University of Michigan Waste to Energy – Feasibility Study for an On-Campus Biodigester

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I. Executive Summary

The University of Michigan has dedicated numerous resources to the cause of sustainability. An on-campus waste-to-energy anaerobic digester system could help advance that cause and assist the University in working towards three of its official Sustainability Goals. Furthermore, based on a preliminary analysis, it could be a revenue-positive investment over ten years. This report is an initial feasibility study on placing a biodigester on University of Michigan campus, and recommends further analysis.

Anaerobic biodigestion is a process that takes organic waste and converts it to biogas, a mixture of methane and other gases. It also creates a liquid/solid residual that can be composted or used as fertilizer. The biogas can be processed and used for electricity, heat, injected into the pipeline system, or compressed and used as a liquid transportation fuel. Biodigesters can be designed to take any type of organic waste; a University of Michigan biodigester would use primarily food waste, yard clippings, and compostable disposables.

A campus biodigester would help the University accomplish three of its Sustainability Goals. First, it would help with the goal of reducing waste by 40% by 2025 through diversion of organic wastes that currently go to the landfill. Second, it would contribute to the goal of reducing greenhouse gas emissions 25% by 2025 by capturing methane that would otherwise likely end up in the atmosphere. Third, it would help foster a sustainability culture on campus by increasing the visibility of sustainability issues and creating educational opportunities.

Numerous stakeholders were consulted over the course of this project. Appendix 1 contains a full list, including key takeaways from meetings with them. In general, stakeholder interactions helped increase our familiarity with the subject, and assisted us in gaining crucial pieces of data. Those who gave particular assistance include Andy Berki of the Office of Campus Sustainability and Tracy Artley of the UM Waste Reduction and Recycling Office.

After gathering the data with assistance from the stakeholders mentioned above and others, we did a cost-benefit analysis of the results. Over a ten-year timeline, we found anywhere between a \$1.7 million and \$3.8 million net present value for a biodigester project, depending on the discount rate used. However, the analysis is only preliminary; at this point, there are still too many unknowns in terms of both costs and benefits to make definite projections.

With that in mind, we recommend that the University look further into pursuing a biodigester project. In particular, we urge the Office of Campus Sustainability to collect further data, both by completing the food waste data collection already planned by the Office of Waste Reduction and Recycling and by initiating a more detailed investigation of the potential costs of a biodigester project. In addition, we recommend that the Office of Campus Sustainability reach out to the stakeholders we have identified in our report and others.

II. Background

A. The University of Michigan's Sustainability Goals

The University of Michigan has dedicated significant efforts and resources to increasing the overall sustainability of the Ann Arbor campus's facilities and operations systems.[1] In 2011,

[1] Woodhouse, K. (2011, September 27). University of Michigan launches \$14M sustainability initiative. Retrieved November 23, 2016, from http://www.annarbor.com/news/university-of-michigan-launches-major-environmental-sustainability-initiative/

the University completed a comprehensive Campus Sustainability Integrated Assessment, which included the establishment of a series of "Campus Sustainability Goals." These goals are primarily comprised of numerical, measurable targets for reducing the environmental impact that the University has on the local area as well as the globe.[2]

The Campus Sustainability Goals pertaining to waste reduction, greenhouse gases, and sustainability culture are key drivers in support of initiating a campus biodigestion project. The installation and operation of an anaerobic digester has the potential to make simultaneous progress on all three of these goals.

1. Waste Reduction

The University has committed to reducing the amount of waste it sends to landfills or incinerators by 40% by 2025, relative to 2006 levels.[3] Currently the University recognizes that while recycling efforts are important, this goal will be extremely difficult to meet without addressing food waste and other organic waste streams from across the campus.[4] According to the latest figures, the University sent approximately 12,000 tons of waste to the landfill in FY 2014. In contrast, the University composted about 431 tons of food waste and 191 tons of animal bedding in FY 2016.[5]

2. Greenhouse Gases

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[2] Campus Sustainability Goals. (n.d.). Retrieved November 23, 2016, from http://sustainability.umich.edu/about/goals

[3] Campus Sustainability Goals. (n.d.). Retrieved November 23, 2016, from http://sustainability.umich.edu/about/goals

[4] *Recommendations Report* (Rep.). (2015, June 29). Retrieved November 23, 2016, from http://sustainability.umich.edu/media/files/Landfill-Waste-Reduction-Committee-Report-2015.pdf

[5] The University uses We Care Organics as a vendor for composting.

The University's current set of goals aim to reduce greenhouse gas emissions by 25% by 2025, relative to 2006 levels, and to reduce the carbon intensity of UM passenger transportation by 30% over the same timeframe.[6] The most recent committee report has, however, recommended that this goal be increased. It also specifically mentions the potential for achieving greenhouse gas emissions reductions by capturing and utilizing landfill gases.[7]

3. Sustainability Culture

By 2025, the University wishes to have "created a vibrant culture focused on sustainability, to have educated our community on environmental stewardship, promoted environmental behavior" and to have tracked this progress over time.[8] These goals place a premium on programs that are visible and participatory.

B. What is Biodigestion?

A biodigester[9] is a system that breaks organic materials down into a number of gases, including methane and carbon dioxide, and leaves nutrient-rich solids and liquids as a residual. This process is completed by combining a feedstock of organic materials with natural microbes that decompose these materials in an oxygen-free (i.e. anerobic) environment. In a closed environment, the gases can then be captured and stored for later use, while the solid and liquid residuals can be separated and disposed of. See Figure 1 for a visual representation of the system.

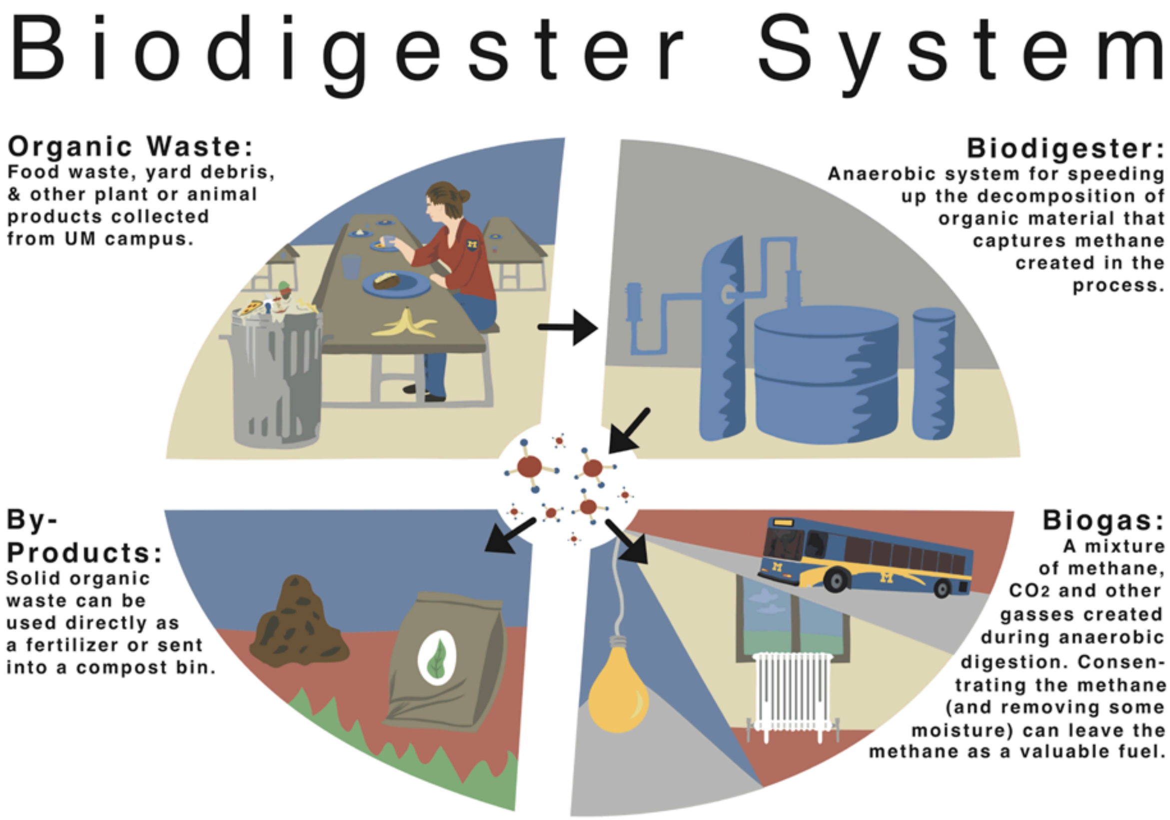
[6] Campus Sustainability Goals. (n.d.). Retrieved November 23, 2016, from http://sustainability.umich.edu/about/goals

