Feasibility of Converting Campus Food Waste into Energy

By: Elizabeth Karlovics, Angela Creely, Erika Jaszka

December 15th, 2017
Final Report
CEE 398PBL

Table of Contents

Executive Summary
This project will research the potential for increased energy output of the Urbana-Champaign Wastewater Treatment Plant by combining food waste from the University of Illinois at Urbana-Champaign (UIUC) into the processes of anaerobic digestion. Currently, UIUC disposes a majority of its food waste through EnviroPure systems where food waste is transformed into grey water that is then sent to the UC Wastewater Treatment Plant. While this allows the UIUC food waste to be diverted from landfills, the EnviroPure System doesn't produce any energy thus causing the energy content leftover in the food waste to go untapped.

Our project determined that the entirety of the UIUC food waste could be diverted from the EnviroPure systems to the anaerobic digestion system at the UC Wastewater Treatment plant. While the cycles of additional space for volatile solids at the plant during each month are on average 16,334 lbs./day, the different volumes of food waste produced at UIUC during each month only average to about 290.1 lbs./day of volatile solids. Additionally, we quantified the additional methane output to be on average 2,504 cubic feet of methane per day thus generating about 734.1kWh per day. This additional methane and the elimination of the EnviroPure systems would save about $48,275 per year on power purchased at the plant, electricity needed for the EnviroPure systems, and biomix required to operate the EnviroPure systems. We advise the university to consider shutting off the EnviroPure systems and divert the campuses food waste to the anaerobic digestion systems at the Urbana Champaign waste water treatment plant.

Introduction & Background

Food waste

According to the United States Department of Agriculture (USDA), in 2010 between 30 to 40 percent of the food supply is wasted. Food waste occurs at all stages of the food supply chain. These stages are pre-harvest, post-harvest, processing, transport, retail, and consumption. In developed nations, such as the United States of America, most food waste occurs at the consumption stage (USDA 2016). Food production in developed nations is plentiful and cheap due to the advanced technology in agriculture and food processing (Hall et al. 2009). The USDA reported that the percent of income U.S. residents spend on food is less than any of the 83 other countries the USDA tracks (USDA 2016). Consequently, Americans are more prone to generate high quantities of food waste.

Food Waste Disposal Methods

Landfill

Food waste can be disposed of in many ways, but the most popular method in the United States is disposal by landfill. Food waste is the second largest percentage of municipal solid waste, and less than 3% of it is diverted from landfills (EPA 2017). This is problematic as municipal solid waste (MSW) landfills are the third-largest source of human-related methane emissions in the United States, making up 15.4 percent of these emissions in 2015 (EPA 2017). However, at the same time, methane emissions from landfills represent a lost opportunity to capture and use a significant energy resource.

Aerobic Digestion

Aerobic digestion is a biological process that takes place in the presence of oxygen that allows bacteria present in the activated sludge to consume the organic matter. This, in turn, creates carbon dioxide while reducing the volume of sludge to dispose of (Woo 2012). However, no energy is generated from these processes, and the energy content of the food waste is unable to be converted into a new, usable form of energy.

Composting

A more efficient way to dispose of large quantities of food waste aerobically is through composting. Composting involves using microbes to help organics such as food waste decompose aerobically into a stable, soil-like material. This material is typically added to soil in order to improve its quality, provide nutrients to plants, and decrease the need for chemical fertilizers.

Hydrothermal Liquefaction

Hydrothermal liquefaction is a form of food waste disposal that uses the energy content leftover in the waste. This process requires a high temperature and pressure environment that makes water a highly reactive medium. This allows the chemical bonds in the food waste to be broken down and reformed into a biocrude oil (Zastrow et al 2013). Biocrude oil is a clean fuel compared to fossil fuels because it keeps a contained carbon cycle, since the carbon released while burning the biocrude oil is the carbon that the plants removed from the atmosphere while the plants were growing. Furthermore, biocrude oil has no SOx emissions, thus companies using this energy source will not be charged an SOx emission tax (Xiu et al. 2012). The advantage of using the process of hydrothermal liquefaction over anaerobic digestion is that it generates a significantly larger amount of energy. However, this is a relatively new technology with less established infrastructure.

