Organic Waste Diversion and Greenhouse Gas Mitigation at UC Berkeley

Crystal L. Sun

ABSTRACT

Each year, excessive amounts of trash are dumped into landfills that can harm the immediate environment and climate through the emission of greenhouse gases (GHG). Since landfilled waste is comprised largely of potentially compostable organic waste, alternative waste management systems can reduce the environmental impacts of landfills. By reducing the GHG impact of the waste sector at UC Berkeley, the campus can move forward in its emission and waste reduction goals. I assessed UC Berkeley's campus composting potential and calculated the GHG reduction possible by maximum organic waste diversion. Using waste audits of a few representative buildings on the core campus, I calculated organic waste diversion potential for buildings based on their building use and occupancy levels. On a campus level, the compost diversion potential was 46.7% of the landfill waste, which could lead to a 45.8% decrease in GHG emissions from landfill waste. Comparing the amount of waste produced by different building types, I found that buildings categorized as "classroom/administration," "classroom" or "administration" have the highest composting potentials. By creating a waste generation map in GIS, I proposed that these buildings be targeted as new sites for additional composting stations as a possible step the university can take to move toward its sustainability and zero waste goals that are as of yet out of reach.

KEYWORDS

compost, landfill, emissions, Waste Reduction Model (WARM), geographic information systems

INTRODUCTION

In 2010, every person in the United States generated about 4.43 pounds of waste, the greatest per capita waste generation in the world (EPA 2008, EPA 2010). The total quantity of municipal solid waste (MSW) in the country increased 185% since 1960 to 250 million tons, but only about 8% of the total MSW was composted (EPA 2010). Currently, 54% of the total MSW is disposed of on land in landfills, wetlands, or is combusted for energy. Landfills pose many environmental problems such as groundwater contamination, methane gas formation, and disease vector hazards because of unknown waste chemical composition and poor land-use planning (EPA 2008). In light of recent climate impact assessments and policy reforms geared towards reducing GHG emissions to mitigate climate change, waste management and diversion strategies have begun to reduce the emissions impact of landfills.

In the past few decades, landfills have become a significant source of national GHG emissions (EPA 2012b), but alternative waste management strategies can abate these emissions by reducing landfill waste. GHG emissions from post-consumer waste constitute 3% of the global emissions (Bogner et al. 2008), and landfills constitute about 16.2% of total U.S. anthropogenic methane emissions, making landfills the third largest methane contributors in the United States behind natural gas systems and enteric fermentation (EPA 2012b). Landfills can emit GHGs for up to 60 years since anaerobic bacteria within the landfill waste continuously produce methane and carbon dioxide after waste disposal (EPA 2012b). The past decade showed a net increase in landfill methane emissions most likely resulting from the growing volumes of municipal waste (EPA 2012b). Alternative waste management systems such as recycling, composting, anaerobic digestion, and incineration divert materials away from landfills and mitigate the climate impacts of landfill waste (Hermann et al. 2011b, EPA 2012b, Piemonte 2011). Waste sector emissions could be reduced by about 70% by implementing existing technologies in waste reduction, reuse, and recycling programs (Bogner et al. 2008). Focusing on organic waste diversion from landfills to compost can help mitigate global warming by GHG emissions and reduce environmental impacts of non-renewable resource use.

The main environmental benefit of composting is returning carbon and nutrients to the soil to prevent wasteful resource use, but composting also plays a role in climate change mitigation by GHG emission reduction (Bogner et al. 2008). Composting is a specific type of biodegradation of organic materials that produces a humus-like mixture that can be returned to soil as fertilizer, in effect reusing the carbon and nutrients in the production new materials (Shah et al. 2007). Though centralized composting systems can still emit high global warming potential gases such as methane and nitrous oxide (Anderson et al. 2010), this emission level is significantly lower than that of landfills (EPA 2012b), and other environmental benefits to soil carbon content and plant biomass can actually counteract these emissions (EPA 2012a). Compost's emission reduction potential is not taken advantage of in landfills, leaving it and other sustainable waste management practices often-overlooked aspects of climate change mitigation strategies (EPA 2011b). As a result, educational institutions spearheaded improvements in cost effective waste management systems and carbon footprint reduction through recycling and composting programs (Razza et al. 2009).

Upon joining the Cal Climate Action Partnership, UC Berkeley implemented several waste management campaigns throughout the campus with the ultimate goal of reducing GHG emissions through 2014 to 1990 levels and to reach a zero waste goal by 2020 (McNeilly and McKanna 2009). Solid waste on the campus largely comes in the form of food, construction and demolition, and plastic waste (Sugerman 2011). To reduce landfill waste and carbon footprint, the campus targeted food waste and implemented composting programs in the dining halls in 2005 (Sugerman 2011, Dauvergne 2010). Since then, there has been notable progress in campus sustainability through the expanding composting and recycling programs. In 2011-2012, the campus diverted 56% of its waste (including construction waste) from the landfill (Office of Sustainability 2012), but did not meet its 75% goal as of June 2012 (Lam 2012). The composting program should continue expanding to reach the zero waste by 2020 goal, since waste audits on representative buildings showed that 45% of landfilled waste could be diverted to compost (Lam 2012). Quantifying the environmental impact of UC Berkeley's waste generation in terms of GHG emissions and identifying the areas generating the most waste would help identify steps to continue to reduce landfill waste and shrink the carbon footprint of the campus.

In this study, I aim to model the waste generation on the UC Berkeley campus and target specific buildings that have the greatest potential for implementing new compost programs. I use projected GHG emission reduction benefits of increasing organic waste diversion to further recommend that the University expand its alternative waste practices and green purchasing policies. The benefits of diverting the compostable organic matter is expected to be substantial and vital for UC Berkeley to move towards its GHG emission reduction and zero waste by 2020 goals.