[7] *Recommendations Report* (Rep.). (2015, June 29). Retrieved November 23, 2016, from http://sustainability.umich.edu/media/files/Greenhouse-Gas-Reduction-Committee-Report-2015.pdf

[8] *Recommendations Report* (Rep.). (2015, June 29). Retrieved November 23, 2016, from http://sustainability.umich.edu/media/files/Sustainability-Culture-Committee-Report-2015.pdf

[9] Also known as an anaerobic digester or a waste digester.

Figure 1



There are many different types of biodigesters currently in use. The types of materials fed into the system ("feedstock") generally define which type is used. The most common biodigesters utilize large quantities of animal waste (typically found on farms) or of solids removed from wastewater treatment facilities. Digesters that use only food waste and yard debris are typically smaller, because finding large quantities of pure organic waste in these forms is often difficult. Finally, some digesters are designed to accept a feedstock made of a mixture of organic and inorganic materials.

III. Why Could Biodigestion work for UM?

The introduction of a biodigestion system at the University of Michigan could be a great benefit to the institution as well as to the environment. This project would simultaneously make progress on the majority of the University's Campus Sustainability Goals, while having measurable, positive impacts on the local and global environment.

A. Sustainability Goal 1: Waste Reduction

While the University of Michigan does not have a large, readily available feedstock of animal waste, a campus biodigester could be fed with food waste and other organic waste collected from landscaping and other similar operations. This would require a significant amount of organic waste separation from the current waste stream, though it would likely result in a significant amount of organic waste that could be dedicated to biodigestion.

The operation of a biodigester to manage organic waste streams from the University would significantly reduce the volume of waste being sent by UM to landfills. Since it is likely that any system installed at UM would be operated only with organic feedstock, 100% of the residual material remaining after digestion could be reused as compost, thereby removing it from the landfill stream altogether. Even if the University chose to operate a campus biodigester with mixed organic and inorganic feedstock, the residual material would be smaller than the original input, thereby sending less volume to landfills.

B. Goal 2: Greenhouse Gas Reduction

A biodigester would effectively remove nearly all greenhouse gases from the digested waste and utilize them for another purpose. This would avoid the accidental release of gases created during landfilling or imperfect composting. After capturing the gases, they could be used or sold for other purposes, including providing more carbon-neutral transportation options around campus.

C. Sustainability Goal 3: Sustainability Culture

Finally, a campus biodigester would foster a stronger sustainability culture. By engaging students, faculty, and staff in the collection of organic waste, and by situating the digestion facility on campus, members of the University community would feel a greater sense of their role in the sustainability efforts undertaken at UM. Whether that means allowing guided tours, putting a live video feed that can be broadcast to dining halls, or using the gas in a CNG-powered bus that can be branded “The Trash Bus” and used in educational events, there are numerous opportunities for reaching out to the community. A biodigester can help Michigan in building an ethos of sustainability around campus.

An on-campus biodigester would also have significant educational benefits for the university. According to Professor Dimitrios Zekkos, a biodigester would provide numerous opportunities for engineering students who are focused on waste or energy in their studies. Both from an academic and an employment perspective, University of Michigan students would be able to do valuable research and gain marketable skills using this innovative technology. Multiple engineering undergraduates have done internships abroad working for biodigestion companies; having those opportunities here would open up that door for students who can’t afford to take it otherwise.

IV. Costs and Benefits—Discussion

A. Physical Products

The most obvious benefit of a biodigester is the environmental impact. A biodigester both shrinks the volume of waste that would need to go to a landfill and is a source of renewable energy. As outlined above, biodigestion creates two physical products: a methane-rich gas and a liquid/solid residual. Both products can be utilized in ways that have a net environmental benefit.

1. Produced Gases

The gas produced by a biodigester has four potential uses, as outlined below. Part of the calculus in deciding between potential uses is the chemical composition of the gas produced (percentage of methane, sulfurs, water, other substances). This will require further study once on the exact mix of materials being fed into the biodigester has been determined.

a) Direct electricity

The produced gas could be run through an engine or microturbine to create electricity directly. One advantage of this approach is its streamlined nature, particularly since UM already has a power plant that handles natural gas; therefore, UM would keep control of this waste-to-energy program throughout the whole process.

There are a few disadvantages, though. If used in the existing UM power plant, the gas would have to be purified enough to prevent UM's turbine from wearing down due to corrosion the non-methane components. Such purification can be quite an expensive process and may not be scalable for the amount of waste running through the system. The purification problem could be avoided if UM builds a separate engine or turbine for the biogas. However, constructing a second turbine would be expensive and redundant since UM already uses this technology. This alternative would also still have the same scaling problem as above.

b) Renewable natural gas

The produced gas could be purified to pipeline specifications—even cleaner than in Option A above—and sent directly into the natural gas pipelines that feed into the school and the rest of the grid. The disadvantages are similar to Option A: a high cost to purify the gas, which would be even greater than Option A, and scale issues.

The advantages are greater than they would be for producing direct electricity, however. Crucially, putting natural gas into the pipeline system might allow UM to generate a Renewable Identification Number (RIN) or a Renewable Electricity Credit (REC) for the gas, because it was generated in a renewable way. RINs are very valuable in comparison with the underlying gas, and RECs are less lucrative but would increase the value of the gas somewhat.[10] In addition, administrative costs would decrease, as UM would relinquish control of the gas once it was in the pipeline.

c) Heating

UM burns natural gas in its central power plant to generate steam for heating the many buildings around campus, and could use biogas as a partial replacement. This gas doesn't need to be cleaned nearly as much for use in a boiler as it does in a turbine, which lowers the cleaning costs as compared to Options A and B. This option has fewer disadvantages than other options, but also likely cannot take advantage of revenue from producing and selling RINs.[11]

[10] The process for generating RINs and RECs is somewhat complicated, particularly when the product is not being used directly as a transportation fuel but is being placed back in the system. RECs are not addressed in detail in this paper, as they are not a part of its final recommendations. For more detail on how RINs work, please see Figure 2. See the following EPA Guidance document for a description of how RINs could potentially be generated from pipeline insertion of landfill gas: United States, Environmental Protection Agency, Office of Transportation and Air Quality. (2016, September). *Guidance on Biogas Quality and RIN Generation When Biogas Is Injected into a Commercial Pipeline for Use in Producing Renewable CNG or LNG under the Renewable Fuel Standard Program*. Retrieved November 23, 2016, from https://www.epa.gov/sites/production/files/2016-09/documents/420b16075_0.pdf

[11] We used the following sources to create Figure 2:

d) Compressed natural gas (CNG).

