibility of a system of on-campus tumblers, similar to those at We Care. The current composting location on Service Drive is an ideal location because of its proximity to the existing yard waste composting efforts. No college has yet implemented an on-campus tumbler, providing an opportunity for Wellesley to be a pioneer among peer institutions. Creating high-quality compost on campus would provide educational value to science classes, just as the Wellesley’s cogeneration plant does. On-campus systems

[1] Project Bread. “Project Bread Reports Massachusetts Income Gap Puts Over 700,000 Residents at Risk for Hunger. Accessed April 30, 2013. http://www.projectbread.org/site/News2?page=NewsArticle&id=12339&news_iv_ctrl=2162&abbr=newsroom.
[2] Hasek, Glenn. “Massachusetts planning food waste ban for business.” Accessed April 30, 2013. http://www.greenbiz.com/blog/2012/05/24/massachusetts-planning-food-waste-ban-for-businesses.

provide students with a more complete picture of the cycling of nutrients, raising awareness of the idea that waste does not just “go away.” The system would also provide a surplus of high-quality compost that could be used by maintenance. The initial and operating cost averaged over the lifetime of the system is $174 per metric ton of compost, or $38,300 per year. The tumblers could potentially be built before the 2014 deadline, but because of the necessity of dialogue with the Town of Wellesley’s Board of Health and other administrative discussions, we imagine that building an on-campus system within the next year would not be realistic.

We also evaluated the option of building an anaerobic digester on campus, which has many potential rewards but also potential complications. A digester would provide biogas to the cogeneration plant, lessening the quantity of natural gas that must be purchased. As the Wellesley 2025 plan will result in many renovations on campus, the timing is right for considering the construction of a digester. The technology of anaerobic digesters is constantly evolving, and Wellesley would be on the front end of bringing this exciting technology into common use.

In spite of these benefits, we do not ultimately recommend building an anaerobic digester on campus. Building the plant would be a large investment, and labor costs are also high. Like the Wellesley power plant, the anaerobic digester would have to be staffed 24 hours each day. In all, costs will average out to $4,988 per metric ton, or $1,097.292 per year. We hope that with technological improvements, this cost will decrease in the future. One possibility for lowering the cost is to create a larger plant in conjunction with Babson College or the Town of Wellesley. The digester requires the same amount of labor regardless of size, so a larger plant would lead to a lower cost per metric ton of waste processed, as well as the potential for generating revenue from disposal fees. In an effort to encourage more anaerobic digesters, the State of Massachusetts has made the permitting process relatively easy and offers a $200,000 subsidy for projects that accept waste from the general public.[3] As with off-campus anaerobic digesters, contamination must be kept to a minimum; monitoring over the coming years will determine whether the campus is capable of reaching acceptably low levels. Installing equipment to screen the waste and remove contaminants is one method of addressing this drawback. Although we recognize the appeal of creating a digester on campus and recommend that the college investigate the option further, we do not currently see it as the best option because of these complications.

18.4 Future Work

Despite the depth of our analysis, there are still many questions that remain, which cannot be fully answered until these waste reduction and diversion methods are implemented. The responsiveness of the Wellesley community to institutionalized organic waste diversion will determine the success of and phase-in time for each method. It will also determine whether we can achieve similar results as our peers in implementing reduction strategies. The best method

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[3] Kimmell, Kenneth. "Streamlining Organic Waste Rules to Foster Clean Energy." Accessed March 11, 2013. http://www.mass.gov/dep/public/publications/0611andi.htm.
Massachusetts Executive Office of Energy and Environmental Affairs. “Clean Energy via Anaerobic Digestion." Accessed March 9, 2013. http://www.mass.gov/eea/docs/doer/green-communities/pubs-reports/anaerobic-digestion-handouts.pdf.

for the College will depend in part on the level of contamination we can achieve, which in turn will depend on whether students or staff members separate the waste. The extent to which the community will embrace the opportunities for education that accompany on-campus composting systems is also unclear. Once the reduction and diversion methods are implemented, the costs and environmental impacts will likely differ from those we have calculated in this report. These costs and impacts should be re-evaluated periodically throughout the next several years to ensure that the methods still meet the College's needs.

18.5 Paradigm Shift - Opportunity for Innovation and Leadership

The environmentally and politically progressive 2014 Organics Waste Ban creates an opportunity for innovation and leadership within the State of Massachusetts and the entire country. In working to meet the goals laid out by the MassDEP's Solid Waste Master Plan, Wellesley College can not only join ranks with its peer institutions in addressing waste in Massachusetts, but also move to the forefront of innovation in reducing environmental impacts of a large institution. This project and the action that must stem from it represent the first step in the type of leadership that the College will need in the coming years in order to be a leader in long-term sustainability.

Our assessment provides the analytical work for the College to plan its next steps towards diverting food waste. We have shown that the College has many feasible options for implementing a successful organic waste diversion strategy which will reduce our impact on the environment, potentially reduce waste management costs, and have positive social impacts within the College. There are many viable paths to creating this cultural and institutional change. Indeed, a combination of these methods might best suit Wellesley's goals and values, and the flexibility offered with these options makes this an opportunity for ambitious leadership in sustainability.

Ultimately, we recognize that any method of food waste diversion that is chosen must be institutionalized and made permanent by the administration. Structural change will be the only way to ensure that waste reduction efforts are sustained over time. It is through this careful and thoughtful analysis coupled with passion for leadership and strong drive from the administration that waste reduction will become ingrained in the culture and identity of Wellesley College.