METHODS

Study site

This study was conducted at the University of California, Berkeley, which has a population of 50,334 students, faculty, and staff (Office of Sustainability 2012). I focused on 213 buildings on the core campus and the surrounding residential and dining halls. The campus currently provides multiple waste management systems including conventional landfills, composting, plastics and aluminum recycling, electronics recycling, and green waste disposal. The landfill waste is taken to West Contra Costa Sanitary Landfill in Richmond, CA, and compostable waste is taken to Recology Grover Environmental Products in Modesto, CA. University officials are considering taking the campus' compostable waste to a closer anaerobic digestion facility East Bay Municipal Utility District (EBMUD) in Oakland, CA. In addition to residence and dining halls, thirteen buildings on the core campus that currently have composting are Architects and Engineers, Barrows Hall, California Hall, Goldman School of Public Policy, Haas School of Business, Mulford Hall, Sproul Hall, Stanley Hall, University Hall, Wurster Hall, Durant Hall, Sutardja Dai Hall, and 2000 Carleton.

Building type characterization

I categorized all 213 UC Berkeley buildings by their uses based on information from Space and Capital Resources (Table 1). For simplicity, I grouped natural science, chemistry, biology, physics, and engineering laboratories together. Buildings that were "Mixed" included three or more other building types. Buildings are considered "Other" when their use is sporadic, such as Sather Tower and Martin Luther King Jr. Student Union. Inactive buildings are buildings that have no regular use or are used for storage.

Table 1. Building type categories. Each building on campus was individually characterized based on its space usage as presented by Space and Capital Resources.

Building Types	
Administration	Classroom
Classroom/Administration	Classroom/Laboratory
Laboratory	Sports
Performance	Dining
Residential	Parking
Parking/Sports	Library
Health	Mixed
Other	Inactive

Waste audits

As a first step to determine the greenhouse gas (GHG) emissions associated with campus waste, I used waste tonnage data provided by the Office of Sustainability and Campus Recycling and Refuse Services (CRRS) to understand the composition of the landfill waste of various building types. During the 2012-2013 academic year, CRRS conducted waste audits on representative buildings Stanley Hall (laboratory), California Hall (administration), Crossroads Dining Commons (dining), and Wurster Hall (mixed). Waste audits in Sutardja Dai Hall were conducted separately as part of a CITRIS project to improve building sustainability. These waste audits disaggregated the composition of landfilled waste in these buildings into landfill, compostable, metal cans, plastics, and mixed paper. I extracted the percentages of compostable waste and assigned each building type a percent potential organic waste diversion rate. Buildings types for which there were no data from waste audits used 37%, a general proportion of compostable waste in commercial buildings (Humboldt 2012).

Building waste generation

Upon understanding the composition of waste of representative buildings through the waste audit data, I calculated the amount of waste theoretically produced by each building on campus. Using data obtained from the Office of Space Management and Capital Programs, I gathered information building type, occupancy, and size. I approximated building occupancy with the sum of "stations" in a building, where a station is defined as a documented seat or designated work area for a single person. I adjusted the total number of stations across campus to sum up to the campus population, 50,334 people. By multiplying the adjusted number of stations by 0.177 tons of waste/person, I found the total amount of waste each building is theoretically generating each year. To take into account preexisting waste diversion practices, I assumed that all buildings recycled at the campus rate of 24.6%, while buildings that also composted had a 43.4% total diversion rate (Table 2).

Table 2. Building waste generation assumptions. These assumptions are based on campus waste generation in tons for 2011-2012. All numbers exclude construction waste.

Total Waste	Waste/person	Compost rate	Recycling rate	Total Diversion
8932	0.177	18.8%	24.6%	43.4%

I obtained the landfill waste generated by each building by subtracting the waste diverted to recycling or compost. Then I multiplied the landfill waste by the compost diversion potentials to find how much compostable waste is being thrown into landfill for each building and ultimately campus-wide. Using these current diversion rates and the additional potential composting rates from the waste audits, I generated a "business as usual" (BAU) scenario where the campus continues its current composting and recycling practices and a maximum composting scenario where all organic waste is composted.

The previous calculations can be summarized by the following equations:

$$\text{Total Building Waste}\left(\frac{\text{tons}}{\text{building}}\right) = \#\frac{\text{people}}{\text{building}} \times 0.177\,\frac{\text{tons}}{\text{person}}$$

$$\text{Building Landfill Waste}\left(\frac{\text{tons}}{\text{building}}\right) = \text{Total Building Waste} - [\text{Recycled} + \text{Composted}]$$

$$\text{Potentially Compostable Waste}\left(\frac{\text{tons}}{\text{building}}\right) = \text{Building Landfill Waste} \times \%\ \text{Compost Potential}$$

Waste to GHG conversion

I calculated potential GHG emission reductions for the BAU and maximum composting scenarios using the EPA's Waste Reduction Model (WARM) (EPA 2012c). This model uses conversion factors for waste transportation, waste management processing, and waste fugitive emissions, such as those from material decomposition to calculate total GHG emissions and energy savings from the disposal of different types of waste. For both the BAU and maximum composting scenarios, I entered campus compost data into the "Mixed Organics" category and landfill data into "Mixed MSW" category. Within the WARM model, I customized the distances from UC Berkeley to the EBMUD and Recology compost sites to see the additional GHG emission reduction possible by making this change to a closer composting facility (Table 3).

Table 3. Distances to different composting sites. Campus Recycling and Refuse Services is currently considering changing the campus compost facility, so understanding the environmental impacts of this decision is crucial. For this study, landfill waste in both scenarios are sent to the same facility in Richmond, CA.