This may be the most attractive of the four options, for a number of reasons.[12] The gas, after minimal processing in comparison with Options A and B, could be compressed and turned into a fuel for specially-built or retrofitted vehicles. While UM does not currently have any CNG vehicles, they are used by the City of Ann Arbor, and there are two CNG fueling stations nearby.

The advantages of CNG are numerous. First, the cleaning costs would be minimal in comparison to Options A or B, and would be replaced by much lower storage costs. Second, CNG can potentially also generate RINs like Option B, which would be valuable.[13] Third, there are numerous public-facing opportunities to roll out CNG buses or other vehicles, both from an educational and a PR perspective.

The disadvantages are those of scale. Building a CNG conversion facility and filling station would not be prohibitively expensive, but would likely require the biodigester facility to occupy a greater physical footprint on campus. The loss of limited campus land may not be worth the tradeoff based on the amount of gas generated.

Nov. 11, 2016 to Nov. 17, 2016. (2016, November 18). *PFL Weekly RIN Recap*. Retrieved from http://www.progressivefuelslimited.com/web_data/PFL_RIN_Recap.pdf

Renewable Identification Numbers (RINs) under the Renewable Fuel Standard Program. (n.d.). Retrieved November 23, 2016, from https://www.epa.gov/renewable-fuel-standard-program/renewable-identification-numbers-rins-under-renewable-fuel-standard

Approved Pathways for Renewable Fuel. (n.d.). Retrieved November 23, 2016, from https://www.epa.gov/renewable-fuel-standard-program/approved-pathways-renewable-fuel

Renewable Fuel Standard Program: Standards for 2014, 2015, and 2016 and Biomass-Based Diesel Volume for 2017, § 40 C.F.R. 80 (2016).

[12] In conversations with DTE’s biogas team, this was the option they recommended.

[13] It’s not clear whether the gas would need to be purified to pipeline specifications or not in order for a RIN to be generated in the CNG case. UM would need to reach out to EPA before starting this process to figure out the level of cleaning necessary (and thus the cost-competitiveness of the CNG method).

However, the UM Greenhouse Gas Reduction Committee has already recommended to President Schlissel that purchase and CNG conversion of landfill gas from an outside landfill might be a revenue-positive way of reducing greenhouse gases.[14] If that recommendation is followed to any extent, it could be extremely cost-competitive to build a CNG conversion facility and filling station and to retrofit UM's bus fleet.

[14] *Recommendations Report* (Rep.). (2015, June 29). Retrieved November 23, 2016, from http://sustainability.umich.edu/media/files/Greenhouse-Gas-Reduction-Committee-Report-2015.pdf

Figure 2: Renewable Identification Numbers (RINs)

What is a RIN?

A RIN is a Renewable Identification Number, issued by the Environmental Protection Agency as part of the Renewable Fuel Standard Program. Whenever certain types of renewable fuel are produced, they also generate a RIN. That RIN can then be sold by the renewable fuel producer either along with sale of the fuel, or in a separate market. At a basic level, when a producer generates a renewable fuel, they get two products: the fuel itself, and a tag (the RIN) that says, "This fuel is renewable." Those two products can be sold separately in different markets.

What are the requirements to generate a RIN?

The most important requirement is that the generated renewable fuel falls into one of EPA's Renewable Energy Pathways, developed as part of the RFS program. Renewable producers have to work with EPA to get their operation approved as falling into one of the pathways before RINs will begin to be generated. Depending on the pathway used, the EPA puts RINs into different categories (D3 through D7).

How does a generator sell its RINs?

The EPA has a set up a federal marketplace called the EPA Moderated Transaction System (EMTS). In general, parties create outside trade deals and then use EMTS to complete their transaction. EMTS also tracks prices of the various types of RIN, both by the D-Code (D3, D4, D5, or D6) and the year the RIN was generated.

Who is buying RINs and why?

As part of the RFS, EPA requires that certain players in the energy system ("Obligated Parties") retire a specific number of RINs per year. In other words, if you are an Obligated Party, you have to produce—either through renewable fuel generation or by buying them from other generators—a certain number of RINs in 2016 and officially take them off the market. These Obligated Parties are generally refiners and importers of gasoline or diesel.

University of Michigan RIN Generation

A UM biodigester could create RINs, depending on how the university uses the biogas it generates. If UM turns the biogas into CNG or LNG, the university would almost certainly be able to get a RIN approved either under EPA's Q pathway, which would generate D3 RINs, or EPA's T pathway, which would generate D5 RINs. D3 RINs are about twice the value of D5 RINs in today's market; UM should be able to get its biodigester approved under the Q pathway if it works with EPA while creating the system. Based on our modeling, the creation of D3 RINs could add up to $285,000 per year of revenue in a high-capture scenario.

2. Residual

The other physical product of the biodigestion process is the residual—liquids and solids that are left over from the process. The value of the residual is highly dependent on two factors: first, the feedstock for the biodigester, and second, the precise technology used to do the biodigestion, which varies depending on the company chosen to manufacture the biodigester. Those two factors determine both the amount of residual generated, and its quality.

Depending on those factors, the quality of the residual could fall into one of three buckets:

a) Fertilizer

Most systems advertise that the output will essentially be fertilizer – with little to no treatment, it can be applied directly to farmland or gardens. This is the most likely outcome for a UM digester as well. Since most of our feedstock is food waste, it would have a fairly well-balanced chemical profile, which means it would likely require almost no processing to reach fertilizer quality.

b) Compostable

Even if the residual isn't quite at the level of fertilizer quality, it will likely still be compostable, depending again on the balance of chemicals. The University would be able to continue using We Care Organics as a vendor, but costs would drop because the volume of waste would decrease significantly.

c) Non-compostable

If the balance of chemicals dictates such, it's possible that the waste product (or at least a significant percentage of it) would have to be disposed of in a landfill or through the wastewater system.

