Achieving Waste & Emissions Reduction Goals on University of Richmond Campus: The Biodigester Approach

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Climate Change Seminar/Capstone Poster Session, April 20, 2017

Introduction

America's Waste Problem: Food waste to landfills is a significant problem in the United States, contributing to 18% of national emission of methane, a pollutant 25x more harmful than carbon dioxide (EPA, 2016). States such as Massachusetts have already faced challenges associated with sending organic waste to landfills and "banned hospitals, universities, and other large organizations from discarding food waste in the trash" (Abel, 2012: pg 5). Some Universities such as Duke, Calvin College, and University of Wisconsin have led the way in waste diversion projects (Kramer, 2015). To keep up with its environmental commitments and other innovative institutions, Richmond needs to find a way to better manage waste.

A Digester for Waste Diversion and Emission Reductions: This project proposes the installation of a small-scale anaerobic digester (biodigester). This is a reactor that breaks down biodegradable organic waste, producing biogas. Food waste is considered one of the most efficient for producing biogas of typical biodigester feedstocks (Poschl, 2010). The UR Dining Hall produces 614 lbs of food waste per day to be used as feedstock, with landscaping scraps available for additional feed. The University boiler plant is capable of using biogas for heat production, making the plant a suitable destination for the digester's waste output. The digester may allow for waste diversion and greenhouse gas (GHG) emissions reductions while also saving money on transportation and natural gas.

Breaking Down Food Waste

The chemical processes of anaerobic digestion, occurring within the digester:

Step 1, Hydrolysis: large organic polymers in the food scraps are broken down and hydrolyzed into smaller molecules like simple sugars, amino acids, and fatty acids.

Step 2, Acidogenesis: fermentative bacteria* break down the remaining components further, producing ammonia, carbon dioxide, hydrogen sulfide, and volatile fatty acids.

Step 3: Remnants are digested by acetogens*, to produce acetic acid, carbon dioxide, and hydrogen.

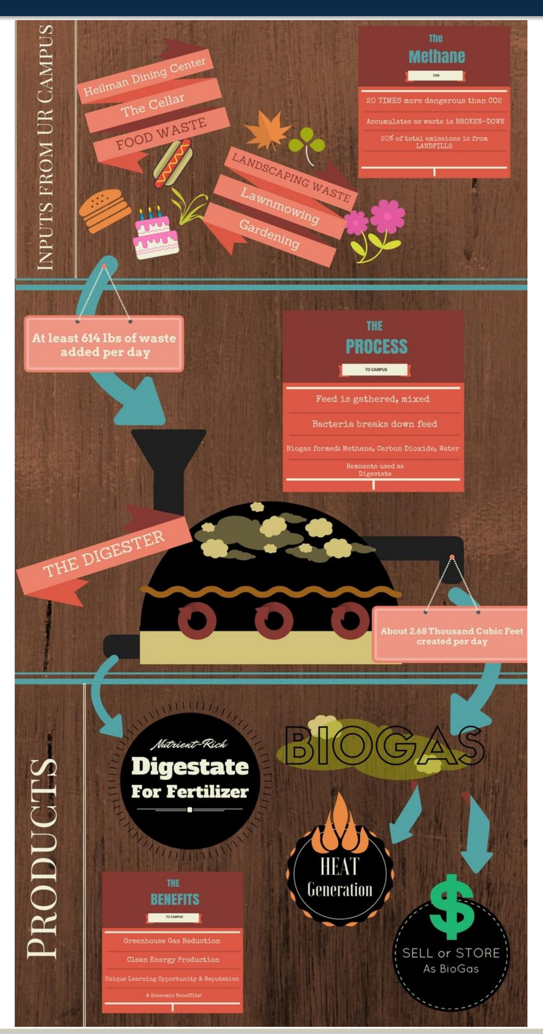
Step 4: Methanogens* convert the intermediate products to biogas, consisting of methane, carbon dioxide, and water.

Step 5: Dead bacteria and indigestible material is leftover as "digestate," which can be collected and used as fertilizer.

*Indicates a microorganism

(Waste-to-Energy Research and Technology Council, 2017)

Figure 1, at right, is an example of an educational visual showing how the biodigester works, demonstrating inputs from campus, the biodigestion process itself, and potential outputs.
(Produced by Williams, 2017)



Methods

The proposal was analyzed with a three-pronged approach:

- **Input Potential**- our team combined data from Dining Services, Office of Sustainability, and previous student projects with research conducted at Universities such as Calvin College to determine the potential size and efficiency of waste input streams.
- **Economic Feasibility**- our team conducted an economic analysis to calculate the payback of a digester using cost estimates and revenues from gas and transportation savings and carbon offsets.
- **Location Analysis**- Suitable digester sites on campus were mapped using GIS. Given the digester must pipe directly to the steam plant, sites were chosen based on proximity to the boiler plant as well as the dining hall to minimize transportation and piping costs.

