Bass Connections In Energy: Feasibility Study for a Campus Digester

Amanda Duggan, Wusi Fan, Yeon Ji Kim, Andrew Seelaus, Jake Steinberg, and Heng Ye

BACKGROUND

A Digester for Carbon Neutrality: In 2009, Duke established the Duke Carbon Offsets Initiative (DCOI) to help achieve carbon neutrality by 2024. One potential method of reducing CO_2 emissions to install an anaerobic digester—a reactor in which microorganisms break down biodegradable organic wastes without oxygen, producing methane.

How does a digester help? Using biomethane to generate electricity qualifies for renewable energy credits (RECs) because the inputs are diverted from landfills, where methane would be produced and released to the atmosphere. However, anaerobic digestion produces odor (nuisance), is subject to policy and permitting issues and incurs a high initial cost and operational costs compared to aerobic composting of food waste.

Bass Connections Task: DCOI created this Bass Connections project to assess the feasibility of installing an anaerobic digester to generate RECs and/or carbon offsets as a method of reaching the climate neutrality goal. In addition to the production of RECs or carbon offsets, DCOI is interested in costs, financial and environmental benefits, and educational value. The team spent fall semester identifying options and spring semester evaluating four with the highest potential, as outlines in the Objectives below.

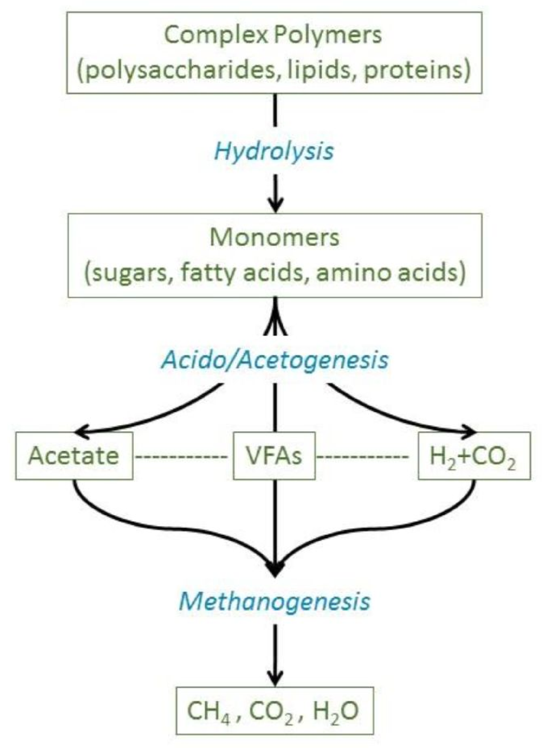


Figure 1: Anaerobic digestion converts lipids, proteins, and sugars into methane, carbon dioxide, and water.

OBJECTIVES

- Quantify and characterize the Duke waste stream
- Identify desired digester outputs and end uses
- Evaluate the following digester options based on available inputs and desired outputs:
  1. **Market Digester**- a commercially available digester that is pre-designed for installation. Input sources to this digester could include all Duke buildings or dining facilities only, with or without the hospital.
  2. **Custom Digester**- a digester designed either by a third party or by graduate students as part of a Master's Project to accommodate the specific waste stream size and characterization of Duke's campus. This digester could be designed for all Duke, or dining facilities only, with or without the hospital.
  3. **DukePlus Digester**- a digester either available on the market or custom designed to accommodate waste from Duke and other organizations through partnerships with local businesses or other universities in order to achieve a minimum waste stream.
  4. **Status Quo**- no digester is built.
- Recommend next steps for pursuing a campus digester.

METHODS

Each option was evaluated on a three-pronged approach:

- **Input Potential-** the team combined data from Duke University Waste Management with literature research and our own waste audit of Environment Hall to determine the expected size of the input streams. Waste audit samples, as well as samples from Penn Pavilion and Marketplace dining facilities were tested for biomethane potential and chemical oxygen demand.
- **Policy-** team members met with the North Carolina Department of Environmental Quality and the Director of Utilities & Engineering at Duke to discuss relevant policies, including necessary permits for handling waste and potential sites for digester location.
- **Economic Feasibility-** team members are developing a model to calculate the net present value of each potential digester size using initial cost and operating cost estimates, permitting costs, potential revenues from electricity of gas generation, and REC and offsets benefits. Results of the model are pending.