V. Costs and Benefits—Analysis

A. Data

The University completes a campus-wide trash sort once every five years to generate data about total waste produced by the university and the content of that waste. The University conducted the most recent trash sort in 2012 and plans to conduct another in 2017. We use the 2012 data as the baseline for our model. The University estimated that it produced approximately 2,500 tons of organic food waste that could be diverted to composting and away from landfills.[15] Additionally, UM's dining hall system collects annual data about its food waste. Our model incorporates the 2016 UM food waste data. In the fiscal year 2016 (July 1, 2015 - June 30, 2016), the University sent 431 tons of food waste and compostable disposables, and 191 tons of animal bedding to the composting site (See Figure 3).[16] The other 1,878 tons of organic waste is composed of other organic waste, including plates, knives, forks, spoons, and napkins. About 75% of the University's food waste is produced in the five undergraduate dining halls; South Quad, East Quad, Mosher Jordan, Bushley Hall, and North Quad (See Figures 4 and 5).[17]

We provided these numbers to numerous anaerobic digester manufacturers to obtain cost estimates and projected revenue streams the University would experience if it built an anaerobic digester facility. Scale was a significant limitation we encountered when working with manufacturers. Bioferm Energy Systems, who constructed an anaerobic digester at the University of Wisconsin-Oshkosh, needs a minimum of 10,000 tons of organic waste to make their systems cost effective. Other companies manufacture smaller-scale systems that fall within

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[15] Tracy Artley, UM Waste Reduction & Recycling Office

[16] Tracy Artley, UM Waste Reduction & Recycling Office

[17] University of Michigan 2015 Composting Data

Figure 3: University of Michigan Projected Compostable Waste (FY 2016)

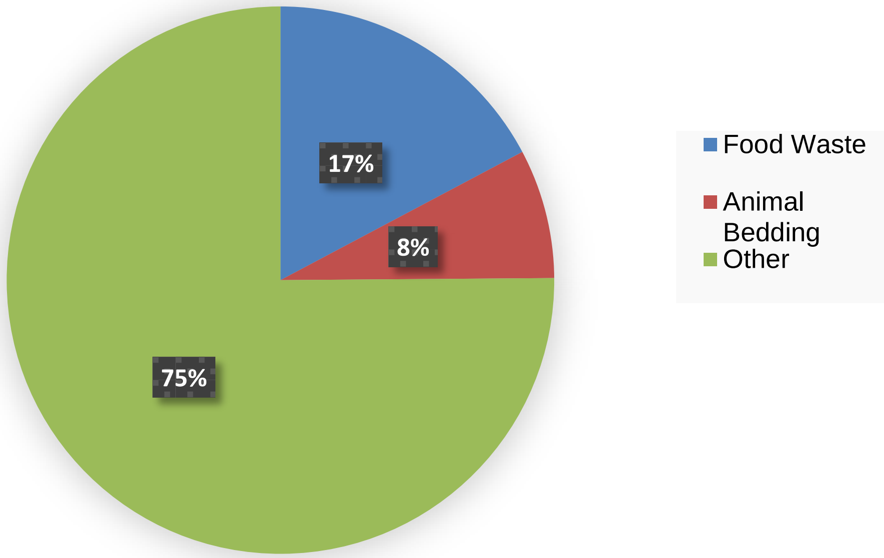
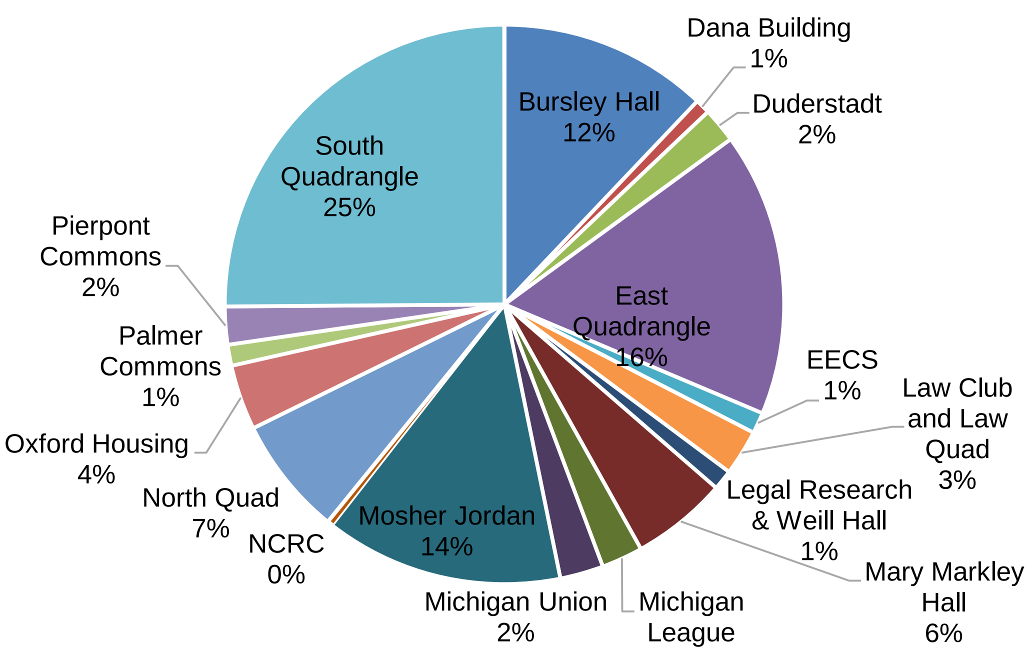
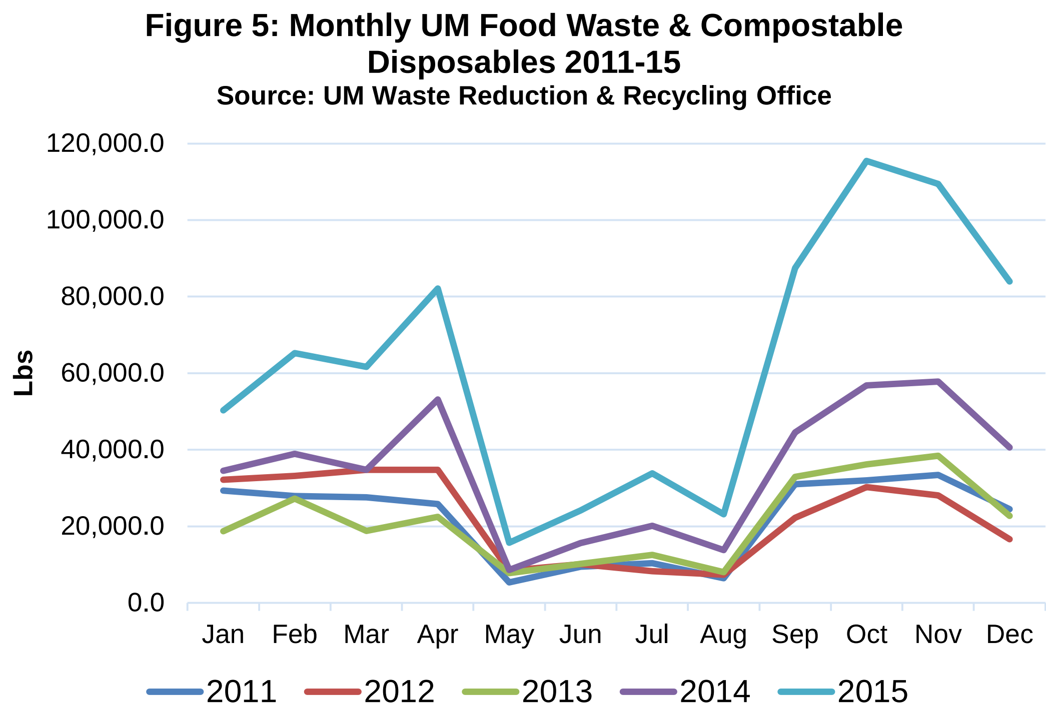