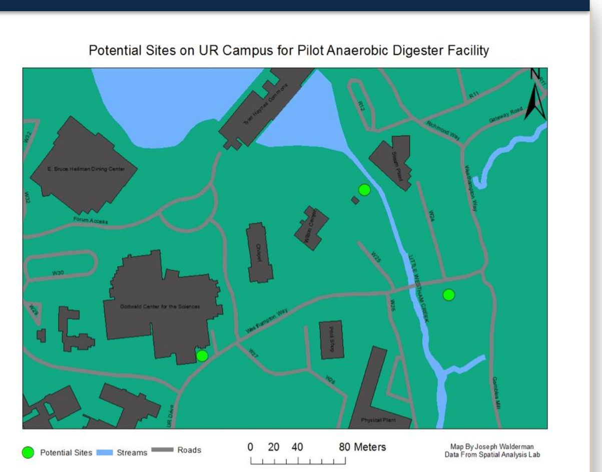


Figure 2: Potential sites on campus for an anaerobic digester. (Produced by Walderman, 2017)

Meeting Goals on Campus

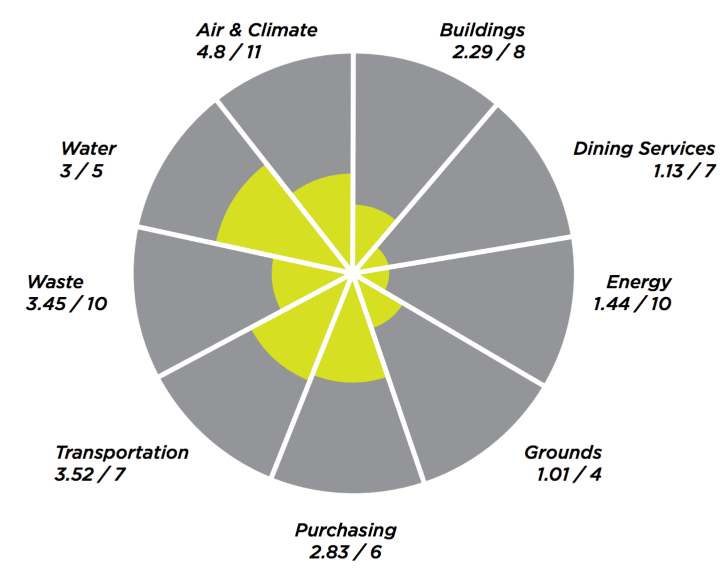


Figure 3: Rating system of sustainability on Richmond Campus (Andrejewski, 2017)

The University of Richmond is dedicated to being a "leader in innovative practices that sustain our environmental, human, and financial resources" (Strategic Plan, 2017, pg 5). This statement is reinforced by the University's commitment **to achieve 80% waste diversion and 30% emissions reduction by 2020** (Climate Action Plan, 2010). A biodigester helps to realize these goals by eliminating food waste to landfills, while simultaneously decreasing GHG emissions from associated transportation, heat generation, and landfills.

Figure 3 (left) displays the sustainability ranking of different aspects of campus, prepared by the 2017 Sustainability report. **This biodigester project helps strengthen the Universities' most poorly rated categories: Dining Services, Energy, and Waste.**

Economic Analysis

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

Table 1: An analysis of economic costs and benefits of an anaerobic digester project. Abatement value is taken from ICF (2011). Gas savings were derived from Facilities data and transportation savings from the Office of Sustainability.

The team determined through converting and calculating data from Facilities, SEAB Energy, and a Calvin College feasibility study that a digester with **production efficiency of 76 m^3/day,** taking inputs of 614 lbs of food waste per day can save the University $5,052.78 on gas and transportation (Brayse et al, 2012).

Value of Methane
Each unit of CH4 abated is valued at $3 per MCF (thousand cubic meters of gas) (ICF, 2011).

Labor options
Maintenance and labor could be performed by students, under work-study or research obligations.