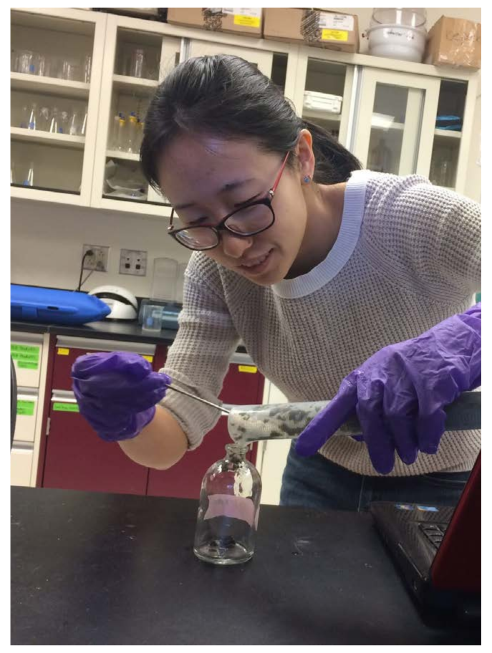


Figure 2: Team member Wusi Fan prepares a waste audit sample for the biomethane potential test.

POLICIES & REGULATIONS

Location: According to the Duke Facilities Management Department, there are two options to locate the bio-digester. If campus food waste is the only resource of the digester, it will be a small facility and could be located on campus. If outside sources are required, since transporting external waste to campus is not allowed, the digester will have to be put into the forest.

Permits: In order to build an anaerobic digester on campus, two major permits are required: 1) Solid Waste Composting Permit (SWC), 2) Air quality permit. Additional permits may be required if waste is transported from other locations.

Tax credits: Currently a small bio-digester system is not eligible for either Investment Tax Credits or Production Tax Credits. No state tax credits are available.

Renewable energy credits: The electricity generated by from a bio-digester system can be awarded Renewable Energy Credits, while the natural gas generated by the system cannot.

GHG emission offset credits: The digester could create emission offsets by both reducing landfill emissions and replacing energy generated by fossil fuels. Any offsets credits would be used by the university to reach the 2024 climate neutrality goal.

DATA

Duke Campus Waste Stream

	Non-Dining Campus Buildings	Dining Facilities	Hospital	Total
Total Solid Waste	4474 tons/year	4646 tons/year	TBD	**9121 tons/year**
Total Current Compost	91 tons/year	337 tons/year	0	**429 tons/year**
Potential Compost	2014 tons/year	2091 tons/year	31 tons/year	**4136 tons/year**
Percent of Digestibles Compost	14%	27%	100%	
Estimated Electricity Production Potentially*	308,000 kWh / year	320,000 kWh / year	7,000 kWh / year	**644,000 kWh / year**

Table 1: Values are based on 2014-2015 fiscal year waste disposal data and the results of our preliminary waste audit. While the audit does not provide a large enough sample to be statistically significant, it is assumed that these are conservative estimates for the volume of potential compost.
*Using potential compost to show maximum electricity production.

Digestible material from dining facilities has the potential to produce 644,000 kWh per year. That's enough energy to power approximately 63 homes.

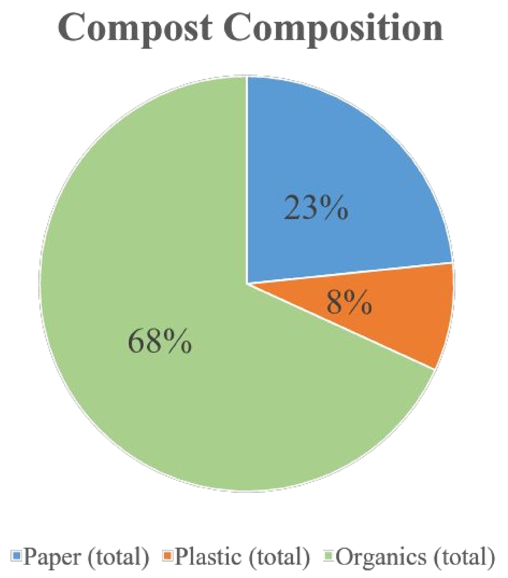


Figure 3: Of the compost audited from Environmental Hall, 23% represents non-digestible paper. This example indicates that nearly ¼ of the input from academic buildings to the digester would be indigestible, resulting in increased sludge and therefore higher maintenance costs.