Figure 4: UM Composted Waste by Building, 2015
Source: UM Waste Reduction & Recycling Office





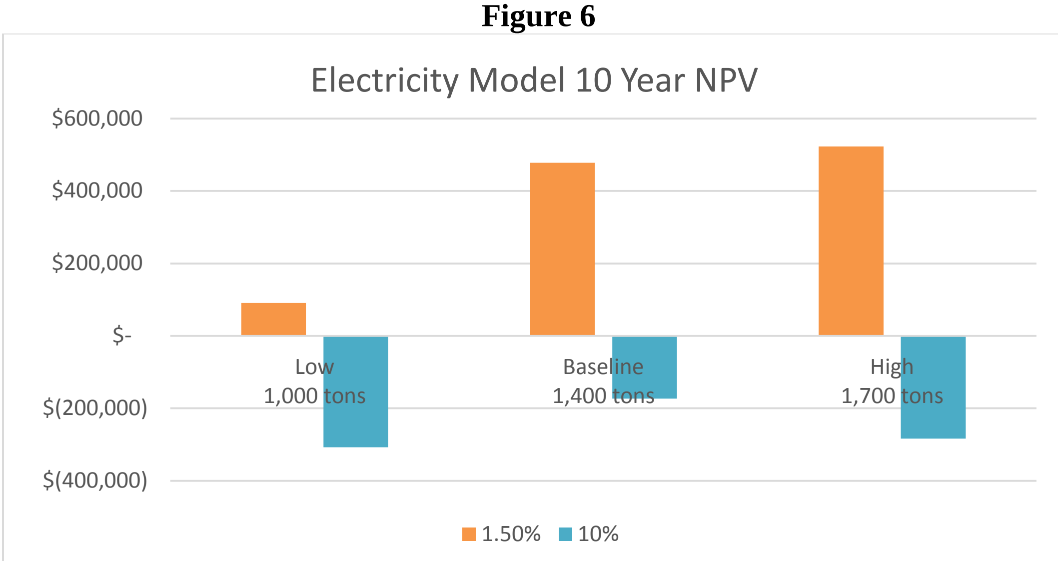
UM's organic waste production threshold. One company that creates systems within UM's waste production scale, NATH Sustainable Solutions, provided us with detailed data and estimates about their anaerobic digester system, which we have incorporated in our cost/benefit analysis. NATH Sustainable Solutions provided us with data about one system that uses organic waste to generate electricity, and a second system that uses organic waste to generate compressed natural gas. Their data incorporate three separate scenarios for the potential organic waste captured and diverted to a digester at the University out of the total of 2,500 tons that are available; 1,000 tons, 1,400 tons, and 1,700 tons.

B. <u>Methods</u>

Using the data provided by NATH Sustainable Solutions, we designed a cost/benefit model to incorporate many of the costs and benefits associated with constructing and operating an anaerobic digester under each of their three scenarios, with 1,400 tons captured as our baseline and high and low scenarios for the others. We used a 10-year time horizon and a 10% discount rate as baseline assumptions in our model. Costs included in the model comprise of capital costs, service and maintenance costs, and composting site tipping fees for the byproduct. Capital costs were estimated between $1.3 million and $2 million depending on the scale of the system under the three scenarios.[18] Revenue streams included in the model were composed of biofuel produced, heat produced, tipping fees for waste collection, heat generated, RINs, and biosolid byproducts.

Under these assumptions with a baseline of 1,400 tons of organic waste captured out of the total of 2,500 tons, the electricity model returned a NPV of negative $173,000 over the 10-year period with an IRR of 7% (See Figures 6 and 7). The CNG model returned an NPV of approximately $1.4 million over ten years with an IRR 30% (See Figures 8 and 9). These estimates are likely overly optimistic given the limitations of the data.

Figure 6



[18] Food Waste Experts, NATH Sustainable Solutions

Figure 7

Electricity Model Scenario Summary			
Discount Rate	Low 1,000 tons	Baseline 1,400 tons	High 1,700 tons
1.50%	$90,692	$477,751	$523,020
10%	$(307,845)	$(173,336)	$(283,330)
IRR	3%	7%	6%

Figure 8

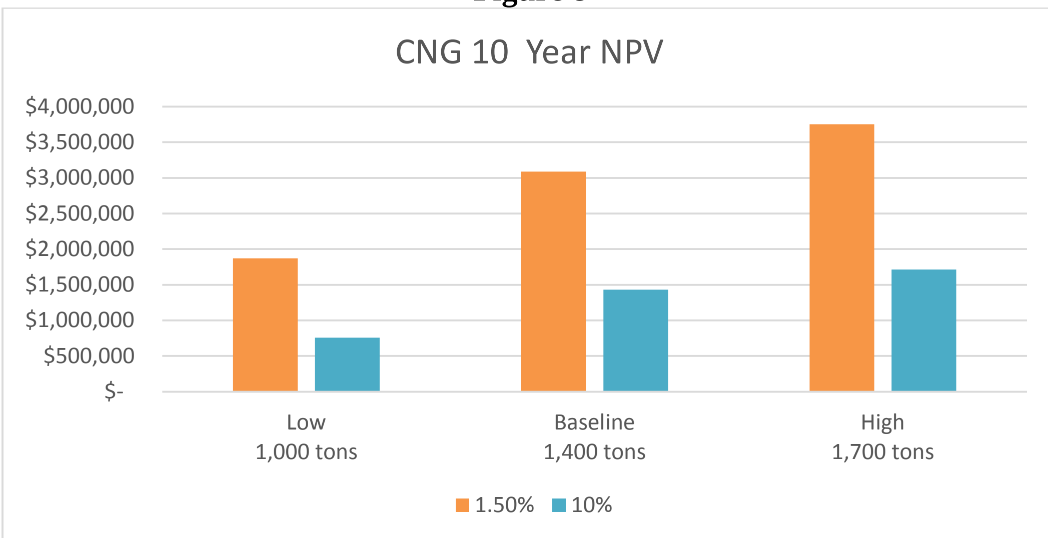


Figure 9

CNG Model Scenario Summary			
Discount Rate	Low 1,000 tons	Baseline 1,400 tons	High 1,700 tons
1.50%	$1,868,872	$3,088,281	$3,753,667
10%	$755,793	$1,429,332	$1,714,629
IRR	23.47%	30.53%	29.58%

C. Findings

Based on our assumptions and the data we do have, an anaerobic digester system is promising technology. Given the size of its waste stream, an anaerobic digester at UM has the potential to reduce carbon emissions by up to 3,800 metric tons of CO_2 equivalent/year, by avoiding the release of 152 metric tons of methane into the atmosphere. The University has a small feedstock, especially compared to other universities that currently use anaerobic digestion to improve waste management. Many anaerobic digester manufacturers build large facilities that can process large quantities of waste. Scale is a limitation for UM if it is going to move forward with an anaerobic digester facility.

The biggest potential unknown regarding the University's waste stream is the UM hospital system. We have not found or incorporated any data regarding organic waste produced at the University's hospital system. Incorporating UM hospital waste into the model would change the scale of a biodigester project on campus, and reduce the limitations of economies of scale. Without data it is uncertain what the potential waste stream might look like. But given the size of the hospital system it could potentially produce a sizable portion of the University's total waste.