Anaerobic Digestion

Anaerobic digestion is a treatment that converts biodegradable waste in the absence of oxygen into biogas that can be used to generate electricity and heat. Anaerobic digesters are commonly found throughout the United States at wastewater treatment facilities where they are used to break down sewage sludge. Recently, there has been an initiative to begin adding food waste to these existing digesters to create more biogas, reduce energy costs, and divert more food waste from landfills. Some limitations are that anaerobic digestion requires more time to process the waste compared to aerobic digestion (AECOM 2012).

Stages of Anaerobic Digestion

Three stages of anaerobic digestion occur simultaneously within the digester. The first stage is acid fermentation, where the microorganisms rapidly process soluble solids such as sugar. This reaction creates organic acids which decrease the pH level to around 6.8 to 5.1 or less. The second stage is acid digestion, where organisms that favor an acidic environment begin to process and liquefy the organic acids and ammonium compounds that were produced in the previous stage. This step occurs at a much slower rate, has a decreased gas production level, and results in an increase of the pH level to around 6.6 to 6.8. The third and final step of anaerobic digestion is intensive digestion. In this stage, the materials that are more difficult to digest, such as proteins and amino acids, are processed. The pH stabilizes to around 6.8 to 7.4, and methane is produced in large amounts. The solids that remain after the process concludes are disposed of safely (AECOM 2012).