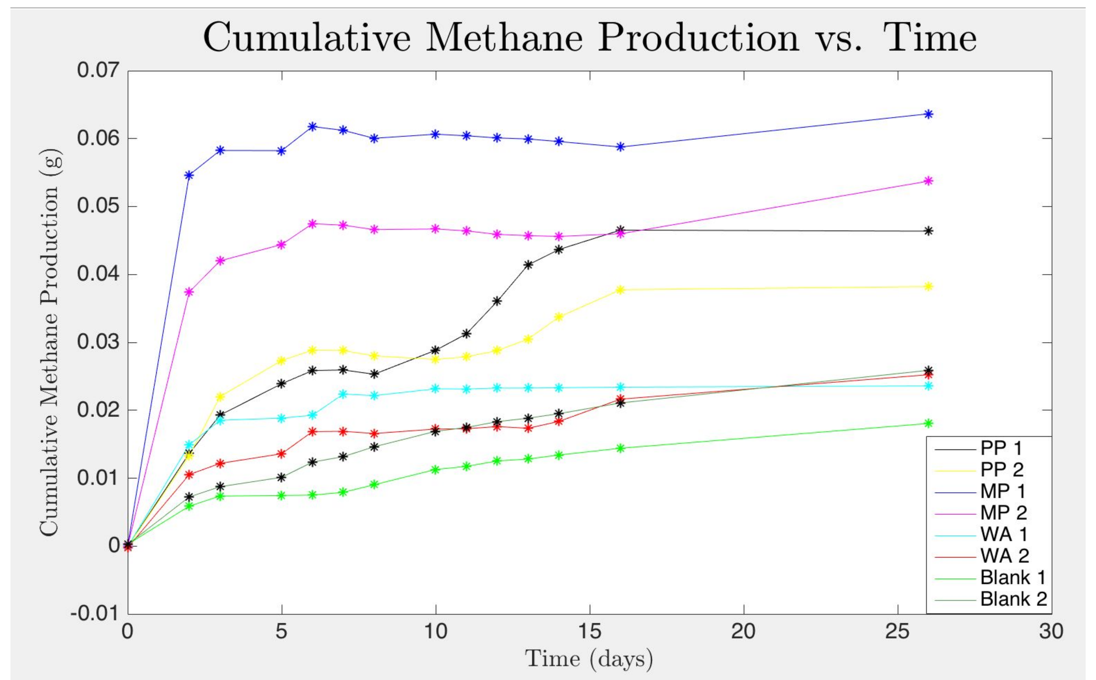


Figure 4: Waste samples from Penn Pavilion (PP) and Marketplace (MP) produced the most biogas. Academic buildings (WA), which contained significant portions of non-digestible materials, produced less gas.

RESULTS

Location Limitations: For educational purposes, the digester should be on campus where it is accessible to the maximum number of students. In addition, an on-campus digester will have better access to the electricity grid or natural gas pipelines. Therefore the DukePlus Digester is eliminated as a potential option. Since there are no tax incentive available, a third-party owned system model is also infeasible.

Input Quality: Past research indicates that input streams with a substantial presence of lignen decrease digester efficiency and increase maintenance frequency. Given the high percentage of paper within the compost of our waste audit and acknowledging that creating additional infrastructure to sort food waste from other compostables is difficult and costly, input wastes from buildings that do not already sort food waste cannot be included; thus, incorporating all Duke building waste is infeasible, and larger Market Digesters are eliminated from consideration.