D. Next Steps

To move forward the University will need more accurate data about it's waste stream including total quantity and content. The University will collect and analyze new data next year as part of its five-year campus-wide trash sort. These data will be essential to garner more accurate cost estimates and energy outputs from an anaerobic digester. New data that is needed includes pre-consumer versus post-consumer food waste, moisture content of the waste, how is the food sorted, and how much is contaminated with inorganic waste, percentage of napkins and tissues versus other compostable disposables, and the percentage of feedstock produced on campus.

Additionally, there were other costs and benefits we were not able to monetize which will have large impacts on both the costs and benefits of using anaerobic digestion at UM. These included input and waste separation costs, collection and transportation costs from the University departments to a digester facility, and education and training to use the new system on campus in the dining halls and across all departments. Collecting these data are important next steps for UM as it continues to evaluate the viability of anaerobic digestion technology to achieve its sustainability goals.

VI. Implementation

A. Risks

A number of risks are inherent in the construction of a biodigester project. Among the most prominent are: a loss of consistently available feedstock, a significant reduction in the value of the produced gas (or the associated RINs), and accidental contamination of the feedstock with inorganic materials (rendering the residual inappropriate for use as compost or fertilizer). While these are serious risks to the proper functioning and financial viability of a campus biodigester, the University can prepare for and prevent or mitigate each of these possibilities. To do so, it is important to design robust and reliable systems of feedstock collection and to utilize conservative estimates of financial returns.

B. Governance

Building a campus biodigester also requires the University to determine how the system will be governed. This is primarily important in answering two questions: (1) How will material be collected, transported, inserted into and removed from the system? (2) How will the physical structure and chemical balance of the biodigester be maintained and repaired?

Theoretically, a system like this could be operated by the City of Ann Arbor, or by a third party utility (such as DTE). However, it is most likely that any biodigester built on UM's campus would be operated by the University itself. That could entail either UM Facilities & Operations or the College of Engineering taking responsibility for the system, or the two could divvy up responsibilities between them. Whatever the decision, it is important for questions of governance to be addressed before the biodigester is operational.

C. Siting

Siting remains one of the most significant hurdles to be overcome. To locate a suitable site for the construction of a biodigester, the University's planning office would have to determine that there is an available space within their five-year master plan for campus development. This biodigester would be competing for space with existing and planned campus buildings.

In addition to locating sufficient physical space for the biodigester, any site would have to include appropriate access to utilities connections, and would have to meet regulatory requirements for fire safety, gas handling, and air pollution monitoring and mitigation. Finally, UM would need to consider community reactions when choosing a site for the biodigester; the construction and operation of this facility could create sights, sounds, and smells that are disruptive to its neighbors.

VII. Recommendations

We recommend that the University look further into pursuing a biodigester project. It was difficult to adequately assess the profitability of using this technology given limitations in of the data, but a biodigester would help the University make substantial progress towards three of its Sustainability Goals. With that in mind, we recommend certain next steps as part of creating a more detailed analysis:

A. Data Collection

1. *Go forward with planned collection of food waste data.* In particular, a more comprehensive analysis of the content of the organic waste would allow for more detailed cost and revenue estimates. This step will be crucial in assessing the viability of constructing a biodigester at UM.

2. *Investigate other costs*. These include costs for further waste separation, costs to build a CNG production facility, and specific operational costs that will be unique to the location the biodigester and where it is sited.

B. Reaching Out to Stakeholders. As is described in Appendix 1 below, we have brought together a wide array of stakeholders who have an interest in the project. Developing relationships with these stakeholders and others will allow the University to gain the expertise necessary to complete a more thorough analysis of creating a campus biodigester. Additionally, UM can learn best practices on using biodigesters and other waste reduction techniques from other universities with similar programs.

APPENDIX 1 – Stakeholders

Interview Approach

In collaboration with UM Blue Lab, the Dow Fellows UM Waste-to-Energy team interviewed 22 different stakeholders. In addition to relevant decision makers on campus, the team spoke to sustainability directors at other universities, the City of Ann Arbor, DTE Energy, and food waste management companies. Interviews with digester companies and universities focused on gaining insight to the following questions:

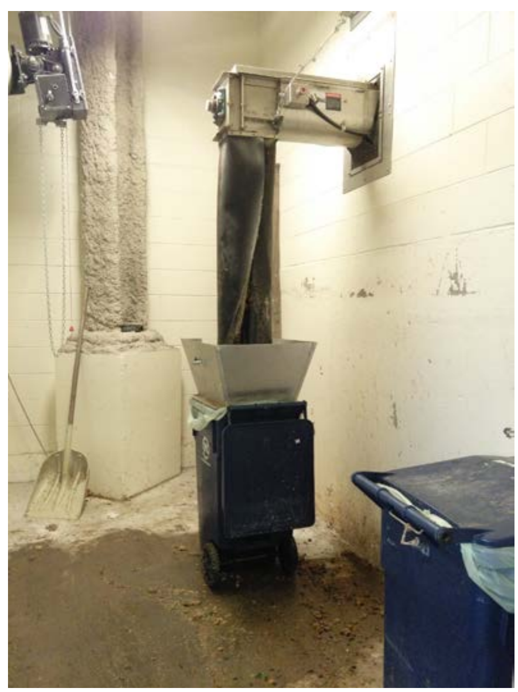
1. How does your company offer a superior product compared to competitors?
2. What was/has been your university's approach to choosing a food waste management system? (e.g. potential for educational opportunities, student built digester rather than sourcing from a company)
3. What were/have been the main decision criteria? (e.g. ROI, carbon abatement, education/student engagement)
4. What are some risks or lessons learned so far to bring a digester on campus?

Interview Results

<u>Food waste management narratives: interests, concerns, and advice from seven central stakeholders</u>

The following narratives from in-person and phone interviews provide insight into current interests, concerns, and advice from seven central stakeholders: UM University Unions and Dining, City of Ann Arbor, MSU's Anaerobic Digestion Research and Education Center, Princeton Office of Sustainability, Duke University Carbon Offsets Initiative, Sustainability Office at the University of Wisconsin-Oshkosh, and DTE Biomass Energy.

<u>UM University Unions and Dining</u>



Background
UM University Unions manages the Michigan League, Michigan Union, and Pierpont Commons. They provide fast food options and other conveniences such as study rooms and event halls to the UM community. UM Dining is responsible for managing and operating seven dining halls, eight on campus markets, and 11 cafés servicing undergraduate dormitories.

Key insights
Collectively, UM University Unions and Dining would like to find a sustainable, efficient, and effective solution to dispose pre and/or post-consumer organic waste. They are currently working on changing UM fees for picking up landfill waste versus compost waste.

Pick-up is a UM service so UM can set the fees to incentivize less landfill waste, more compost. However, waste management across UM dining halls differs. Current solutions include a food pulper at South Quad dining hall shown right, which has frequent problems (e.g. clogging, unpleasant smell during summer). Other dining halls have some major composting programs already in place for pre and post-consumer organic waste. At Bursley, managers are currently piloting dorm post-consumer compost bins. This has dramatically reduced amount of waste sent to landfills from the dorms. Any new solution will need to emphasize sanitation to avoid trash sitting for rodents and the like to take over.