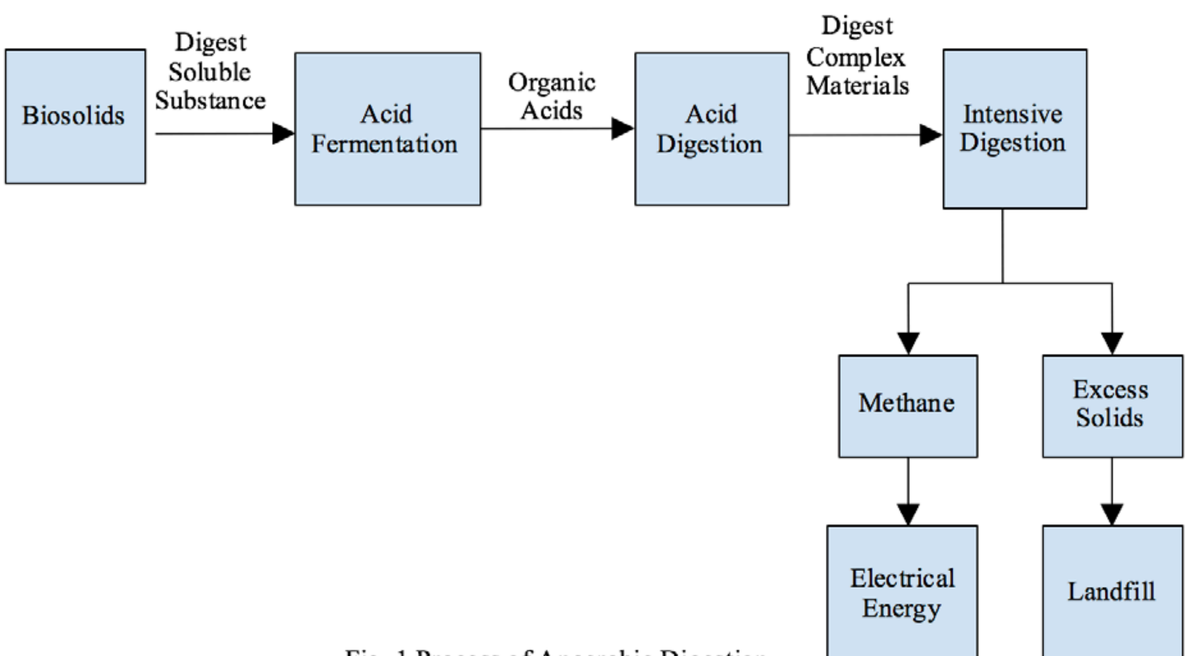

Fig. 1 Process of Anaerobic Digestion

Current Solution

The University of Illinois at Urbana-Champaign is currently attempting to create a sustainable dining process through initiatives such as recycling and reducing food waste. Around 7 tons of food is being diverted from landfills into different processes such as EnviroPure systems (University Housing 2016). EnviroPure systems work by using microbes and mechanical processes to transform the food waste into grey water that meets/ surpasses government standards in order to give the water to the wastewater treatment plant. Currently, 90 percent of the food is put through the EnviroPure system, and the leftover food waste is given to sustainable on-campus farming which uses it to enrich their soil through composting (Waste360 2016).

Although EnviroPure systems are more sustainable than landfills, they do not produce energy and require additional energy inputs. Another process such as anaerobic digestion could be used to allow energy to be produced. Food waste that undergoes anaerobic digestion has “three times the methane production potential as biosolids” (EPA 2015), which would allow for the Urbana-Champaign Wastewater Treatment Plant to produce more methane, thus, reducing their energy costs. Diverting more of the campus food waste into this pre-existing system that the Urbana-Champaign Wastewater Treatment Plant has would make our campus food waste management more sustainable while benefiting the wastewater treatment plant.

Objective

The objective of our project is to research the change in energy-outputs by incorporating the food waste on campus with the biosolids at the Urbana-Champaign Wastewater Treatment Plant in the preexisting processes of anaerobic digestion. In addition, we will quantify the projected benefits to the wastewater treatment plant by collecting data on the cycles of food waste on campus and compare it to the cycles of holding capacity at the plant. This project is important because it could allow the energy content in the campus food waste to be turned into a usable form of energy through electricity and heating in the form of methane.

Methodology

In order to accomplish this project's objective, we created 4 main tasks along with specific subtasks. The four main tasks are to review literature, conduct the capacity evaluation, complete the economic evaluation, and write the report.

Task 1: Review literature

1.1 Research Processes at UC Wastewater Plant

We started by researching the current processes of anaerobic digestion that the UC Wastewater Treatment Plant has in place for generating energy from biosolids. We obtained this information by reviewing scientific literature on this process. Our research allowed us to become familiar with the steps of each process and the typical energy output.

1.2 Research Current Food Waste Management at UIUC

The next step was to research the current processes of food disposal at UIUC by reviewing the University Dining website and speaking with UIUC Housing and Dining representatives, Dawn Aubrey and Thurman Etchison. We spoke with them about the EnviroPure systems, and the meal plans. The representatives provided us with data on the specifications of the EnviroPure systems, price of the vitamins, data on meal swipes, and a waste diversion study. Furthermore, we looked into the possibility of redirecting this waste to the wastewater treatment plant to be used in energy-generating processes.

1.3 Research Effects of Incorporating UIUC Food Waste with the Existing Biosolids
We reviewed case studies to determine how combining the food waste with the existing biosolids in the anaerobic digesters would impact the energy output, the capacity, and the wastewater management plant as a whole. Additionally, we researched online sources to determine if pretreatment is necessary for the food waste to be put into the anaerobic digestion system or the hydrothermal liquefaction system.

<u>Task 2: Capacity Evaluation</u>
2.1 Contact Sources
As a part of the capacity evaluation, contacted an associate of the UC Wastewater Treatment Plant, associates of UIUC Dining, and Professor Schideman through email as well as in-person conversations.

A. We determined the storage capacity of the plant by emailing and calling Jackie Christensen, Director of Operations at the UC Wastewater Treatment Plant, for data on the total capacity of the anaerobic digesters and hydrothermal liquefaction, the current influx of biosolids going through these processes, and the current energy output of these processes.
B. We emailed and met with Dawn Aubrey, the Associate Director of Housing and Dining, and Thurman Etchison, the Assistant Director of Dining Equipment and Facilities, to determine the volume of food waste UIUC produces and where the different quantities of food waste are being sent.
C. We met with and emailed Professor Schideman, who is a knowledgeable resource about the UC Wastewater Treatment Plant and the processes of anaerobic digestion.

