Waste Reduction at the University of Richmond

Recommendations for a Greener, Cleaner Campus

J.R. Mastro, Jaquelyn Pearlmutter, Joe Walderman, Alexa Williams

1. Introduction

"In the United States it takes 12.2 acres to supply the average person's basic needs; in the Netherlands, 8 acres, in India, 1 acre. . . if the entire world lived like North Americans, it would take three planet Earths to support the present world population" (Hart, 1996). Clearly, there is need for changes in both consumption and waste habits in the United States.

About 133 billion pounds of food is wasted annually in the United States, contributing to 18% of national methane emissions (EPA, 2016). This impacts food security, as much of the food wasted could otherwise feed millions of food insecure Americans (EPA, 2016). With proper education and diversion programs, much of this waste could be eliminated. In 2014 each U.S. citizen produces 4.40 pounds of municipal solid waste each day (Advancing Sustainable Management, 2014). Trash accumulates in landfills, taking up acres of land, decomposing, and producing methane, a potent greenhouse gas (GHG) that is 25-times more potent as a heat trapping gas than carbon dioxide, even in smaller concentrations (EPA, 2016). By 2030, the Environmental Protection Agency (EPA) has called for a 50% reduction in waste in efforts to conserve lands, preserve natural resources, and reduce emissions of various pollutants (EPA, 2016). In order to address this problem and reach the goals set by the EPA, Universities need to be a driving force. There have been many national campaigns designed to diminish waste, including the well-known "Reduce, Reuse, Recycle" program nationwide, which the University of Richmond promotes through continual recycling-geared events. However, the waste epidemic remains, leading us to propose changes in this research paper.

Connecting with the University of Richmond goals of stewardship and academic achievement both in and outside the classroom, we have constructed a plan for making the University campus more sustainable. By applying knowledge acquired throughout our Environmental Studies education, and understanding its connection to global issues, we hope to make a positive, lasting impact on our campus community. In the 2017 Strategic Plan, the University describes a vision of "modelling the way that colleges and universities can effectively meet the challenges of our time" (UR Strategic Plan, 2017). Although there is a broad range of environmental issues that can be addressed by universities, we focus on a solution to address food waste on the University of Richmond campus.

By finding successful waste management solutions and incorporating these practices, The University of Richmond can become a stronger leader among the highly selective liberal arts colleges it competes with. With a challenge to "Rethink Waste" on campus, student and faculty initiatives will continue to be important to help the University of Richmond to reach its goal of an 80% waste diversion by 2020. This implies that by 2020, 80% of the waste generated will be composted, recycled, or donated instead of accumulating in landfills (2010 UR Climate Action Plan). Currently, a consultancy firm called "Reduction In Motion" is working with the University to increase the percentage of waste both recycled and composted on campus. Composting is an important mechanism for reducing waste because it educates the local community, creates natural, nutrient-rich soil that can be used to grow crops, and reduces the quantity of waste going to landfills. To further increase recycling and composting on campus, each building has conducted multiple waste audits to further understand the amount of waste produced and the types of waste products generated on different parts of campus. All of these findings can help the University more effectively and actively recycle on campus. However, additional waste reduction initiatives and programs will be critical to help ensure that the University reaches these ambitious goals in a timely manner.

Although the University generates food waste from each of the dining locations on campus, the largest single source is the Heilman Dining Center (HDC). Currently, the HDC produces about 4,322.5 pounds of waste each week, amounting to about 1.44 pounds per student. Therefore, we have devised a two-part proposal for the University to implement, which will help to achieve substantial reductions in food waste from HDC. A combined effort in (1) removing trays from HDC and (2) diverting food waste to an on-campus anaerobic digester, will help reduce the University waste stream while using remaining food waste to produce clean energy on campus and support composting projects.

This project has many other far-reaching benefits to campus. First, it will raise awareness of the waste epidemic, by promoting sustainable student habits. Secondly, it will reduce GHG emissions from the University, primarily carbon dioxide and methane, the most threatening of all GHGs. Additionally, it will produce more renewable energy on-campus, and save University expenses on food, transportation, water, and electricity.

By implementing both programs, the University does much more than simply achieve its stated 80% waste reduction goals—this project also has significant benefits for University accreditation (UR Strategic Plan, 2017). Both projects can be applied and integrated into the academics of the school, bringing students out of the classroom and into a “living-lab" to learn more about waste reduction in motion. Studies associated with this project could be performed by a variety of disciplines, for both student and faculty alike. Accomplishing both projects will also provide the University with a competitive edge over admissions rivals by demonstrating a commitment to the environment and displaying leadership through a unique energy project.

An additional outcome of this proposal is enhanced sustainability at the University. Sustainability is demonstrated by a commitment for environmentally friendly practices through limiting waste, reducing emissions, and embracing student initiatives (Burgett *et Al.* 2012). Sustainability incorporates economic, social, and environmental equity by preserving the environment in a natural state for both the current and future generations (Burgett *et Al.* 2012). In a world where humans are both directly and indirectly dependent on the natural environment, we must continue to preserve and conserve vital resources.

2. Literature Review:

Waste reduction can provide widespread advantages on both local and global scales. A large component of changing waste reduction behavior is through education. Several researchers studied a low-income urban community in East Harlem, New York to understand the effectiveness of waste reduction education, specifically on recycling. The researchers designed an outreach program about waste reduction and focused on how the attitudes and behaviors of the community changed over a year as a result of educational programs. The results indicated an increase in total daily recyclables by 2.7 tons within the community (Margai, 1997). These results are applicable to the Richmond community because they demonstrate the importance of educational programs geared at changing habits in consumption and disposal of waste. Local waste reduction on a university campus can be particularly effective in improving student understanding of the important pathways to sustainable living. Exposing students to the benefits and practices of waste reduction during their college career can ensure their continuation when those students are in the real world, making daily lifestyle choices. One of the main ways the University of Richmond has incorporated this educational component is by promoting the active engagement of students in waste audits. These audits help students to fully understand the complexity and severity of the waste issue on campus. This experience is often very alarming and transformative, as it teaches both students and faculty how much the university community wastes that could be recycled and composted.

In *Beyond Greening: Strategies for a Sustainable World*, Stuart Hart (1996) discusses the need for developing a "*sustainable global economy:* an economy that the planet is capable of supporting indefinitely." The three stages for incorporating this "sustainable global economy" are (1) pollution prevention, (2) product stewardship, and (3) clean technology. Pollution prevention involves both reducing and/or eliminating waste on the production side and minimizing the disposal of this waste, typically through recycling or composting. Product stewardship describes reducing and/or eliminating the environmental impacts caused by waste by designing innovative ways of reusing waste, while clean technology involves rethinking current waste systems and investing in more environmentally sustainable practices (Hart, 1996). Hart (1996) discusses how companies can apply these clean practices and technologies, serving as leaders for developing nations who often reproduce the successful westernized technologies they see. This strategy can also be applied to a university setting. Hart's three stages directly relate to our project in promoting a sustainable vision on campus: the trayless movement represents pollution prevention, while the biodigester represents product stewardship. Our entire project represents clean technology, as we are streamlining our waste system and promoting University investment in sustainable practices. Combining these factors, this project will allow us to take steps towards achieving a sustainable local economy.

Student initiatives among college campuses can translate to larger and more widespread energy and waste projects capable of cumulatively aiding the global environment and promotion of the practices world-wide. Adopting a "whole-of-university approach" by "linking academic curriculum, research, campus operations, and student engagement," has been demonstrated to increase the successful implementation of sustainable practices on college campuses (McMillin and Dyball, 2009). The "whole-of-university" approach recognizes that sharing knowledge across a university community can provide benefits and contribute towards a positive student learning experience by creating an understanding to the applications of sustainability. Additionally, different green technology and outreach programs on campus can contribute to maintaining these lifestyles beyond an undergraduate education (McMillin and Dyball, 2009). Therefore, even this local project has ties to increased sustainability on a much larger scale.