Waste type	**Recology** Modesto, CA	**EBMUD** Oakland, CA
Landfill	50 miles	50 miles
Compost	85 miles	5.5 miles

Campus waste generation map

To generate a visual representation of waste generation on the UC Berkeley campus, I used Esri ArcGIS 10.1 (ESRI 2012) to pinpoint buildings with greatest waste production and compost diversion potential that should be prioritized when choosing locations for new composting stations. To build the GIS, I digitized every building on the campus, including housing and dining complexes by using satellite images of UC Berkeley and drawing polygons in ArcMap. After I created the building data layer, I associated information about building name, type, and waste generation to each polygon. I created another point layer of existing compost bins layer showing the location of buildings that have existing compost bins. By characterizing each polygon by the building's potentially compostable waste, the maps yielded a visual representation of the buildings that have greatest need for organic waste diversion efforts.

RESULTS

From the waste audit data, I calculated organic waste diversion potentials for each building type (Table 4). Buildings used for classroom and/or administration purposes have the highest diversion potential. Combination building types and “Mixed” buildings used the average of the individual components.

Table 4. Compost diversion potentials by building type. Diversion potentials were derived from waste audit data of representative buildings.

Building Type	Compost diversion potential (%)
Administration	50%
Classroom	55.6%
Classroom/Administration	52.8%
Classroom/Laboratory	43.1%
Laboratory	27%
Sports	37%
Performance	50%
Dining	45.3%
Residential	43%
Parking	37%
Parking/Sports	37%
Library	37%
Health	37%
Mixed	Variable
Other	0%
Inactive	0%

I determined that 46.7% of the landfill waste could be diverted to compost campus wide. Using the 46.7% maximum compost diversion scenario, I found that 7,592 tons of MSW in 2011-2012 could have been composted.

The 46.7% organic waste diversion lead to a 45.8% decrease in landfill GHG emissions (Table 5). Under the BAU scenario, the campus landfill waste emitted 2625 $MTCO_2E$ of GHGs in 2011. Using the 46.7% organics diversion scenario and leaving other waste streams constant (i.e. recycling, electronic waste, etc.), GHG emissions dropped by 1203 $MTCO_2E$. Transportation to the EBMUD facility reduced emissions by an additional 29 $MTCO_2E$.

Table 5. Landfill waste greenhouse gas emissions by scenario in $MTCO_2E$. Metric tons CO_2 equivalent is a common unit of GHGs that describes the amount of CO_2 that will result in the same global warming potential of a particular GHG.

Compost site scenario	BAU	46.7% Organics Diversion	Emission Reduction
Modesto, CA	2625	1422	1203
Oakland, CA	2606	1374	1232

Various building types contributed different percentages of organic waste based on the building type, size, and occupancy. Classroom/administration and administration contributed the most compostable waste (Fig. 1), as well as the highest amounts of landfilled waste (Fig. 2).

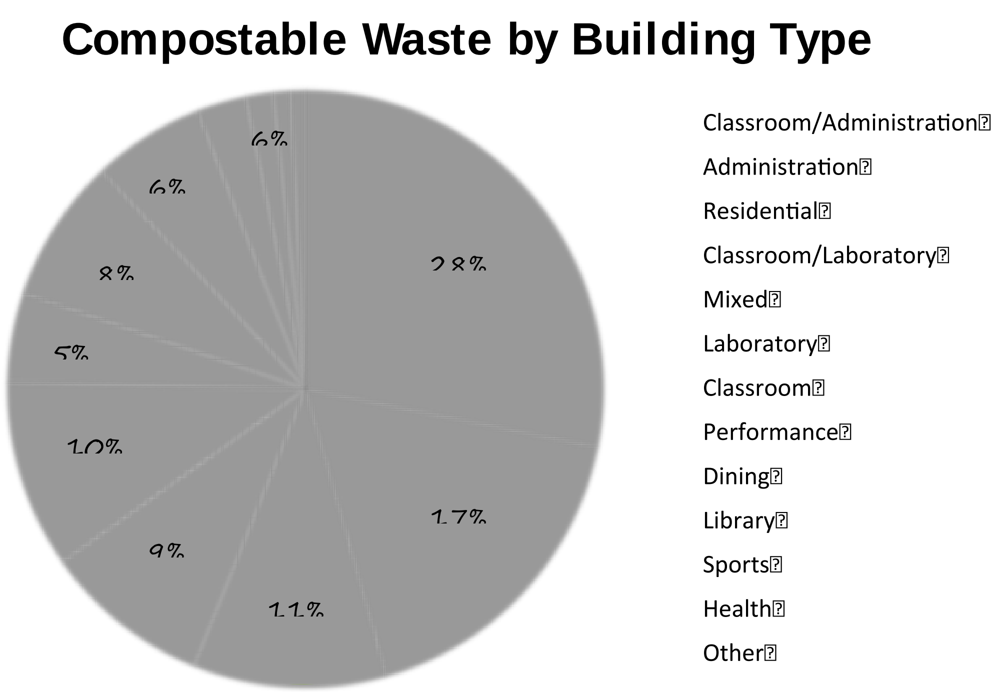

Figure 1. Compostable waste by building type. Buildings categorized as classroom/administration contribute the greatest amounts of compostable waste by mass.