City of Ann Arbor

Background

The City of Ann Arbor is currently in the process of selecting a consulting firm to develop a second feasibility study for an anaerobic digester system. The goal is gain more exact data regarding waste stream volumes. Specifically, they are evaluating the potential volumes from restaurants and more exact cost estimates. Biodigestor companies and industry experts thought the first report's estimated costs were too low. Finally, they are in the process of identifying a team of engineers with experience in building digesters for cities/universities rather than systems that rely on agricultural waste.

Key insights

For any collaboration between the City and UM, the City would need to have control of waste stream. This might have been a challenge of collaboration in the past. It is not clear if UM is willing to cede control of its waste streams to the City. The City should have enough waste to move forward without UM, but it would be better if UM participated. If UM did participate, they would pay the City to manage the waste. Usually payment comes from millages on property taxes but UM does not pay taxes.

The City would need a long-term deal in place to move forward. Again this might be a challenge if UM is unwilling to commit to a long-term deal. If UM did decide to build their own they would need to look at output content of solids and liquids. If liquids are high in phosphorus, they might not be disposable in City dump or other City areas. This issue caused the Fremont Community Digester in Fremont, Michigan biodigestor shutdown in 2015.

UM would not be able to take advantage of any State or Federal Incentives in the form of tax breaks since UM does not pay any taxes. This is why it might be advantageous for a third party to own the facility. They could get the tax incentives and the partner with the University. The City is looking into several options with using a third party that would own and operate the digester or lease land from the City to operate the facility.

The City could simply put out a regulation that prevents organics from going to the landfill but this is harder for UM to do because it requires better systems to manage and separate waste more efficiently. The City's Fire Department and the Fire Marshall would oversee any biodigestor UM would build; thus, the system would need to meet the City's specific regulations and codes.

MSU's Anaerobic Digestion Research and Education Center

Background

Founded in 2008, the Michigan State University Anaerobic Digestion Research and Education Center (MSU ADREC) comprehensively researches, develops, and evaluates technologies associated with integrated anaerobic digestion systems. Related education and outreach activities emphasize cost-effective and efficient technologies on small and medium-sized dairy farms, along with other biomass energy topics and environmental protection.

Key insights

The majority of their waste come from manure and food waste. However, only 2% of the food waste comes from the cafeterias. Most of it comes from industrial food waste from milk producers and grocery stores. For example, partnership with Meijer provides a sustainable alternative for processing food waste. Processing pineapples alone creates 10 tons of waste per day.

MSU ADREC enjoys revenue streams from tipping fees and biogas electrical offset at 9.8 cents per kWh. Fertilizer should be another source but they currently pay $30,000 to dispose of it when it could sell at $70,000. It comes down to the lack of resources to market it. Some of the fertilizer is being used to hydro seed in construction areas. Paypack period is about double what they expected partially because of issues selling the fertilizer (18 years instead of 7-10 years). Because of this, the system absolutely cannot go offline. It would be very expensive to restart the system.

Students are very involved with the development and testing of biodigester simulators. The large-scale anaerobic digester itself is operated by employees.

A Spartan enthusiastically feeding the biodigester simulator

Four biodigester simulators operated by MSU

Princeton Office of Sustainability

Background

The Princeton Office of Sustainability coordinates the multiple student and university sustainability initiatives. Director Shana Weber emphasizes their focus on creating hands on learning opportunities for students. Their “Explore Campus as a Lab” program highlights this practice. They believe Princeton is “a living laboratory filled with opportunities to study sustainability issues right here on campus through any discipline.” The main objective of the alternative food waste management system is to give students action-based learning opportunities. Because of this, they ultimately decided to not pursue an on-campus anaerobic digestion system.

Key insights
After vetting multiple systems and poor experience with inefficient systems, Weber found that digester systems were too tricky of a process and require careful monitoring that would restrict participation from the greater campus community. She decided to go with the FOR Solutions composting system.

The campus lab concept in tandem with the composting system will allow students to get their hands dirty and see the direct link between the amount of food waste diverted from landfills. It allows the campus community to have broader conversations of what is involved. They wanted the technology to be flexible and forgiving. The FOR Solutions composting system operates on water, vapor, and CO_2. It is a simpler technology to accelerate composting replicating the stomach of a worm (aerobic process).

There was also a central practical reason for their decision: there was no local solution for food waste composting. A facility 90 miles away was shut down by the EPA a few years ago. They sent food waste to a family run pig farm for 15 years until operations shut down. Today, they are considering collaboration with a local start-up called AgriArc that ferments food waste to produce high-end soil nutrients. However, this is not a perfect solution either. If the start-up folds, they will still need to find a way to process their own food waste and must mitigate risk of not having any other solutions.

It also helped that they could observe a FOR Solutions composting system functioning and its maintenance needs at Kane University. Weber and her team were impressed with the quality of the materials used, low maintenance, and energy use. In contrast, some other systems have been reported to break often and are more complex. She is currently working on getting the necessary permits to install the system on campus. The most difficult part of this process has been deciding where to put it. It has taken three years to get to this point.

From a funding perspective, they had a donor who was interested in food waste issues and kicked off the process. There has been immense academic and residential life interest from faculty, dining halls, and students. It is a prevalent and visible topic along with a unique opportunity for educational activities and real impacts. This conversation has been critical to getting buy-in from administrators.

<u>Duke University Carbon Offsets Initiative, Office of the Executive Vice President</u>

Background
To meet its goal of climate neutrality by 2024, Duke University will need to offset approximately 185,000 tons of carbon dioxide equivalent-emissions per year. The Initiative is responsible for developing the University's strategy for meeting its offset goals in a way that provides significant local, state and regional environmental, economic, and societal co-benefits beyond the benefits of greenhouse gas emission reductions. They are currently wrapping up a student project to complete a feasibility study for a campus digester. They only have enough waste for a small demonstration project and will be pursuing the idea of students designing and building a demonstration project on campus.

Key insights
The biggest surprise in their study was the amount of waste they would need. They would need to bring in waste to feed the digester and their operations department said that they would not want to bring waste onto campus. Moreover, facilities management would have to play a big role to operate a commercial size digester to work. They are considering a small, custom made digester that would be designed by an engineering class and located near an engineering school that could use the natural gas directly.

In their initial study, they could not find a way to make the digester revenue positive, even taking into account carbon offsets ($5-10) and RECs. Energy costs are really low at .05 cents per kWh. One system cost $50M (5 megawatt) and could have a three year payback revenue from tipping fees. They did this study from an emissions perspective as well and it is not low hanging fruit. At this point, solar seems like a more accessible avenue to meet emissions goals. From a public relations standpoint, it is also simpler.

<u>Sustainability Office at the University of Wisconsin-Oshkosh</u>

Background
UW Oshkosh is frequently mentioned for its biogas program. Its dry fermentation anaerobic digester processes more than 11,000 tons of organic waste annually. Located on campus, the plant produces methane gas from organic wastes including food, municipal yards waste, and farm bedding. At full capacity, the plant is equipped generate 10% of campus electricity needs. Thermal energy will heat Facilities Services, saving campus $20,000/year.

UW Oshkosh signed the American College and University Presidents Climate Commitment (ACUPCC) in 2007, which obligates campuses to strive for climate neutrality by mid-century or sooner. UW Oshkosh uses STARS (Sustainability Tracking, Assessment, and Rating System), created by the Association for the Advancement of Sustainability in Higher Education (AASHE), to assess and report sustainability data and progress. The campus registered as a charter member in August 2010 and has had a Gold rating since 2013.