The University of Richmond has begun to educate students on green technology through the solar array located over the Weinstein Recreational Center (WRC). The WRC solar array produces 237,000 kilowatt-hours of electricity for campus, offsetting 364,000 pounds of potential carbon dioxide emissions (Andrejewski, 2017). However, this represents only 1% percent of our overall energy consumption, equating to the electricity use of the Gateway Apartments on campus (Andrejewski, 2017). The University should continue to invest in clean, renewable energy to reduce our carbon footprint and GHG contributions, while also decreasing spending on fossil fuels. The production of more renewable energy through our project will benefit the campus by saving money in the long-run and also improving energy security through the creation of a local and reliable source of energy from the power plant on campus.

The University has other goals that this project will help to achieve and expand upon. According to the 2010 Climate Action Plan, the University of Richmond is dedicated to the reduction of GHG emissions by 30% by 2020 from 2009 baseline levels, and becoming completely carbon neutral by 2050 (Climate Action Plan, 2010). Continuous production of high levels of waste and its diversion to landfills is not only dangerous for the environment, but cannot be sustained. The HDC alone sends about 617.5 lbs of food waste to the landfill daily (Clemmor, 2017). The University has to transport this waste to landfills weekly, which has affiliated GHG emissions of its own. Currently, the University has a small composting program in place, diverting some of our food waste leftovers and instead using their nutrients to replenish the land. This practice reduces University contributions to landfill emissions; however, this program alone is insufficient in meeting the University's waste reduction goals. Trayless dining and an on-campus anaerobic digester may provide the solution, creating a decrease in our GHG emissions.

3. Waste Reduction Methods:

In order to meet the University goals of stewardship, academic integrity, emission elimination, and waste reductions, we identified two linked projects: a trayless movement and an anaerobic biodigester. Trayless dining is a system that eliminates the larger trays in HDC used for holding multiple plates, bowls, cups, and utensils. Decreasing the amount of food a patron walks away with decreases the amount of food they inevitably do not consume. Trayless dining has been studied by many universities and has been proven to achieve further sustainability on campuses (Burgett e*t. Al*., 2012). The biodigester project is a method of closing the food-waste loop. The process takes the undesired food waste and turns it into two separately valuable products. Pre- and post- consumer food waste is collected to be chemically decomposed in an air-tight chamber. As the waste breaks down, the biogas created can be harnessed to produce clean, versatile energy. Solid remnants after decomposition are nutrient-rich and used as compost, returning the food waste back to the earth.

Although waste is a global issue, this project will focus on the University of Richmond campus. Reducing our own impact is the first step in promoting lasting change for the broader community. We utilized the "whole-of-university" approach discussed by McMiller and Dyball (2009), because it highlights the interconnectivity of a college campus, and the critical components for introducing a new sustainable practice on campus. To successfully transition to a trayless dining system and a biodigester process, it is integral to have a "whole-of-university" collaboration; this will promote understanding of these more sustainable actions on campus and the many benefits they provide in furthering environmental education and creating awareness of individual environmental impacts (McMillin and Dyball, 2009).

Incorporating this approach, we gathered data from keys leaders on campus including facilities, dining services, landscaping crew, as well as other individuals responsible for fulfilling the strategic plan. The data gathered was important for understanding the current waste management systems on campus and the obstacles that the University must overcome to become more sustainable in its waste disposal practices. We also contacted universities that have serve as models of sustainability, attempting to learn how their various student-run initiatives succeeded in implementing similar projects. Additionally, we predict that customers of HDC such as University students, faculty, administrators, and visitors will be integral to the success of this proposal. These customers will be educated on advantages of reducing waste and going trayless; their understanding of and cooperation with the proposed changes are integral to its success and lasting impact on campus.

4. Trayless

Literature Review

In the United States, food waste is a national challenge with financial, environmental and social ramifications (Retail Food Waste, 2016). Annually, 90 billion pounds of food is wasted in the United States, which is equivalent to $161.6 billion (Retail Food Waste, 2016). After being disposed of, over 50% of waste is diverted to landfills (Lopez *et al*., 2016). The food material deposited in landfills across the country rapidly decomposes and produces the dangerous GHG methane. This makes food waste a detrimental contributor to climate change. In addition to economic and environmental consequences, food waste has negative social implications given some individuals waste food while others lack food security. In 2014, 48.1 million Americans (32.8 million adults and 15.3 million children) “lived in food insecure households” (Retail Food Waste, 2016: 2). Food insecurity is a state of limited or uncertain access to sufficient nutritious food, and 14% U.S. households fall into this category (Retail Food Waste, 2016).

With food waste negatively affecting various aspects of society, we must begin to understand and educate the general public on how individual actions can help curb this issue. A great way to start this conversation is among colleges and universities across the country. University campuses serve a vital role in education and experimentation as their population size represents smaller versions of cities, thus giving their actions financial and environmental implications (Painter *et al*., 2016). To put university impacts into perspective, universities worldwide are responsible for about 540 million tons of food waste every year (Painter *et al*., 2016). College campuses need to take a proactive approach to become leaders in progressive change by introducing sustainable and innovative ways to address their own waste issues. As greener practices become successfully integrated on campus "they can in turn be replicated in surrounding communities" (Painter *et al*., 2016). Sustainable initiatives have an educational component for the local community, they teach students about their "moral and ethical responsibility… towards sustainability" and shape how students interact with the environment and conceptualize waste beyond the campus (Painter *et al*., 2016: 492). This allows for students to work directly with global issues, making them a more conscious citizen of the world. To reach the goals of 80% reduction in waste in the Strategic Plan, students, administration, and faculty will have to be agents of change by incorporating sustainable practices into their daily lifestyles and being receptive to adapting to new policies on campus (McMillin and Dyball, 2009).

Background On Trayless Dining

Becoming trayless represents a commitment of universities to sustainable practices. Increasingly, universities have adopted trayless initiatives because of the many benefits in terms of water, energy, and food savings. Trayless dining has grown with the sustainability movement because it reduces over-consumption and the amount of waste left on the dishware after a dining period. This is not a new concept to the University; in the past, the HDC has initiated "Trayless Fridays" as an educational awareness opportunity, and to study and show the benefits of eliminating trays. These trayless dining days have been a major success in demonstrating the feasibility of transitioning to a permanent trayless dining system at the University of Richmond.

Methods

In order to learn more about the process of transitioning to trayless dining, we gathered information from HDC and other liberal arts colleges that have already made the switch. To learn about the waste disposal practices at HDC, we toured the facilities, conducted interviews with key leaders at dining services, and compared the system on trayless days versus non-trayless days. We then analyzed the food waste data on trayless versus non-trayless days, to evaluate whether there was a measurable reduction in waste by removing trays.

In a tour of the dining facilities conducted by Glen Pruden, the executive chef and system director of the HDC, we first explored the dish room to learn about the waste management system. The trays, dishware, and utensils that customers place onto the conveyor belt travel to the dishroom, where workers take these items and place them under a constant trough of water to scrape food waste into a constant stream of wastewater that leads to a pulper machine. This machine extracts the solids, reducing the solid waste that goes into water treatment. The pulp that comes out of this machine goes to the landfill. After this pre-wash process, the trays, dishware, and utensils go into a washing machine, where they are washed and sanitized. This washing machine has many horizontal slits that fit both trays and plates. This tour and associated interviews gave us a better understanding of the current practices for handling waste in the HDC (Glen Pruden, 2017).