Results

- Economic analysis showed investment in a 5-component Muckbuster would allow the school to **divert at least 650 lbs of waste each day**, and begin to **profit after 4.3 years**.
- Analysis of its efficiency determined the system would **produce 2.68 MCF** each day for the school, and **reduce methane emissions by 115.43 m^3/day**.
- Research into digesters at Duke, Calvin College, and Wisconsin displayed the potential for **academic and environmental benefits** to campus (Duggan et al, 2012) (Brayse et al, 2012) (Hambrick, 2011)

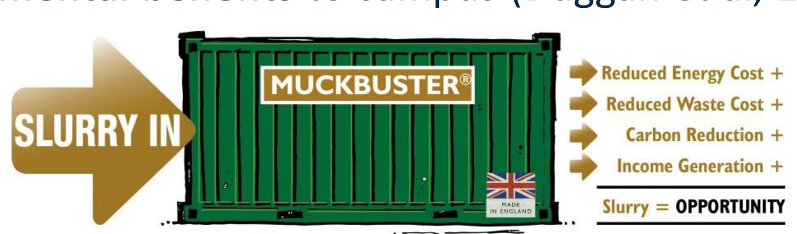
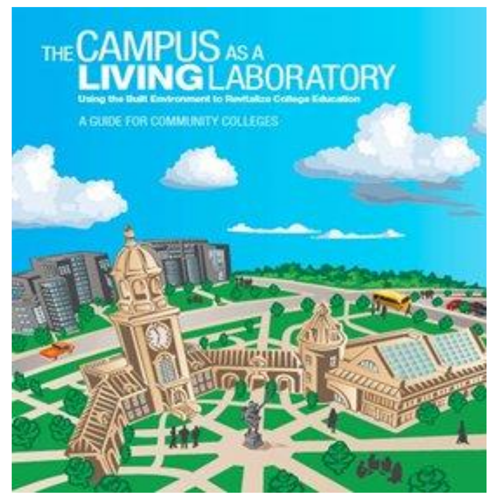


Figure 4: An example of a Muckbuster, provided by SEAB Energy.

Advantages to Campus

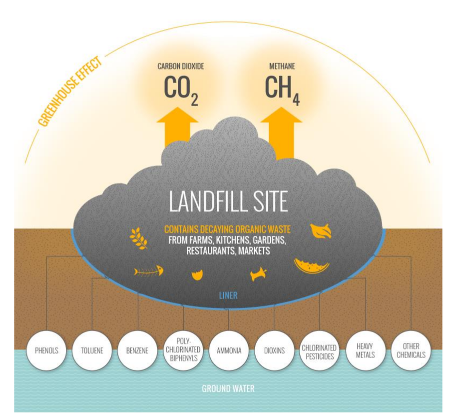


http://www.theseedcenter.org/

Academic Benefits

An on-site digester could be a "living lab" and integrated into current classes and studied across campus: sciences, business, etc.

- First-year seminars could be focused on its applications and examined in a larger context
- Efficiency and cost-benefit analysis could be performed continuously throughout its use
- Jobs in operating and monitoring the facility could serve as an opportunity for individual students as well as clubs or classes
- Improved recognition as a sustainable, progressive university



http://www.geoengineer.org/

Environmental Benefits

- Methane reduction, rather than accumulation in landfills
- Carbon emission reductions from eliminated transportation
- Reduction in natural gas burned and purchased
- Clean, renewable energy produced
- Digestate for safe, clean fertilizer
- Commitment to sustainability and climate change action

Economic Benefits

A biodigester on campus could bring revenue to the University as early as 4.3 years past installation. After initial costs, annual costs are minimal while annual savings and benefits are significant. The chart and graph indicate expenses and payback:

Year 1:	-$27,282.22
Year 2:	-$18,964.44
Year 3:	-$10,646.66
Year 4:	-$2,328.88
Year 5:	$5,988.90
Payback Period (years):	**4.280**

Table 2: An analysis of the payback period

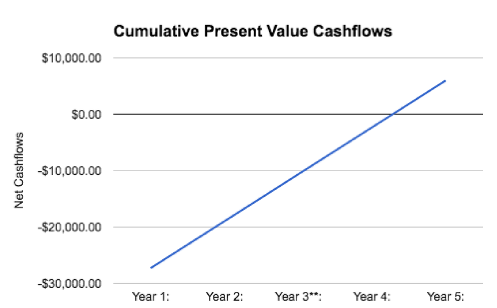


Figure 5: Graph of payback period, calculated by dividing total capital cost by annual cash flow

There are other potential economic benefits as well, including selling digestate or biogas, and offering to take in food waste from local business and homes.

Recommendations

An on campus anaerobic digester would provide environmental, educational, and economic benefits for the University. We advise a SEAB Energy Muckbuster unit with feedstocks coming from Heilman Dining Center pre- and post-consumer food waste. Landscaping compost should also be integrated. The unit should be located next to the boiler plant on campus, with the produced biogas compressed to supplement stocks of natural gas to produce heat on campus. Digestate from the biodigester could be utilized as fertilizer on campus, or sold externally.

Acknowledgements and References

This project benefited from the guidance of David Salisbury, Jerry Clemmer, Rob Andrejewski, Andrew McBride, Timothy Hamilton, George Souleret, Nicole Rahil, and Allison Steele.

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