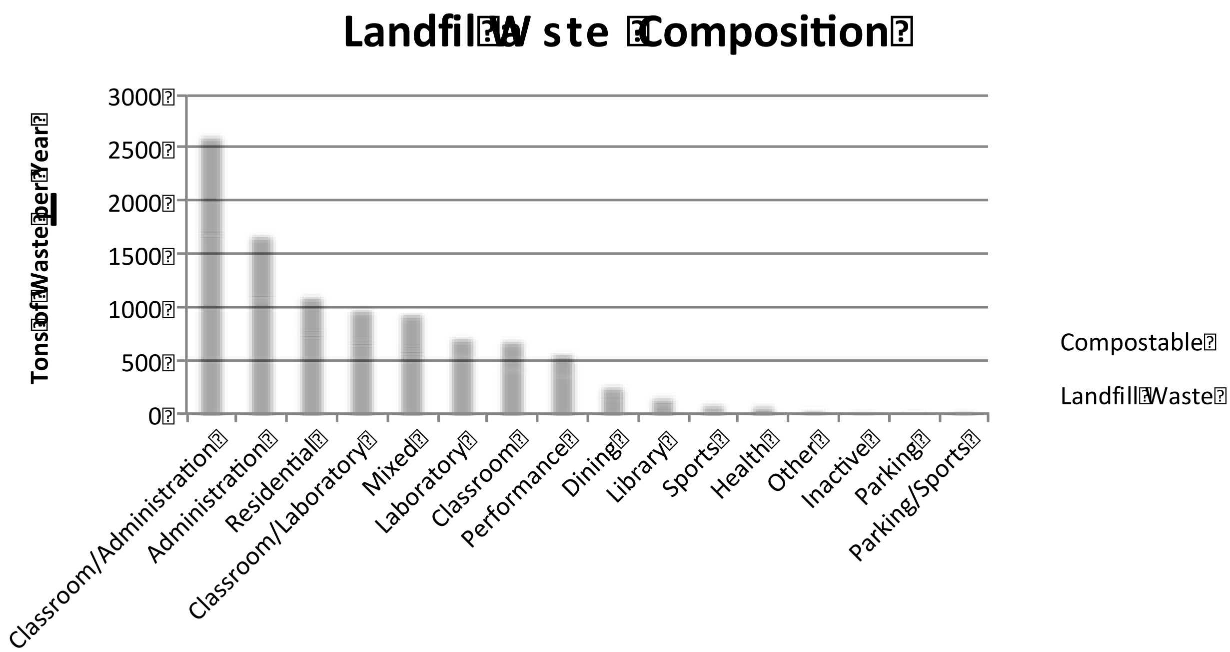

Figure 2. Landfill waste by building type. It is evident that classroom/administration buildings contribute the greatest amount of landfill waste, and also the greatest amount of potentially compostable waste.

The GIS analysis showed that the majority of the buildings are classroom, administration, or a combination of the two (Fig. 3) and that the majority of the campus has a high compost diversion potential (Fig. 4). The maps indicate in which buildings new compost bins could be introduced. For example, buildings that generate high levels of organic waste that should begin to compost include Valley Life Science Building, Dwinelle Hall, Wheeler Hall, Evans Hall, and Barrows Hall. Such targets are intuitive because these buildings also have among the highest occupancy levels. The maps also indicate that despite the presence of compost bins in some buildings, the organic waste generation is still high, as in the cases of Mulford Hall, Sutardja Dai Hall, and Wurster Hall.

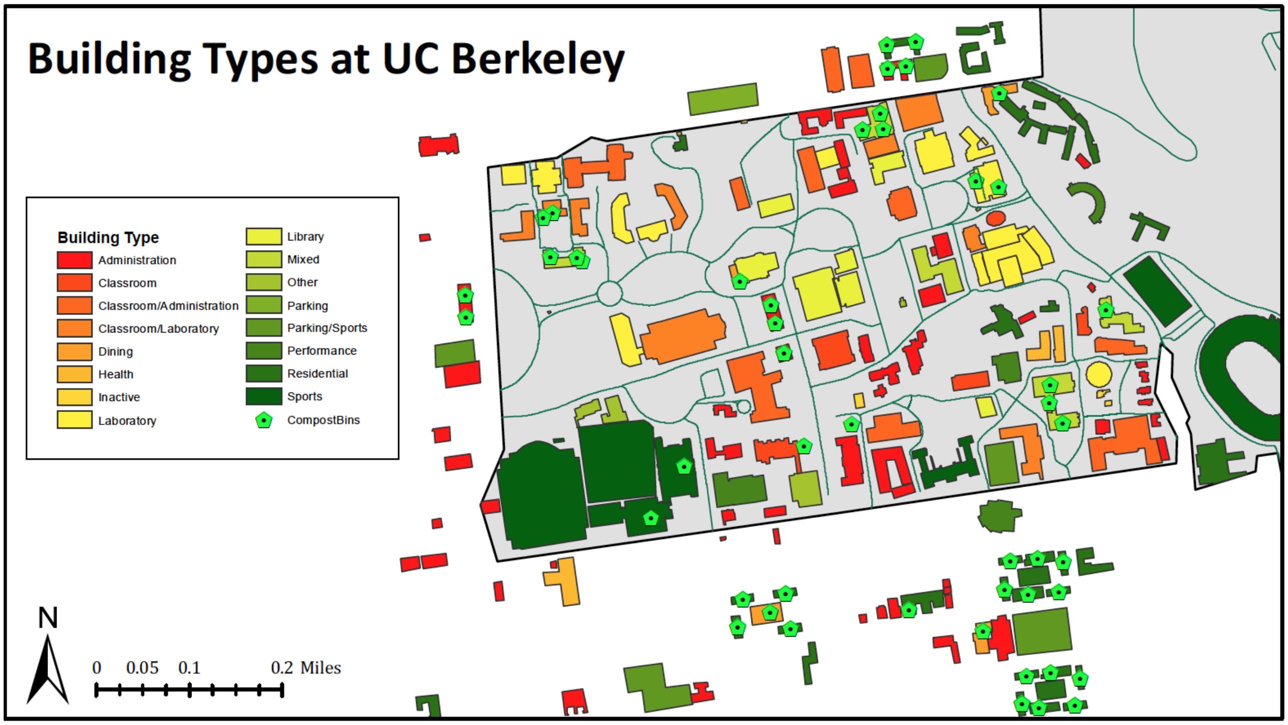

Figure 3. Building types at UC Berkeley. Buildings were characterized based on building information provided by Space and Capital Resources at UC Berkeley. The majority of the buildings on campus are used for administration or classroom purposes.