Additional research included collecting data to understand the dining approaches of the top 30 liberal arts colleges based on the U.S. News Ranking System (U.S. News, 2017). To collect this data, we reached out to these colleges and universities either through email or phone to inquire about their current dining systems. For the colleges and universities that had made the switch to trayless dining, we paid special attention to the benefits and drawbacks of their systems and the transitions, if any, their dining halls underwent. We also contacted the University of Richmond's Dean of Admissions, Gil Villanueva, to learn which schools Richmond typically competes with academically for students. Bucknell, Wake Forest, Boston University, and Colgate are four of Richmond's top competitors for students. The main school we analyzed was Colgate University, where an extensive proposal called *Exploring the Economic, Environment and Social Implications of Trayless Dining at Colgate University* successfully initiated trayless dining at Colgate when it was recognized by the student government (Burgett *et al*., 2011). We analyzed this proposal to learn whether Colgate University experienced economic savings by transitioning to a trayless dining program, along with the potential obstacles that need to be overcome.

Results

Other Universities

An important way to gauge the potential success of a trayless initiative was to directly compare Richmond to schools that are academically and ideologically similar. Of the top 30 liberal arts colleges, 23 schools have implemented some form of a trayless dining program (Figure 1). The seven schools that do not have trayless dining include Swarthmore, Davidson, the Naval Academy, West Point, Grinnell, Barnard, and the University of Richmond. Interestingly, the top four liberal arts colleges (Williams, Amherst, Wellesley, and Middlebury) each have implemented trayless dining. Bucknell, Wake Forest, Boston University, and Colgate (four schools that Richmond competes intensively with for students) all have successfully removed trays. The data received from these universities emphasizes the economic savings achieved from the transition. After transitioning in 2011, Bucknell has reduced 150 pounds of waste per day, while also saving water and electricity.

The Trayless Dining Transition Among the Top 30 Liberal Arts Colleges		
Rank	Name	Trayless Program
1	Williams College	YES
2	Amherst College	YES
3	Wellesley College	YES
4	Middlebury College	YES
5	Swarthmore College	NO
6	Bowdoin College	YES
7	Carleton College	YES
8	Pomona College	YES
9	Claremont McKenna College	YES
10	Davidson College	NO
11	Washington and Lee University	YES
12	Colby College	YES
13	Colgate University	YES
14	Hamilton College	YES
15	Haverford College	YES
16	Smith College	YES
17	Naval Academy	NO
18	Vassar College	YES
19	Grinnell College	NO
20	West Point	NO
21	Harvey Mudd College	YES
22	Wesleyan University	YES
23	Scripps College	YES
24	Colorado College	YES
25	Macalester College	YES
26	Oberlin College	YES
27	Barnard College	NO
27	Bates College	YES
27	Kenyon College	YES
27	**University of Richmond**	**NO**

Figure 1. Dining at the top 30 liberal arts colleges. 77% of top 30 colleges/universities have transitioned to trayless dining

Wake Forest University has reported saving 900 gallons of water a day, which equates to 198,000 gallons of water saved every school year (Dining FAQs, 2017). Boston University also reported significant savings of 35,000 gallons of water a week since becoming trayless (Trayless Dining, 2017).

Similarly, Burgett *et al.* (2011) found that schools which have transitioned to trayless dining have experienced an overall 30% reduction in waste. The study at Colgate University reported savings in both water and electricity because water must be heated to between 140°F to 160°F to sanitize trays, which requires a significant amount of energy. The study also estimates about 1/3 of a gallon of water is needed to clean one tray (Burgett *et al.*, 2011).

An obstacle that Colgate successfully overcame was student perception, an issue we considered as well. According to HDC administrators, current trayless dining days are met with perceived discontent among the student body, but there is no statistical evidence to back this up (Jerry Clemmor, 2017). In addition to student disapproval, HDC administrators worry that removing trays will result in longer lines and wait times (Jerry Clemmor 2017). However, observational studies conducted in the Colgate dining hall on trayless days have debunked this perception, with findings of no significant increase in wait times on trayless days. Through these observations, Burget *et al*. (2011) selected students randomly and measured the amount of time they waited in line, along with the number of people in line on both trayless and non-trayless days. Burget et al. (2011) found that mean wait times actually decreased on the trayless dining day in the entrée line.

Colgate is a university comparable to the University of Richmond, with total undergraduate enrollments of 2,884, and 2,990, respectively. This comparison allows us to consider the information from the Colgate proposal in our analysis of the University of Richmond and roughly estimate the potential savings the University of Richmond could experience by going trayless, along with information that future studies at HDC should address. One aspect of the Colgate proposal that contributed to its success was the inclusion of survey studies to gage student perceptions on becoming trayless (n=79). In the survey conducted, 47% of students supported the switch to trayless dining, while 33% did not support to the switch. The remaining 20% had no opinion (Burgett *et al.,* 2011).

Waste Savings at the University of Richmond

Analyzing data from dining services at HDC, there is a 40% reduction in waste on trayless days. On average, the HDC has 3,687 customers per day and the HDC estimates that about 2 to 2.6 oz of waste is produced for every tray a customer uses (Jerry Clemmor, 2017). The average waste produced per day with trays at the University of Richmond is 617.5 lbs (Figure 2). This number provides a comparison for waste saved by going trayless. The average value of waste produced per day on trayless days is 370.56 lbs. This average value was taken from nine different “Trayless Friday” waste audit events during the 2015-2016 academic school year (Figure 2). Using these values, the University would save an average of 246.94 lbs of waste per day by going trayless. During an entire academic year (210 days), this would save an average of 51,857.4 lbs of waste currently transported to landfills from the University of Richmond.

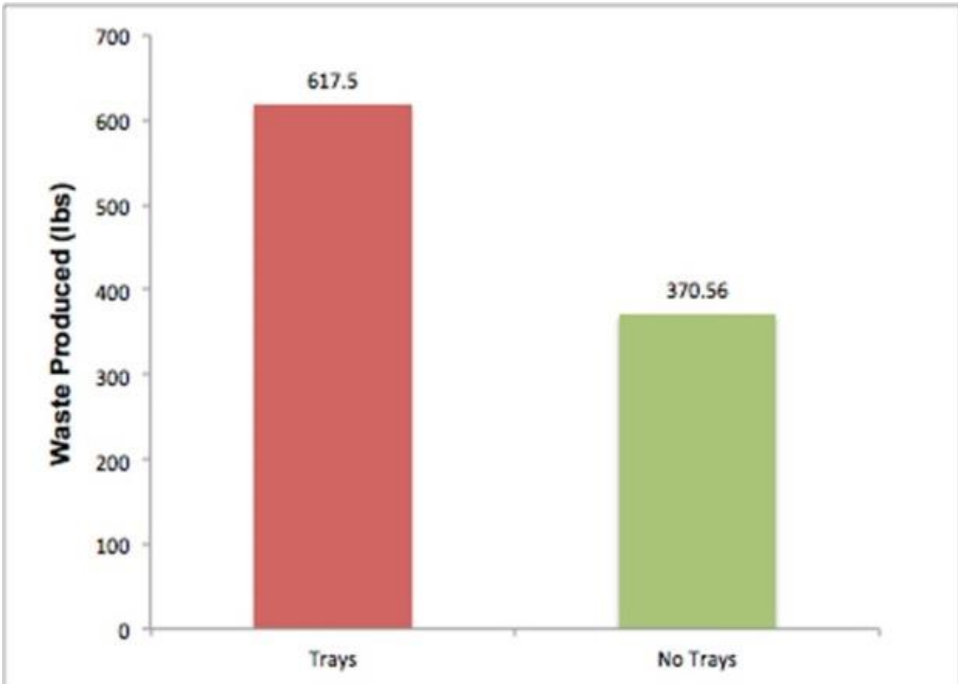

Figure 2. Trayless dining events at the University of Richmond. Average food waste produced on nine trayless dining events during the academic school year of Fall 2015 through Spring

Discussion

Overall, based on our analysis of the feasibility and benefits of trayless dining at the University of Richmond, we recommend a transition to trayless dining. This section will focus on the benefits of a trayless dining program at the University of Richmond, the feasibility, how to overcome some of the potential obstacles, and future studies/ recommendations to initiate this transition.