Key insights
Bioferm constructed UW-Oshkosh's dry anaerobic digester, the first in the country. A university administrator was involved in a group related to renewable energy companies and met Bioferm's parent company's CEO. Nearly the entire system came from Germany. It is located on campus and has no affluent. It produces nutrient rich compost and generates energy.

Only 800 tons of the feed comes from campus food waste. The University offers a competitive price for waste disposal to local restaurants and grocery stores. Though, the city is the largest provider of trash, which is mostly yard waste. UW-Oshkosh also has farm contracts where they can ask the farms to bring more waste like bedding straw if grocery stores decrease waste. Utilities put a cap on how much you can produce. They would have built a bigger facility if they could sell more back to the grid.

Understanding the rules and regulations of heating plant and power plant is the first lessons learned in bringing a biodigester to UW-Oshkosh. An alternative approach is to develop power purchase agreement for a length of time with a third party that could own and operate the system. You pay them through the savings that you realize.

The payback period for their system is 8-10 years. The university foundation took out loans and made the investment. Sell RECs or internalize them for a neutrality plan reducing emissions.

In addition to making compost out of the digestate and tipping fees, they have explored installing a generator burning natural gas that would turn a generator to make electricity. They would capture and transfer heat to save about $30,000 year in heating. However, they could not do this today because of the capital outlay required. Investors are hesitant even though there would be long-term savings with a 10-year payback. The university doesn't have the cash for it today.

<u>DTE Biomass Energy</u>

Background
Offers extensive experience and expertise in the acquisition, construction, development, ownership and operation of landfill gas recovery systems, landfill gas-to-energy facilities and carbon offset projects, providing environmentally sustainable products to the market.

Key insights
DTE recommends a waste-to-energy strategy that considers the following four options: 1) fuel fleet vehicles with compressed natural gas (CNG) 2) generate electricity with bio turbines, 3) purify gas to meet pipeline specifications, and 4) fire gas for boilers, chilled water, etc.

Since the cost to connect and sell to the grid is too much for the amount of waste UM is considering, DTE would first recommend the other three options noting CNG powered fleet vehicles might be the best approach. It does not require much refining and UM would not have to buy gas from anyone else for their fleet. However, this approach would require a place to store the gas. The Cornerstone landfill site near Ann Arbor has CNG powered fleet vehicles and could serve as a model. Additionally, review different types of Renewable Identification Numbers (RINs) that track renewable transportation fuels and could provide a significant revenue stream.

If UM considers using the energy to heat boilers, they would only have to make a few adjustments to the gas to make it suitable. Again, level of refinement required is not as stringent as pumping the gas into the pipeline. Though, if UM can purify for pipeline specifications, then it can sell it as renewable natural gas.

Of course, UM must consider biosolid and other waste disposal costs of any approach. This is often overlooked in waste-to-energy projects and is the biggest reason for failure. Often, the cost of disposing the waste outweighs the benefits. DTE has an arrangement with GE, which is an excellent system that could be scaled down for bio turbines.

Companies contacted

Company	Type of equipment	Responded to information	Equipment capital (000)	Capacity (input in	Can scale

		request?		tons)	up?
FOR Solutions, LLC	In-vessel rotary drum composting system	Yes	$350	925	No
Food Waste Experts	AD system - QUBE Technology & CNG	Yes	$1,539	1,700	Yes, up to 2,500
Food Waste Experts	AD system - QUBE Technology & Electricity	Yes	$1,547	1,700	Yes, up to 2,500
CH Four Biogas	-	No	-	-	-
BIOFerm™ Energy Systems	AD system - Dry fermentation	Yes	$1,200	10,000 (min)	Yes
Impact Bioenergy	AD system - Microdigester AD 185	Yes	$350 - $600	185 - 925	No
Wright Environmental	In-vessel composting system	Yes	$450	730	No
Digested Organics	-	No	-	-	-
Bioworks Energy, LLC	-	No	-	-	-
MWK Biogas North America	-	No	-	-	-

Key contact information by stakeholder type

Type of Stake-holder	Company or organization	Contact	Position	Email	Phone	Interview date
Private Sector	DTE Biomass Energy	Phil O'Niel	Manager, New Business Development and Commercial Strategy	philip.oniel@dteenergy.com	(734) 302-4800	9/26/2016
Private Sector	FOR Solutions, LLC	Nick Smith-Sebasto	Founder & Executive Chairman FOR Solutions, LLC	nsmithsebasto@forsolutionsllc.com	(973) 945-9150	7/15/2016

Private Sector	Food Waste Experts	Gerardo Soto	Founder	gsoto@foodwastexperts.com	(212) 729-0757	9/28/2016
Private Sector	CH Four Biogas	-	-	info@chfourbiogas.com	-	n/a
Private Sector	BIOFerm™ Energy Systems	Whitney Beadle	Channel Marketing Manager	beaw@biofermenergy.com	(608) 229-6504	
Private Sector	Impact Bioenergy	Michael J. Smith Jr	JD, LEED AP Legal, Green Buildings, Business Development	michael.s@impactbioenergy.com	(425) 773-2231	n/a
Private Sector	Wright Environmental	Stephen Wright	Vice President	stephen.wright@wrightenvironmental.com	(905) 881-4651	n/a
Private Sector	Digested Organics	ROBERT LEVINE	Ph.D. CEO & Founder	robert.levine@digestedorganics.com	(847) 707-8433	n/a
Private Sector	Bioworks Energy, LLC	Chad L. Antle	P.E. CEO	chad.antle@bioworksenergy.com	(740) 972-2499	n/a
Private Sector	MWK Biogas North America	-	-	-	-	n/a
Public Sector	City of Ann Arbor	Matt Naud	Environmental Coordinator	mnaud@a2gov.org	(734) 794-6430 ext. 43712	7/1/2016
UM	UM Waste Reduction & Recycling Office	Tracy Artley	Sustainability Programs Coordinator for PBGS	artleyt@umich.edu	(734) 764-1600	
UM	UM University Unions	Keith Soster	Director of Student Engagement	ksoster@umich.edu	(734) 763-5766	
UM	UM Dining	Steven Mangan	Director	smmangan@umich.edu	(734) 764-7451	
UM	UM Dining,	Martin	General	mjfolk@umich.edu	(734)	

	Bursley	Folk	Manager		763-1120	
UM	UM Department of Civil and Environmental Engineering	Dimitrios Zekkos	Ph.D., P.E., Associate Professor	zekkos@umich.edu	(734) 647-1843	
University	University of Wisconsin-Oshkosh	Brian Kermath	Director of Sustainability	kermathb@uwosh.edu	(920) 252-1322	
University	Duke University, Carbon Offsets Initiative, Office of the Executive Vice President	Charles Adair	Program Manager	charles.adair@duke.edu	(919) 613-7466	8/17/2016
University	Princeton Office of Sustainability	Shana Weber	Director	shanaw@princeton.edu	(609) 647-0056	8/3/2016
University	MSU's Anaerobic Digestion Research and Education Center	Dana M. Kirk	Ph.D., P.E., Assistant professor and Manager	kirkdana@msu.edu	(517) 432-6530	7/22/2016