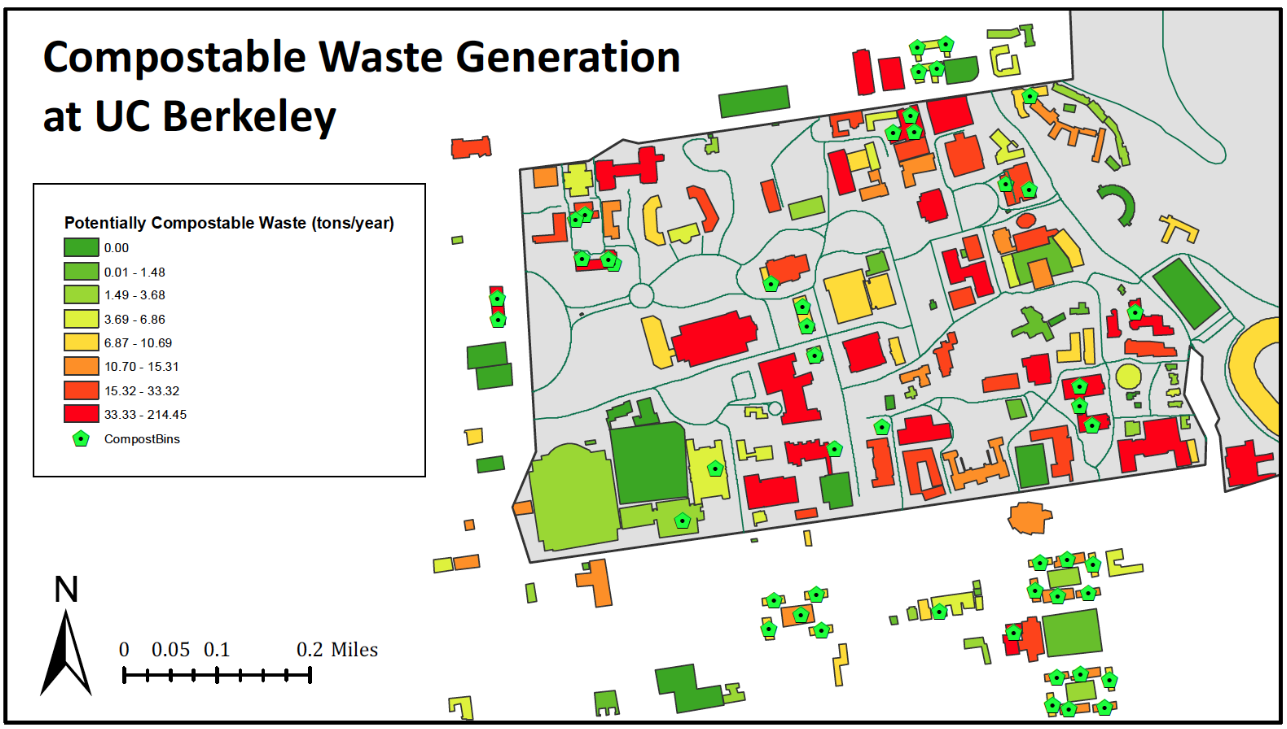

Figure 4. Organic waste generation in UC Berkeley buildings. Organic waste generation for each building was calculated based on building occupancy and the presence of preexisting compost bins. The majority of the campus is generating high levels of organic waste that should be directed to compost.

DISCUSSION

The results indicated that there is great potential for the University to move closer to its zero waste and GHG emission reduction goals by maximizing its organic waste diversion via new compost programs throughout the core campus. Under predicted compost diversion potentials, the campus can eliminate about 46.7% of its landfill waste, making the zero waste by 2020 goal attainable with efforts to increase green purchasing, recycling, and compost participation. The landfill waste GHG emissions will be minimized by 1203 $MTCO_2E$ towards the 2014 reduction goal, bringing the campus 6% closer to reaching 1990 emission levels. The campus waste generation map indicates specific building types to target new composting programs. This map will be a useful tool that informs decisions made by University officials to improve campus sustainability by revealing opportunities for significant waste reduction and suggesting the implementation of a more extensive compost program.

GHG emissions reduction

Addressing the climate impacts of municipal solid waste at UC Berkeley is an important step of the climate action plan to reduce GHG emissions to 1990 levels by 2014. Though GHG emission reduction by waste is still relatively small compared to other GHG sources such as electricity, commuter miles, construction, and water use, reducing waste is a minimally invasive and affordable step the University can take to reduce emissions. GHG emission reduction found at UC Berkeley was on the same order of magnitude as a compost diversion program implemented in a residential area in Vancouver (Cameron et al. 2012). These potential GHG reductions indicate the limited use of composting practices in both institutions and residential communities. Since waste management improvement is not limited to compost, the waste diversion and GHG reduction would be greater when paired with increased participation in recycling and decreased resource consumption. At current waste diversion rates and stalled expansion of campus-wide composting, the University is not on track to reach both 1990 GHG levels by 2014 and zero waste by 2020, and must expand its alternative waste management practices across campus for these goals to be attainable.