Reduction in waste

One of the main benefits of transitioning to trayless dining is the reduction in waste. This has been proved at the University of Richmond, and at the other 23 top liberal arts colleges which have switched to trayless dining. In the long term, going trayless at the University of Richmond will reduce the amount of food acquired, prepared, and disposed. By reducing the amount of food purchased and prepared, the University of Richmond will experience financial savings and reduce its environmental impact. Since making the transition to trayless dining in 2012, Colgate estimated an annual savings of $100,700 and reduced 2 metric tons of CO_2 from 2011 to 2015 (Food and Dining, 2015).

Reduction in Energy and Water Savings Benefit

Another benefit of transitioning to a trayless dining system is the reduction in water and energy consumption. Although we were unable to use data collected on water and energy savings at the University of Richmond, Colgate served as a model to illustrate these potential savings. Burgett el al. (2011) estimates savings of up to 12,075 gallons of water a year by going trayless. Without trays, university dishwashing machines run less frequently, resulting in less energy and water used, translating to monetary savings (Burgett *et al.*, 2011). Although the University of Richmond washing machine fits both trays and dishware, it would be expected to run less frequently and use less energy without the average 3,687 trays that it must clean during a school day. Applying the estimate of 1/3 gallons of water used to clean a day, and assuming all customers at HDC use trays, this would indicate 1,229 gallons of water is used per day to clean trays (Burgett *et al*., 2011). Furthermore, the waste water produced by the washing machine is contaminated because it has been mixed with food and chemicals. Water conservation is an important issue for future generations, so by acting now, the University would become a key leader in preserving water (Green Tip, 2012). Additionally, the process of heating water to sanitize trays requires energy, as illustrated in the Colgate Proposal, and the specific amount should be further explored in future studies at the HDC.

Health Benefits

As observed on trayless dining days at the University of Richmond, less waste is being produced because of the smaller portions students take on these days. The smaller serving sizes provide health benefits because smaller portions enable students to have time to digest their food before going back for second or even third servings (Tagtwon and Harmon, 2009). With a tray, students take larger portions and often overload, later realizing that they had overestimated their appetite. Many students do not think about the implications of this waste left on their plate, so by becoming trayless, students begin to understand the benefits and become actively engaged in applying sustainable practices in their everyday lifestyles by reducing food waste (McMiller and Dyball, 2009).

Increase in School Status

Overall, universities aspire to be key leaders in sustainable practices. The University of Richmond has an opportunity to lead by transitioning to trayless dining. With UR competing for top students, it is important to understand where our competitors stand on trayless dining and other sustainability practices. As mentioned before, trayless dining represents a commitment to reducing environmental damages, which is an attractive attribute that is valued by prospective students. With the top four liberal arts colleges (Williams, Amherst, Wellesley, and Middlebury) having a trayless dining program, as well as 77% of the top 30 liberal arts colleges, it should be apparent that trayless dining is a direction that top universities are moving in. The willingness and successful transition of these schools demonstrates the feasibility of initiating a trayless dining program at the University of Richmond.

Educational Component: Introducing Sustainability

Through the implementation of a trayless dining program, students are educated on the negative impacts of over consumption and wastefulness. They serve as participants and witnesses to the benefits of trayless dining. Sustainable practices on campus, like trayless dining, introduce students to the fact that their choices have a direct impact on the world around them, on both a local and a global scale by reducing waste. By continuing to incorporate classes and projects around the driving forces behind the transition and the issue of food waste in general, the University of Richmond can adopt a 'whole-of-university' approach to sustainability. A 'whole-of-university' approach incorporates "research, educational, operational, and outreach activities and engages students in each" with a purpose of successfully integrate sustainable practices on campus (McMillin and Dyball, 2009).

Feasibility/ Overcoming the Obstacles

A main obstacle to becoming trayless is the fear of student unrest. Currently, students are accustomed to the ease of having trays, so there may be some initial pushback against the program. However, often when a new program is initiated, there is often some initial resistance, but this typically fades with time (McMillin and Dyball, 2009). This was found to be the case with Colgate, as students learned to adjust to a new dining experience without trays (Burget *et al.*, 2011). In order to ease the transition to trayless dining at HDC, the program should be started at the beginning of a new academic year, so that the freshman class would be unfamiliar with the idea of having trays. To accommodate those who still need trays, such as the elderly, the University could still provide trays under certain circumstances. Another solution could be larger dishware; however, this would contribute to upfront costs, and is not a strict requirement of implementing the trayless program at HDC.

To eradicate trays at the University of Richmond, several changes have been recommended by HDC administrators. The main challenge is the current conveyor belt system for returning dishware. One option is to keep the current system as it is, but require students to scrape their plates off into trash cans before sending them to the dish room to prevent an overwhelming amount of dishware and waste build up on the conveyor belt. This system is similar to how "trayless Friday" events are currently administered. The other option is to completely change the system. Plans to renovate HDC are already underway, so an updated conveyor belt system could be implemented during the renovations; but this is also not a strict requirement for the University to go trayless. Similar to Richmond, Colgate University had plans to renovate their dining hall when Burget *et al.* (2011) prepared their trayless proposal. This allowed the conveyor belt to be redesigned during these changes to their dining facility (Burget *et al.*, 2011). Overall, we have concluded that trayless dining would be feasible with the current conveyor belt, and if the HDC does choose to make renovations, the system could be changed to have a spot to place utensils and cups in efforts to separate these items from the dishware that would continue down the conveyor belt. This new system could be similar to the dishware system at Dana dining hall at Colby College, which has two bins at the beginning of the conveyor belt, one for utensils and another for cups, and then a flat conveyor belt where students place dishware that goes around to a backroom, where workers dump any remaining waste and clean the items. Since the current dishwasher at HDC fits both trays and dishware, this machine would not have to be updated, which makes the trayless program even more feasible at Richmond.

Another recommendation to make the trayless system more feasible at HDC is to change the current layout of the utensil stations. Currently, utensils are provided in the food area of the dining hall, rather than in the dining area. Many universities that have been successful at becoming trayless, including Colby College, have the utensil stations in the dining room, which makes it easier for students to carry their plates without a tray. These utensil stations could be moved into each dining room of the HDC to make it convenient for students to access them after placing down their dishware onto the tables. This would entail an initial upfront cost to move these utensil stations; however, over time less waste and reduced energy and water consumption due to the elimination of trays would contribute to savings. Again, with impending renovations to HDC, key alterations could be made to the dining facility during this time.

Additional suggestions to reduce waste include switching to bulk butter and cream cheese instead of individual packets, which would also create savings. The peanut butter and Nutella is currently provided in bulk, but the drawback for dairy-based products is potential expiration or excess waste at the end of a day. However, a similar argument can be applied to nut products in bulk as these are potential allergens and the University was still able to create a section of HDC for these products. Dining facilities mentioned the issue of contamination with these communal stations, but did not report any current problems with the bulk products offered already.

Dining Services also expressed concern over students leaving more dishware and trash on tables when not provided with a tray (Glen Pruden, 2017). This increases the need for dining staff to clear and clean the tables. A solution would be to leave signs on the table to remind students to bring all their dishware as they leave. A potential sign that can be used to help ease this transition and also prevent students from leaving dishes on tables by understanding the benefits is illustrated in figure 3. Another way students can prevent the buildup of dishware is by bringing their plates to the conveyor belt as they are on their way to get second or third servings. This makes it easier at the end of the meal because dishware does not accumulate on the table.

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Figure 3: Trayless Poster that could be placed in the HDC to illustrate the benefits to students, faculty, administrators, and other customers.

Recommendations

- **Surveys**

  In the future, surveys should be distributed to the student body, faculty, and HDC staff. These surveys would allow for a better understanding of where the University body stands on the topic of trayless dining. Future findings from these surveys could be used to further persuade administrators to approve the transition to trayless dining, as they did in the case of the Colgate proposal (Burget *et al.*, 2011).