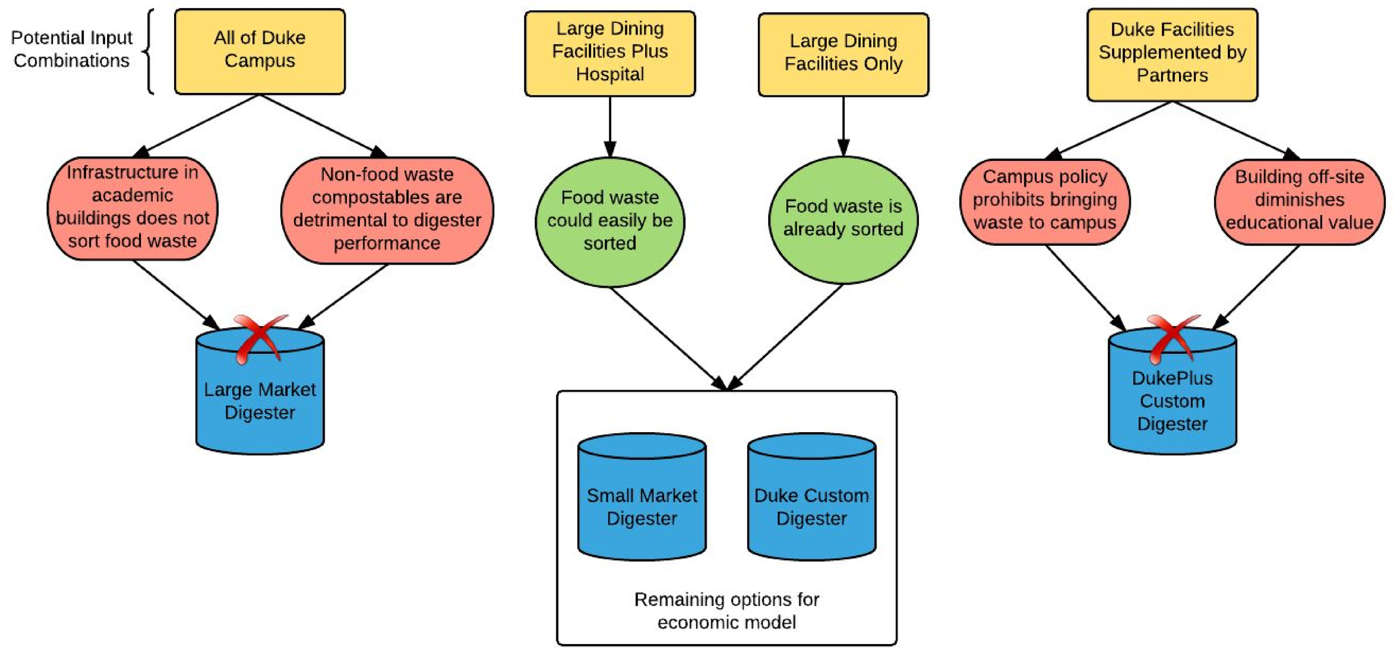
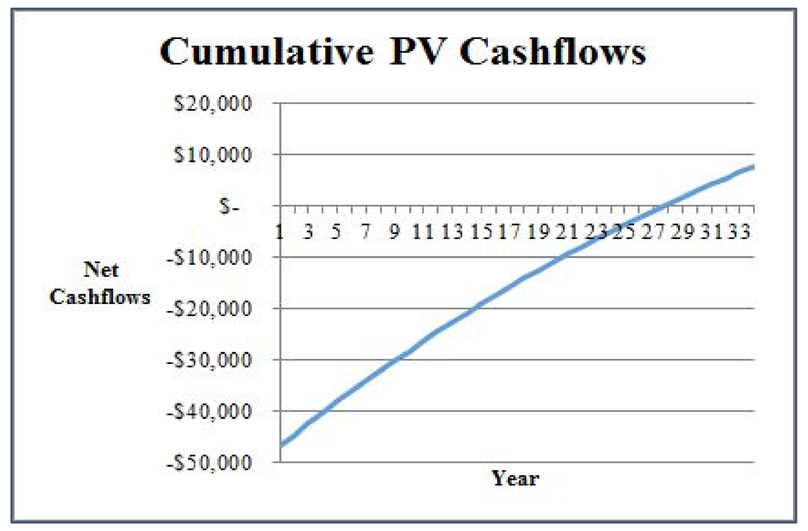


Figure 4: In addition to managing ideal waste streams, a Custom Digester or small Market Digester can easily be sited on campus near the build to which resulting energy would be directed. A Custom Digester has the added educational potential of being designed and completed by students, which greatly increases its overall value to the university.

Economic Model: A negative NPV means that a digester would need to provide significant educational value to justify the investment.

Potential Revenue Streams
- Electricity Generation
- Natural Gas Sales
- REC sales
- Carbon Offsets

Key Indicators
- Capital Costs: **$51,800**
- Annual O&M: **$2,000**
- Net Present Value: **$-15,477**



RECOMMENDATIONS

Preliminary Recommendations

Waste input: Collect Duke University waste only, mostly from food service facilities.

Digester technology: Build a custom-designed CSTR with feedstock pre-processing unit. Duke's waste streams are too small to justify most commercially available digesters, and trucking in additional waste would force the digester to be located off-campus. CSTR provides the HRT required to process waste with the minimum footprint. It is recommended that the final digester be designed and constructed by university graduate students for maximum educational value.

Output destination: Couple digester with an on-site biogas engine. Electricity production generates RECs, while natural gas added to pipelines does not. Additionally, there are more restrictions for adding gas to pipelines in terms of refinement, and therefore added costs that make natural gas less desirable than electricity.

Future Research: If a digester is pursued, a full-year waste audit of the inputs is recommended to ensure waste stream supply.

ACKNOWLEDGEMENTS

The team would like to thank Team Leads Charles Adair, Marc Deshusses, Jay Golden, and Brian Murray for their on-going support throughout the year. Additional thanks to Arwen Buchholz for assistance with waste data and the auditing process, and Ryke Longest for policy explanations. Final thanks to the Energy Initiative and the Bass Connections in Energy program for the opportunity to participate in a hands-on learning environment.