EPA Waste Reduction Model

The EPA WARM calculator is a widely accepted model of waste GHG emissions in the United States, but some assumptions are generalized for the entire country and are not California-specific (EPA 2011b). For example some landfills and composting facilities may use technologies that are not recognized by the WARM model, such as anaerobic digestion or other methods of energy and emissions capture. The lack of waste disaggregation from the waste audits introduced some error in the GHG conversion since I entered waste tonnage into the WARM model in the category labeled “Mixed Organics,” rather than other categories like food scraps, yard trimmings, PLA (polylactic acid), or paper. Disambiguation of the waste types may have yielded more accurate GHG emissions for all scenarios. The results of the EPA WARM model indicated that composting has negative GHG emissions because of increased soil carbon content and the carbon uptake of plants that grow using the compost (EPA 2012a). These emissions are not directly associated with the compost process and may change the campus GHG inventory depending on if campus researchers take into account agricultural and ecosystem benefits. Though the focus of my study was GHG emissions, the model does not address other environmental and health effects of increasing waste diversion from landfill, since benefits such as preventing soil leaching and groundwater contamination are hard to quantify in a general calculation (Morrissey et al. 2004). The relative lack of comprehensive waste audit data and the model’s flexibility limits the WARM’s accuracy, but the tool is still useful in gauging the order of magnitude of GHG reduction potential and will improve as the composition of the waste stream composition becomes more transparent.

Waste audits limitations

A greater understanding of the campus population’s waste disposal habits and more detailed information about waste composition are needed to fully assess the state of waste management on campus. There were several limitations that compromised the level of detail with which the audits were conducted and presented. CRRS conducted waste audits for only a few building types: administration, dining, classroom/administration, and laboratory. I based many assumptions on the limited waste audit data and my study would be more complete if more buildings types were audited. Waste audits for every building on campus ensures maximum understanding of the campus' waste, like the definitive waste audits conducted at Furman University that found that the campus had a 61% percent waste reduction potential via recycling and compost (Baldwin et al. 2012). For this to work at UC Berkeley, the methods used at Furman University would have to be scaled up for the larger building and campus population, but may not be timely or economically feasible.

An additional limitation of the waste audits was the lack of an in-depth breakdown of materials by the waste audits. For instance, it does not show the proportions of food scraps, food soiled paper, biodegradable plastics, waxed paper/cardboard, yard waste etc. Understanding the composition of the waste and the prevalence of different types of recyclable or compostable waste will help the University target certain waste types and possibly eliminating others through different purchasing practices. A study in Humboldt County used a more thorough waste audit procedure to separate the different types of organic waste, concluding that food waste is the most prevalent waste type (30%) in its residential sector (Humboldt 2012). The ability of Humboldt County to identify food waste as a prevalent source of compostable waste allowed the officials to target education and food scrap composting programs where they were needed. Similar results could be had at UC Berkeley if waste audits allowed waste management to target specific types of waste for diversion through targeted education and expanded disposal programs.

Waste generation calculation assumptions

Because the waste audit data was limited to a few building types, I made some assumptions about the waste disposal behavior of the campus and the different building uses I assigned to each building. My assumptions that every building recycles at campus recycling rate 24.6% and that all buildings with compost are diverting organic waste at the campus compost diversion rate 18.8% may be overestimates for the majority of buildings, since some building types may recycle or compost more than others. Buildings for which I had no data on organics diversion potential used a 37% potential that was found in the commercial sector of Humboldt County (Humboldt 2012). Mixed potential diversion rates equaled the average of the individual components (e.g. classroom/administrative diversion potential equaled the average of classroom and administrative potentials), even though the actual proportions may not be evenly distributed as the average assumes. The number of stations in a building approximated building occupancy and gave a general magnitude of how much waste a building might generate. However because building occupancy is dynamic and time-dependent, using the number of stations in a building is an overestimate of actual average building occupancy. Furthermore, the grand total of number of stations for all 213 buildings was greater than the campus population, so I scaled down the occupancy and building waste generation numbers by the appropriate percentage. The lack of information about building occupancy and trash disposal behavior demanded assumptions that may lead to an overestimation of waste generation in building types that have a greater number of stations than actual occupancy.

Organic waste diversion

Based on the waste audit data collected by CRRS, waste diversion potentials at UC Berkeley were indicative of a composting program with a limited service area and the need for program expansion. Currently, compost bins exist primarily in buildings with food vendors, however the results of the GIS analysis indicates that a large majority of campus buildings generate significant amounts of organic waste but are unserviced by existing bins. Further inquiry of these buildings indicates that the amount of organic waste generated is related to the building type. For example administration and classroom/administration buildings generate the greatest amount of organic waste compared to buildings such as parking structures or sports facilities. Waste generated by certain building types may be overestimates because the nature of the waste regulates its disposal methods. For instance, “Heath” and “Laboratory” buildings generate high levels of organic waste but are unable to compost them due to hazardous waste and health regulations. Even by maintaining current purchasing policies and maximum waste diversion, the campus will continue to send a significant proportion of its waste to landfill. Nevertheless, the results of the potential organic waste diversion analysis indicates that large administrative and classroom buildings should serve as the next targets for compost programs when the University approves their expansion.

In this study, I focused on buildings and excluded outdoor spaces and plazas because waste is far better understood by building since the occupant composition is more regular and predictable. Logistically, building occupants are easier to target for sustainability outreach programs, while the outdoor spaces also include visitors unaffiliated with UC Berkeley such as tourists, visitors, or city locals whose waste disposal behaviors are difficult to regulate. According to Lin King of CRRS, the large majority of the campus waste is from buildings, and outdoor trashcans contribute a small proportion of the campus total tonnage. Though ideally outdoor waste should be included in an authoritative campus waste audit, it is unrealistic it be targeted for organic waste diversion without the cooperation from businesses and citizens of the City of Berkeley.

Future actions

Besides targeting buildings for composting efforts, UC Berkeley can improve its understanding of its non-point-source waste generation in outdoor bins to increase its waste diversion levels through compost education programs and more compost waste management services. Future studies on campus waste generation should include regular waste audits of more building types, including residential halls, parking lots, and sports facilities. Behavioral studies on individual purchasing habits and willingness to take the extra step to compost or recycle are critical in deciding implementation strategies of compost programs the location of new compost bins. These steps will provide transparent data that can be used to easily assess the success of both recycling and compost programs and the steps necessary to improve them.