- **Economic Analysis**

  To further understand the economic savings that will come with going trayless, future studies need to address the following questions:

  - What percentage of the HDC dishwasher is filled with trays?
  - How much energy and water is used to run the machine?
  - How much water does the machine use in an operating day cycle?

- How many trays does the machine process?

With answers to these questions the University administration will be able to better understand the economic benefits of a transition to trayless dining in the HDC.

- **Pilot Program**

A two week pilot program in the HDC will allow for further data to be collected on student perception, dining hall capacity for going trayless, and waste reductions.

5. Biodigester

Literature Review

Integrating an anaerobic biodigester into the University's waste stream may be integral to achievement of the University's waste reduction and emissions reduction goals. According to the EPA, biodigesters have become an increasingly effective solution for diverting food waste and associated GHGs emitted. There are already nearly 2,000 biodigesters in the United States and 8,000 more in Europe (Kemp, 2013). This trend can be attributed to the flexibility of the systems in input, size, and output. A biodigester takes in various feedstocks, then harnesses the gas formed during its chemical breakdown within the digester. The type of input can also be adjusted based on what there is excess of, such as animal manure, grass clippings, agricultural products, or food waste. The produced biogas provides a versatile energy source which can be used for electricity or heat generation, as well as a transport fuel (Poeschl, 2010). Additionally, the biodigester produces a solid "digestate" output, this product is high in nutrients and can be used as an eco-friendly fertilizer (Querol, 2015). Biodigesters can be constructed of various size, to suit an individual family or an entire community. Diverting the waste from landfills is already a more sustainable practice, but the flexible implementation and production of usable outputs makes this a very exciting process.

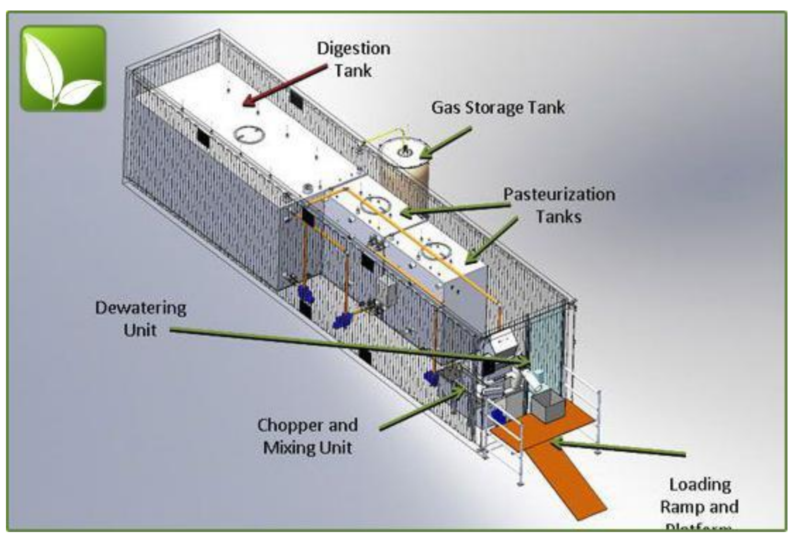


Figure 4: An example of a Muckbuster biodigester system (Tanglewood Organics, 2012)

One example of a small-scale biodigestor with Richmond-area distribution is the Muckbuster, a $30,000 unit that consists of five different components. This system is capable of taking in 300-1,200 pounds of feedstock per day. As you can see in Figure 4 (at right), the Muckbuster contains a chopper and mixing unit where the waste is loaded and combined with water and recycled liquids to achieve the right consistency for digestion. This mixture constitutes the "feed slurry," which is next cooled slightly in the buffering tank before the pasteurization tanks apply heat to remove any harmful bacteria. In the digestion tank, the slurry is converted to biogas and the digestate is stabilized over a 3 week period. The gas storage tank collects the biogas or sends it directly to a generation system, meanwhile the solids and liquids are separated and the solids removed through a screw filter mechanism in the dewatering liquid storage tank. (Tanglewood Organics, 2012)

Study of various feedstock efficiencies shows that as a university, we produce a surplus of the products on campus which can most efficiently produce biogas. Food waste is high in fats, oils, and protein, ranking higher in efficiency than animal by-products (Poschl, 2010). Estimates of biogas yield from food residues are as high as 592 m^3 per ton of dry matter, while estimates for cattle manure and straw are 297 and 341 m^3 per ton of dry matter, respectively (Poschl, 2010). Additionally, grass clippings and similar landscaping waste rank higher than many other inputs, estimated at 492 m^3 per ton of dry matter. (Poschl, 2010). The kind of waste that a campus produces the most of seems well-suited for producing biogas.

Many studies mentioned the importance of a pulper system as part of the process. Calvin College found that the pulpers produce an input for the digester that make it run smoother, negating maintenance costs associated with clogging (Brayse, 2012). Similarly, a study at the University of Georgia found that pulpers decrease dining hall waste by 85% in volume (Andrews, 2011). The HDC currently utilizes two pulpers as a part of its waste management system, and these would continue to be used, with the produced material better-suited for the biodigestion process.

Universities like the University of Wisconsin-Oshkosh, University of Georgia, Michigan State, Pennsylvania State, and Clarkson University have already led the way in implementing campus biodigestion systems to convert their food waste into fuel for energy (Brayse *et al.* 2012). The faculty of engineering from the Driftmier Engineering Center in Athens, Georgia developed a plan with the University of Georgia to anaerobically digest and compost diverted cafeteria food waste (Andrews et al, 2011). The system UGA developed consisted of the physical digester, a rainwater catchment facility, and a composting station. Their project report outlined a final cost estimate of $41,900 for the sum of the anaerobic digester, rainwater harvesting, gas compression and storage, composting, and effluent management construction materials.

Economic feasibility remains a key topic with biodigesters, found to be a main component of the studied proposals and literature. Payback period estimates were from 5-16 years depending on operating conditions, but this has shown to decrease by including the value of producing a fuel source, potential government incentives, and factoring in typical transportation costs (Navaratnasamy, 2008). Differences in scale have also accounted for varied payback periods, with large-scale digesters in general found to have earlier returns (Andrews et al, 2011). The implementation of a campus biodigestor would be most feasible and cost-effective if a “prefabricated anaerobic digestive system were installed” rather than one constructed from individual components, according to a study conducted at the University of Georgia-Athens (Andrews et al, 2011).

Methods

In order to evaluate the possibility of incorporating a biodigester on campus we have implemented a multi-pronged approach. We gathered data from interviews, past University projects, other universities' projects, and consulted scientific literature to determine the feasibility and impact of adding a biodigester to campus.

We conducted interviews with HDC and sustainability offices staff to get estimates on University food waste amounts, which could be applied to literature values and similar project proposals. This allowed us to determine the size of biodigester that best fits our waste stream, as well as the amounts of methane and natural gas that the system would offset. These interviews also provided us with insight into the current waste management system, allowing us to determine if it was compatible with a biodigester system.

Economic analysis of the project was formulated to produce a viable payback period. An up-front cost was established by assuming the purchase of a Muckbuster 3000, with values for installation and other components sourced from the Calvin College study (Brayse et al. 2012). Using studied efficiency values from Calvin College, and current University of Richmond natural gas consumption, we determined savings from decreased natural gas purchases. The amount of methane abated also received a value, with each MCF (thousand cubic feet of gas) of methane valued at $3 (ICF, 2011). Additional savings were predicted from the decrease in transportation costs. Full evaluation of upfront costs and yearly cost-benefit analysis allowed us to produce a payback period for the project, and predict potential revenues after reaching the break-even point. Results are shown in Figure 5, below.

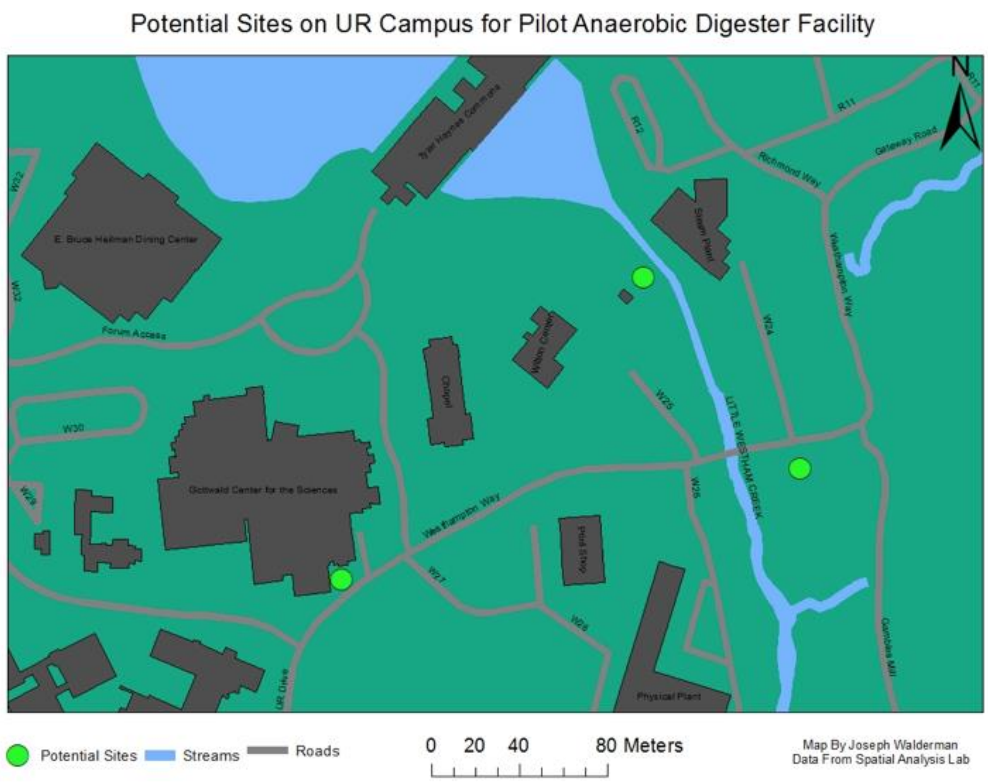
Capital Costs	
Biodigester System	$33,000.00
Compressor	$600.00
Piping & Valves	$1,000.00
Installation	$1,000.00
	$35,600.00
Annual Savings	
Savings on Gas ($/Year)	$5,052.78
Methane Reduction ($/Year)	$4,461.00
Savings on Compost Transportation ($/Year)	$4,864.00
	$14,377.78
Annual Costs	
Maintenance ($/Year)	$1,500.00
Operating Cost ($/Year)	$816.00
Daily Inspection ($/Year)	$3,744.00
	$6,060.00

Figure 5: Results of economic analysis

Closer analysis of current biodigester systems in place provided us with evidence of potential benefits to campus. Studies from Duke, Calvin College, and Wisconsin provided insight into various benefits from implementing a biodigester system (Brayse *et al.*, 2012; Duggan *et al.*, 2012; Hambrick, 2011). These included environmental benefits such as carbon offset, clean energy, and clean fertilizer, but also key advantages for University academics

(Brayse *et al.*, 2012; Duggan *et al.*, 2012; Hambrick, 2011). Disciplines such as engineering, economics, and chemistry have used biodigester projects as teaching tools and an on campus biodigester at UR certainly has potential in other fields such as environmental studies, geography, and biology. The studies mentioned the importance of student involvement and getting students out of the typical classroom setting (Brayse *et al.*, 2012; Duggan *et al.*, 2012; Hambrick, 2011).

To identify the best locations on campus for an anaerobic digester we conducted a landscape analysis of campus. Utilizing data from the University's Spatial Analysis Lab, criteria for the biodigester location included the slope of the ground, distance from water bodies and residence halls, as well as proximity to HDC, the steam plant, and major roads. Based on these criteria and through GIS analysis we determined three locations that that would be suitable for the digestion facility: the land north of Gambles Mill trail, the elevated land behind the Commons, and across from the Steam Plant, and the parking lot of the Physical Plant (Figure 6,



below). These locations would be safe, away from major student throughways, and convenient for the transportation of inputs and outputs.

Figure 6: A map of feasible locations of an anaerobic biodigester on campus. (Walderman, 2017)

Discussion

Based on our analysis, the implementation of a biodigester on campus would provide a variety of benefits to the University, while also helping to achieve the University's goals in waste and GHG emission reductions. We propose diverting pre- and post-consumer waste from HDC, along with input from landscaping, to the biodigester. Each student produces 2.0-2.6 ounces of waste per meal, times 30,000 customers a week (roughly). This equates to 3,750 pounds of post-consumer food waste per week, to be supplemented by 3,000-5,000 pounds per week of pre-consumer food waste, and varied but negligible amounts of landscaping scraps. Assuming the minimum amount of operating weeks for the University in Fall and Spring semesters at 30 weeks, HDC is producing 56 tons of food waste annually, all of which could go to the digester. This would produce 1,487 MCF of biogas per year. We propose diverting the produced biogas to the steam plant on campus, to be mixed with natural gas to produce cleaner heat energy. This output would save the University $5,052.78 on natural gas and transportation costs annually.

Currently, pre-consumer food waste is directed to a correctional facility for composting; however, as this would add another 3,000 to 5,000 pounds of waste per week for the biodigester, we propose adjusting this program slightly. We would not need to dissolve the program; instead, the biodigester's digestate can be shared with the correctional facility for the same purpose. The digester extracts natural gas from the input, but still outputs 80 percent of the original input as digestate, which could replace is the food waste currently sent to the correctional facility for composting. This would achieve a much higher level of both energy production and waste diversion.

The biodigester will brings benefits in regards to GHG emissions. The digester will reduce the methane emissions of the school by 115.43 m^3 per day, critical within the context of sustainability and climate change. Some states such as Massachusetts have already recognized the issues associated with continued massive input into landfills and in 2012 banned “hospitals, universities, hotels, large restaurants, and other big organizations from discarding food waste in the trash” (Abel, 2012). Thus, the University may soon be required by law to manage food waste. A biodigester offers a reasonable and impactful place to start managing food waste on campus. Other evolving action on climate change may make this investment increasingly valuable, and decrease the payback period. These may come in the form of carbon offset credits or renewable energy credits. There are also evolving policies such as tax benefits, financing options, and grants which could help the economic feasibility of the biodigester system.

Having this unique system offers many benefits to the students. A biodigester “living lab” could be integrated into current classes and studies, from the sciences to the business school. Sustainability focused first-year seminars could dedicate a unit on the biodigester’s use, applications, or implications in a larger context. Studies on biodigester efficiency, cost-benefit analysis, etc. could be performed continuously throughout its use, valuable to several disciplines on campus. Jobs in operating and monitoring the biodigester facility could also be given to students at the University or completed voluntarily by a club or class, which would provide an extra component to the "living lab" aspect of the digester as well as reduce labor costs. Additionally, lessons on waste and GHG reductions could serve the students as they start making independent decisions about their lifestyle in and after college. Emphasizing the importance of and connections between food, waste, and energy provides important lessons, helping to build a base of more environmentally aware US citizens.

Finally, the uniqueness of a project of this style serves as beneficial to the reputation of the university. Only a handful of other schools have a biodigester (listed below in Figure 7), many of which are in rural Mid-Western areas taking in animal and agricultural feedstocks from local farms. Our project on the edge of a well-known city, an excellent example of improving the efficiency of densely populated areas. The biodigester is also directed specifically at mitigating human food waste. A project like this places the University on the forefront of a technology with close ties to climate change, presenting the University as a leader in green technology.