However there are economic and logistic limitations to alternative waste management program expansion because certain facilities must be equipped to handle compostable waste, staff must be properly trained, and the waste must be collected and hauled by separate campus services. To facilitate the logistic and custodial jobs, the campus can push for greater efforts in green product purchasing to begin to eliminate the need for landfill waste. Green product purchasing has been expanding for the past few years (Office of Sustainability 2012), but the composting programs have been slow to keep up. In addition to compost expansion, waste management education is vital for the campus population to understand and contribute to the University’s sustainability goals. Convenience and availability of compost bins paired with improved education and awareness of compostable materials and their benefits will help the University progress towards these goals faster than current practices allow.

CONCLUSION

In this study, I found that UC Berkeley should continue to expand its alternative waste management programs beyond its current scope to all buildings across campus. I suggest that the campus considers the buildings I classified as classroom/administration and administration buildings for future composting programs since they are heavy contributors of organic waste. Despite the University's commitment to sustainability, many policies and economic barriers impede the progress and success of sustainability programs, including recycling and composting efforts. Because of these current conditions, the possibility that the University reaches zero waste by 2020 and its emissions reduction goal by 2014 is questionable. However, identifying high waste generating areas and providing the resources for sustainable waste disposal will go long way in ensuring a zero waste and low emission future at UC Berkeley.

ACKNOWLEDGEMENTS

This project would not have been possible without the vision, guidance, and support of Lin King from Campus Refuse and Recycling Services and Kira Stoll at the Office of Sustainability. The Compost Alliance provided invaluable knowledge of campus composting practices and was essential for my understanding of current composting programs. Hanna Miller and the CRRS student waste audit team were the keystones to this project, since it would be nothing without their commitment to sorting trash and fearlessness of dumpster diving. Much thanks to the instructors and graduate students of Team 196 for all the work they put into grading assignments and giving invaluable feedback, particularly Patina Mendez and Vicki Wojcik for their helpful comments and Rachael Marzion for her insight and guidance in GIS. Kamini Iyer also provided GIS support and creative manipulation of data visualization. My workgroup provided endless moral support, especially my faithful peer reviewer, Monica Harnoto. Eva Wong generously shared her compost expertise and provided exhaustingly productive brainstorming opportunities. Carina Galicia helped me navigate through the trials and tribulations of the year with unwavering confidence and encouragement. Thanks to Jennifer Jong and my family for continued support and inspiration in all I do.

REFERENCES

Andersen, J.K., A. Boldrin, T.H. Christensen, and C. Scheutz. 2010. Greenhouse gas emissions from home composting of organic household waste. Waste Management 30:2475–2482.

Baldwin, E. and W. Dripps. 2012. Spatial characterization and analysis of the campus residential waste stream at a small private Liberal Arts Institution. Resources, Conservation and Recycling 65:107-115.

Bogner J., R. Pipatti, S. Hashimoto, C. Diaz, K. Mareckova, L. Diaz, P. Kjeldsen, S. Monni, A. Faaij, Q. Gao, T. Zhang, M. A. Ahmed, R. T. M. Sutamihardja, and R. Gregory. 2008. Mitigation of global greenhouse gas emissions from waste: conclusions and strategies from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report. Working Group III (Mitigation). Waste Management & Research 26:11-32.

Cameron, B., T. Khuu, D. Samels, A. Sheikh, C. Sun. 2012. Implementing a Food Scrap Composting Program in Downtown, Vancouver, British Columbia. The University of British Columbia, Vancouver, Canada.

Dauvergne P. 2010. The Problem of Consumption. Global Environmental Politics 10:1.

Environmental Protection Agency (EPA). 2008. Report on the Environment. Environmental Protection Agency, Washington D.C., USA.

Environmental Protection Agency (EPA). 2010. Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2010. Environmental Protection Agency, Washington D.C., USA.

Environmental Protection Agency (EPA). 2011a. Greenhouse Gas Emissions from a Typical Passenger Vehicle. Office of Transportation and Air Quality, Ann Arbor, MI, USA.

Environmental Protection Agency (EPA). 2011b. Reducing Greenhouse Gas Emissions through Recycling and Composting. Environmental Protection Agency, Region 10.

Environmental Protection Agency (EPA). 2012a. Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM). Environmental Protection Agency, Washington D.C.

Environmental Protection Agency (EPA). 2012b. Inventory of U.S. Greenhouse gas emissions and sinks: 1990-2010. Environmental Protection Agency, Washington D.C., USA.

Environmental Protection Agency (EPA). 2012c. Waste Reduction Model. <http://www.epa.gov/climatechange/waste/calculators/Warm_home.html>.

ESRI (Environmental Systems Resource Institute). 2012. ArcMap 10.1. ESRI, Redlands, CA, USA.

Hermann B. G., L. Debeer, B. De Wilde, K. Blok, and M. K. Patel. 2011. To compost or not to compost: Carbon and energy footprints of biodegradable materials' waste treatment. Polymer Degradation and Stability 96:1159-1171.

Humboldt Waste Management Authority. 2012. Humboldt County Waste Characterization Report. Cascadia Consulting Group, San Jose, CA.

Lam, Kimberly. 2012. Executive Summary of Report: Getting to 75% Diversion and Striving for Zero Waste. Chancellor's Advisory Committee on Sustainability. University of California, Berkeley.

McNeilly, L. and K. McKanna. 2009. 2009 Campus Sustainability Plan, University of California, Berkeley.

Morrissey, A.J. and J. Browne. 2004. Waste management models and their application to sustainable waste management. Waste Management 24:297-308.

Office of Sustainability. 2012. Campus Sustainability Report 2012. University of California, Berkeley.

Piemonte, V. 2011. Bioplastic Wastes: The Best Final Disposition for Energy Saving. Journal of polymers and the environment 19(4):988-994.