University	Total Enrollment	Annual Organic Waste Converted (tons)
Michigan State University	50,344	10,000
University of Wisconsin-Oshkosh	13,513	10,000
Calvin College	4,008	73
University of Georgia	36,130	5,000
Clarkson University	3,257	110
Pennsylvania State University	80,150	16,000
University of California-Davis	35,186	18,000

Figure 7: Other schools with biodigesters

Potential opposition

The anaerobic digestion process has a reputation of producing a bad odor, given that it deals with the processing of food waste. However, this understanding of anaerobic digestion is misguided. While the anaerobic digestion process may produce a bad odor in a smaller, simple, uncontrolled system, it does not within the airtight facility proposed, except in the occasion of a leak in the storage tank. The digestate byproduct of the process is simply "remaining effluent" that is "low in odor, and rich in nutrients" (Penn State Extension, 2017). In fact, anaerobic digestion has been proposed as a method for odor control of manure and other decomposing substances (Noyola *et al.*, 2006).

Additionally, the current food distribution choices of HDC can pose challenges for the digester. Current systems offer cream cheese, butter, and jelly in individual plastic containers that would disrupt the anaerobic digestion process if incorporated with the food waste. A viable solution would be to offer these foods in a bulk tub for students to take from; however, this would require more continuous labor dedicated to the replacement and restocking of these foods, and could expire more quickly, leading to greater food waste. Regardless, this added cost is small when considering all the benefits that the biodigester would provide.

One last challenge for implementation may be that the biodigester needs a consistent supply of food waste input at a minimum of 75% capacity (Brayse et al, 2012). Otherwise, waste may build up and require extra maintenance costs. The proposed Muckbuster system is suited for 300-1,200 pounds of food waste input per day, while the University currently produces 617.5 pounds of post-consumer food waste per day, based on dining services data. This will be supplemented by the pre-consumer waste of 430-715 pounds per day, and landscaping scraps to meet daily needs. Therefore, this digester should be of sufficient size to mitigate this problem, but other options also remain for input. This expansion could include other dining locations on campus, or local homes and businesses with food waste streams.

Financing options

Other issues associated with university campus anaerobic digesters are its large upfront costs and financial risk of operating cost overruns. Undertaking large capital expenditures can also invite a number of bond indentures and detrimentally affect a university's credit rating (Navaratnasamy *et al.*, 2008). Additionally, projects related to sustainability often do not have the same competitive edge as other capital projects. Unlike library, classroom, and student housing buildings, operating and owning energy projects is not a core business for universities, though sustainability missions and academic benefits may flatten this uphill battle. There are a number of different incentives and financing options available to ameliorate associated upfront costs. As mentioned, these programs may expand and increase in value, helping to justify the inital cost. One structuring option to minimize risks and costs is to work the project through a third-party owned project, like the power purchase agreement utilized with the new solar array on the Robins Center. In this structure the third party project sponsor takes on the project risks including delay damage, operating cost overruns, and maintenance costs (Brayse *et al.*, 2012). Most importantly, this project would on the balance sheets of the third party who would be eligible for depreciation and the substantial tax benefits associated with an anaerobic digester, which would otherwise not apply if it were on the University's balance sheet (Navaratnasamy *et al.*, 2008).

Additionally, the University of Richmond’s Green Revolving Fund, currently maintained by the Green UR campus sustainability club could alleviate upfront capital costs for the biodigester project as a fund created in the interest of supporting renewable energy projects on campus. The fund could then be replenished over time by portions of the profits made from the project. In short, if a biodigester project is properly structured to maximize its value and minimize its risks, it can be both an economically and environmentally sound proposition for the University.

6. Waste Reduction Discussion

The global community is running out of both clean air and livable land, with 75% of the world's energy and resources being consumed by those living in developed countries (Hart, 1996). This only accounts for 1/6th of the world's population, meaning as a developed country, we need to learn how to better conserve both our land and resources for future generations by reducing the exorbitant amounts of waste we produce (Hart, 1996). With this in mind, the University of Richmond must become an active leader in solving this waste problem, rather than perpetuating the issue.

The University has goals within its Strategic Plan and Climate Action Plan for decreasing both waste and emissions. Achieving 80% reductions in waste and 30% reductions in emissions by 2020 will require swift and impactful changes (Strategic Plan, 2017; Climate Action Plan, 2010). The full implementation of this two-part project will be certain to help the University achieve its ambitious goals. Trayless dining is projected to decrease HDC food waste by 40% with the rest processed efficiently and sustainably by the biodigester.

Other than helping to achieve its own goals, the University campus and administration will greatly benefit from these projects. Most importantly, their incorporation will provide a unique academic opportunity for current and incoming students. For current students, it means a "living lab" to observe and study, which can be incorporated into the curriculum of all five of Richmond's schools, and further unify the University (McMiller and Dyball, 2009). For example, the complex digestion process of the biodigester could be applied to chemistry classes, and sustainable campus development could be a First-Year Seminar. This class would create exposure to the issues and wide scope of sustainability during a freshman's first year at the University of Richmond, and possibily there could be a component of this course where students continue to think of other ways the University can continue to reduce waste. The applications to University curricula are boundless and distinctive.

For potential students, this project will enhance their perception of the University and bring in a wider range of potential attendees. This project highlights the University's creative initiative and dedication to sustainability and climate action. A functioning and visible biodigester will enhance the University's reputation in the academic community, bringing in more students interested in topics of the environment, and increased interest from a generation with a growing concern and awareness of climate change (Easby and Manning, 2014). This generational change may be stronger than anticipated, making it a priority for the school to display environmentally-minded investments and leadership on environmental issues.

Successful implementation of this project requires support from several key constituencies: students, staff, faculty, and administration. The foundation for the implementation of these waste reducing practices is the students. If students want to see more efforts in sustainability, this desire must be expressed to University administration. Following a student push, the cooperation from administration and faculty is integral to the success of going trayless within HDC, and their active interest in sustainable practices will be important for justifying any of the expenses associated with this project.

7. Conclusions

Waste reduction is a global issue, with the United States being a leader in waste produced per capita. Combating an issue of this scale first requires an examination of one's immediate surroundings—for this project, the University of Richmond campus. Diverting waste and reducing GHG emissions are current goals of the University, and this two-part proposal introducing trayless dining and constructing a biodigester are two of the best ways for meeting them (Climate Action Plan, 2015). Changes within HDC to remove trays will effectively reduce our accumulated food waste, while reusing this waste to produce energy with a biodigester will reduce remaining waste, and ultimately reduce our carbon footprint and GHG emissions.

An exciting aspect of this project is its potential for expansion. HDC has many ways which it can better promote the trayless process, and this can be continuously worked on to improve efficiency and campus understanding of sustainability. A multi-phase project may prove the best method for transitioning the HDC to reach sustainability, productivity, and popularity goals. The biodigester project also has growth potential, either to be larger, or to take in different types of feedstock. The feedstock sourcing could be expanded first to other locations on campus, then to the greater community from local restaurants, homes or stores. A project of this type has not only widespread benefits, but also strong future possibilities.

We would recommend further research once available to better specify the financial and environmental benefits of this project. Exploration into which federal and state policies are legally applicable to the University may bring projected costs down further. More data on University emissions, water use, and waste composition would also clarify the benefits to campus and efficiency predictions. Estimates of the economic cost to renovate HDC should also be conducted, which may be smaller or larger than expected.

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9. References

Andrejewski, Rob. *University of Richmond Sustainability Report*. PDF. Richmond, VA, 2016.

Abel, David. 11 Nov. 2012. "Commercial Food Waste to Be Banned." *Boston Globe*. Pg 5.

Andrews, C., M. Brannen, J. Dimitroff, C. Elliot, J. Johnson, and T. Smith. 2012. "Sustainable Cafeteria Food Waste Remediation and Methane Production by Two-Stage Mesophilic Anaerobic Digestion." Trans. Array ENVE 4920 Final Report. University of Georgia: Driftmier Engineering Center, 2011. 1-32. Web. Accessed 18 Dec. 2014.

<http://archwaypartnership.uga.edu/wpcontent/uploads/2011/05/Sustainable-Food-Waste-Remediation.pdf>.

“Biogas/Anaerobic Digesters Energy Self Assessment." Energy Self Assessment. United States Department of Agriculture.

Boston University Sustainability. 2008. Trayless Dining. Accessed April 17, 2017. http://www.bu.edu/sustainability/what-were-doing/food/trayless-dining/.

Brayse, K., A. Diepstra, M. Groenenboom, P. Reinken. Dec. 7 2012. "Calvin College Dynamic Organics: Project Proposal Feasibility Study.” Accessed April 5, 2017. http://www.calvin.edu/academic/engineering/2012-13-team2/Team02_PPFS_Final.pdf

Burgett, C., A. Costello, N. Dennis, A. Felicetti, J. Horgan, and K. Johnescu. 2011. Exploring the Economic, Environmental and Social Implications of Trayless Dining at Colgate University. Report. Environmental Studies. Accessed March 16, 2017. https://www.colgate.edu/docs/default-source/default-document-library/trayless-dining-colgate.pdf?sfvrsn=0.

"Dining FAQs | New Undergraduate Students | Wake Forest University." New Undergraduate Students. Accessed April 17, 2017. http://newstudents.wfu.edu/dining/dining-faqs/.

DSIRE. 2017. “Programs.” North Carolina Clean Energy Center. U.S. Department of Energy, Web. 20 March 2017.

Duggan, Amanda et al. 10 Oct. 2012. "Duke Connections in Energy: Feasibility Study for a Campus Digester."

Easby, S. and T. Manning. 2014. "Attitudes Toward Climate Change and Sustainability." Climate Change and the University of Richmond: Current Challenges and Future Directions. University of Richmond.

Environmental Protection Agency. April 22, 2016 “America’s Food Waste Problem.” Accessed April 10, 2017. <https://www.epa.gov/sciencematters/americas-food-waste-problem>

Environmental Protection Agency. July 15, 2016. "EPA Issues Final Actions to Cut Methane Emissions from Municipal Solid Waste Landfills." Accessed April 14, 2017 <https://www.epa.gov/newsreleases/epa-issues-final-actions-cut-methane-emissions-municipal-solid-waste-landfills>.

Environmental Protection Agency. April 4, 2017. Overview of Greenhouse Gases. Accessed April 17, 2017. https://www.epa.gov/ghgemissions/overview-greenhouse-gases#methane.

Google Sites. 2015. Food and Dining - Colgate University's 2011-2015 Sustainability and Climate Action Plan. Accessed April 12, 2017. https://sites.google.com/a/colgate.edu/2011-2015-sustainability-and-climate-action-plan/food-and-dining

Hart, S. L. 1996. Beyond Greening: Strategies for a Sustainable World. President and Fellows of Harvard College. http://dnr.wi.gov/topic/SmallBusiness/documents/sustainability/BeyondGreeningStrategiesForASustainableWorld.pdf

Hambrick, Glenn. Mar 2011. "The Biogas Opportunity in University of Wisconsin"

Hubley, D. July 31, 2013. "Bates earns third star for ‘green’ dining, joining just five other schools in category." Bates University News. Accessed March 16, 2017. http://www.bates.edu/news/2013/07/31/green-restaurant-association-three-star-sustainable-dining/.

ICF International. March 2014. "Economic Analysis of Methane Emission Reduction Opportunities in the U.S. Onshore Oil and Natural Gas Industries" Accessed March 21, 2017. https://www.edf.org/sites/default/files/methane_cost_curve_report.pdf

Levin, Amelia. September 30, 2012. "Green Tip: Trayless Dining - Foodservice Equipment & Supplies." Green Tip: Trayless Dining - Foodservice Equipment & Supplies. Accessed March 15, 2017. http://fesmag.com/features/foodservice-issues/10237-trayless-dining.

Lopez, V. M., F. B. De La Cruz, and M. A. Barlaz. August 6, 2016. "Chemical composition and methane potential of commercial food wastes." *Waste Management* 56: 477-490.

Margai, F. L. 1996. Analyzing Changes in Waste Reduction Behavior in a Low-Income Urban Community Following a Public Outreach Program." *Environment and Behavior* 29: 769-792.

McMillin, J. and R. Dyball. 2009. Developing a Whole-of-University Approach to Educating for Sustainability. *Journal of Education for Sustainable Development* 3 (1): 55-64. http://journals.sagepub.com/doi/pdf/10.1177/097340820900300113

Navaratnasamy, M., I. Edeogu, and L. Papworth. August 2008. "Economic Feasibility of Anaerobic Digesters." The BioEnergy Site. Alberta Agriculture and Rural Development. Web. 11 Nov 2012. <http://www.thebioenergysite.com/articles/121/economic-feasibility-of-anaerobicdigesters>.

Noyola, A., J. M. Morgan-Sagastume, and J. E. López-Hernández. 2006. "Treatment of biogas produced in anaerobic reactors for domestic wastewater: odor control and energy/resource recovery." *Reviews in Environmental Science and Biotechnology* 5 (1): 93-114.

Office of Sustainability. 12 Dec. 2010. "University of Richmond Climate Action Plan."

Painter, K., G. Thondhlana, and H. Wei Kua. 2016. Food waste generation and potential interventions at Rhodes University, South Africa. *Science Direct* 56: 491-497 http://www.sciencedirect.com/science/article/pii/S0956053X16303592

Pennsylvania State Extension. Accessed April 14, 2017. "Anaerobic Digestion: Biogas Production and Odor Reduction from Manure." http://extension.psu.edu/natural-resources/energy/waste-to-energy/resources/biogas/projects/g-77

Poschl, M., S. Ward, and P. Owende. 2011. Evaluation of Energy Efficiency of Various Biogas Production and Utilization Pathways. *Applied Energy* 87(11): 3305-3321.

Querol, M. P., L. Seppänen, and J. M. Jackson Filho. 2015. Understanding the Motivational Perspectives of Sustainability: A Case of Biogas Production. *Production* 25(2): 266-77.

Quest Resource Management Group. June 22, 2016. Retail Food Waste in the U.S. Accessed April 3, 2017. http://questrmg.com/retail-food-waste-white-paper/

Retail Food Waste in the U.S. White Paper. PDF. Plano, TX: Quest Resource Management Group , June 22, 2016.

Serna, Emmanuel. 25 November 2009. “Anaerobic Digestion Process.” Waste to Energy Technology Council, Web. 25 March 2017.

Strategic Plan. Stewardship in a Changing World- University of Richmond. February 10, 2017. Accessed April 03, 2017. https://strategicplan.richmond.edu/stewardship/index.html.

Tanglewood Organics: Renewable Energy Solutions. November 11, 2012. Make Your Own Green Energy: The Muckbuster. Accessed April 3, 2017. http://tanglewoodorganics.com/?page_id=13>

Tagtow, A. and A. Harmon. 2009. Healthy Land, Healthy Food, and Healthy Eaters. *Food and Society Policy Fellow and Owner, Environmental Nutritious Solutions.*

http://scholarworks.montana.edu/xmlui/bitstream/handle/1/3029/HillerHarmon_HLHFHE_2009.pdf?sequence=1&isAllowed=y

University of Richmond. Rep. The Sustainability Tracking, Assessment & Rating System™ (STARS), 18 Feb. 2018. Web. 10 Nov. 2015. <https://stars.aashe.org/institutions/university-of-richmond-va/report/2013-02-18/>.

University of Richmond Office of Sustainability. 2016. *Intro to Sustainability at UR*. Accessed February 27, 2017. http://sustainability.richmond.edu/story/Intro%20to%20Sustainability%20at%20UR.pdf

US Census Bureau. *Population Trends in Incorporated Places: 2000 to 2013*. By Darryl T. Cohen. 2015. Web.