Razza, F., M. Fieschi, F.D. Innocenti and C. Bastioli. "Compostable Cutlery and Waste Management: An LCA Approach." *Waste Management* 29(4):1424–1433.

Shah, A.A., F. Hasan, A. Hameed and S.Ahmed. 2007. Biological degradation of plastics: a comprehensive review. Biotechnology Advances 26:246–265.

Sugerman, K.A. 2011. 2011 Campus Sustainability Report, University of California, Berkeley.

APPENDIX A: Greenhouse Gas Emissions

Table A1. UC Berkeley campus GHG levels throughout the years. California Assembly Bill 32, the Global Warming Solutions Act set a goal to lower 2020 GHG levels to 1990 levels. UC Berkeley plans to reach this by 2014.

Year	Total Campus Emissions ($MTCO_2E$)
1990	163,646
1995	168,318
2000	245,587
2007	207,215
2008	209,998
2009	188,959
2010	180,390
2011	183,339

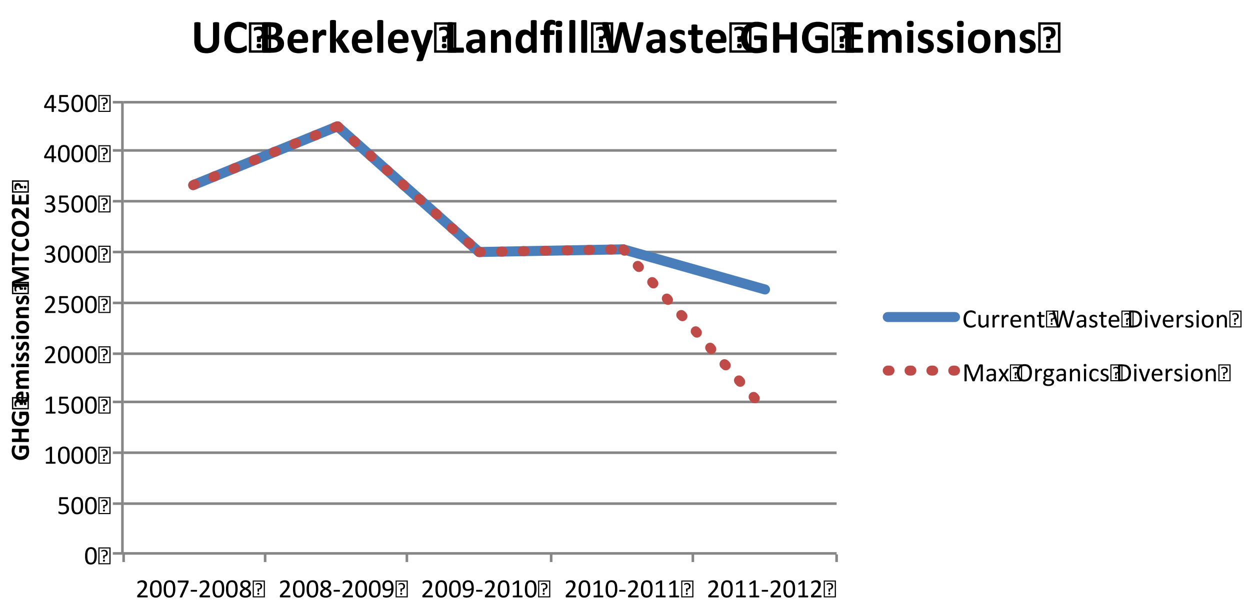

Figure A2. Campus landfill waste GHG reductions 2007-2012. The landfill GHG emissions at UC Berkeley are steadily declining, but could be dropping at a faster rate if the campus reaches maximum organics diversion.

Table A2. Effects of transporting compost to a closer facility. a) Emissions reduction possible with compost transported to the current site in Modesto CA. b) Emissions reduction possible when compost is sent to an Oakland anaerobic digester facility. All data is in $MTCO_2E$.

(a)

BAU Scenario	
Current Waste Diversion	2625
46.7% Organics Diversion	1422
GHG reduction	1203
% Reduction	45.8%

(b)

EBMUD Scenario	
Current Waste Diversion	2606
46.7% Organics Diversion	1374
GHG reduction	1232
% Reduction	47.3%

APPENDIX B: Building Waste Generation

Table B1. Campus waste generation by building type. Classroom/Administration buildings contribute the greatest tonnage and percentages of all waste types (landfill, organics, total MSW).

Building Type	Landfill Waste (tons)	Potential Compost (tons)	% of Total Landfill	% of All Organics	% Total MSW
Classroom/Administration	1724.08	910.31	24.88%	28.13%	25.06%
Administration	1131.69	565.84	16.33%	17.48%	16.45%
Residential	790.41	339.88	11.41%	10.50%	11.13%
Classroom/Laboratory	709.84	293.16	10.24%	9.06%	10.42%
Mixed	635.66	329.78	9.17%	10.19%	9.09%
Laboratory	581.16	156.91	8.39%	4.85%	8.54%
Classroom	455.29	253.14	6.57%	7.82%	6.41%
Performance	392.35	196.17	5.66%	6.06%	5.47%
Dining	191.26	86.64	2.76%	2.68%	2.76%
Library	129.33	47.85	1.87%	1.48%	1.91%
Sports	81.61	30.19	1.18%	0.93%	1.20%
Health	72.06	26.66	1.04%	0.82%	1.06%
Other	33.90	0	0.49%	0.00%	0.50%
Inactive	0.19	0	0.00%	0.00%	0.00%
Parking	0	0	0.00%	0.00%	0.00%
Parking/Sports	0.096	0.036	0.00%	0.00%	0.00%
Grand Total	**6928.92**	**3236.59**	**100.00%**	**100.00%**	**100.00%**