2.2 Determine Storage Capacity of Plant
After contacting the UC Wastewater Treatment Plant, we determined the amount of space available for additional inputs at the plant during different time periods. Through conducting calculations, we were able to determine the capacity of UIUC food waste that the UC Wastewater Treatment Plant can process during certain times of the year. This allowed us to determine if and when the plant can handle an additional influx of food waste.

2.3 Determine Quantity of UIUC Food Waste
After contacting the associates of UIUC Dining, we were able to use the data given to us on where different volumes of food waste are being sent to determine if a portion can be redirected from non-energy generating processes to the energy generating processes at the UC Wastewater Treatment Plant. This way, the energy content leftover in the food waste could be converted into usable energy through anaerobic digestion and possibly hydrothermal liquefaction at the plant.

2.4 Analyze Benefits and Drawbacks of Sending more Waste Through AD than the EnviroPure Systems
Deeper analysis of benefits and drawbacks of sending various quantities of UIUC food waste to the wastewater treatment plant were done after collecting the information on the current

additional capacity of the UC Wastewater Treatment Plant as well as the available volumes of UIUC food waste. We graphed this data to visualize differences between the available storage capacity of the wastewater treatment plant and the quantity of UIUC food waste over time.

Task 3: Economic Evaluation

3.1 Finalize Scope

Based on the information received from our contacts, we finalized our scope, and started the economic evaluation.

3.2 Calculate

A. We used information that we gathered from contacting the sources to determine the feasibility of diverting campus food waste from the EnviroPure systems into the anaerobic digestion system.
B. We calculated the energy outputs using the amounts of food waste gathered from UIUC Housing and Dining along with the information collected from data that was provided by the Urbana-Champaign Wastewater Treatment Plant. Additionally, we calculated the cost saved on power purchased at the plant as well as the electricity and biomix purchased for the EnviroPure systems.

3.3 Conclude Benefits and Drawbacks

Based upon the calculations, we were able to determine the advantages and drawbacks of using different methods of food disposal for UIUC Dining food waste. The calculations completed in previous step were put into informational graphs.

Task 4: Write Report

We compiled a final report on the feasibility of converting campus food waste into energy. This report includes a background, objective, methodology, table of values, written calculations, any assumptions made, analysis of data, conclusion, and all references used throughout the paper. This allows us to confirm if sending campus food waste to the UC Wastewater Treatment Plant to be converted to usable energy through the processes of anaerobic digestion and hydrothermal liquefaction would be a sustainable and efficient way for our campus to manage the excess food waste.

Schedule

Below is the schedule our project followed in order to complete our feasibility study in a timely manner. It is divided into four tasks with subtasks that specifically outline what needs to be completed by the 19th of December. (Refer to schedule on next page).

Task:	Oct. 8	Oct. 15	Oct. 22	Oct. 29	Nov. 5	Nov. 12	Nov.19	Nov. 26	Dec. 3
1. Review literature									
1.1 Research energy-generating processes currently used at UC Wastewater Treatment Plant									
1.2 Research current food waste management at UIUC									
1.3 Research effects of incorporating UIUC food waste with the existing biosolids									
2. Capacity Evaluation									
2.1 Contact:									
a. UC Wastewater Treatment Plant									
b. Director of Housing for Dining									
c. Prof. Schideman									
2.2 Determine storage capacity of plant									
2.3 Determine quantity of UIUC food waste									
2.4 Analyze benefits and drawbacks of sending more waste through AD than the enviropure systems									
3. Economic Evaluation									
3.1 Finalize scope									
3.2 Calculate									
a. Additional cost									
b. Energy Outputs									
3.3 Conclude benefits and drawbacks									
4. Write report									
4.1 Background, objectives, and references									
4.2 Methodology									
4.3 Results and analysis									
4.4 Discussion and conclusions									

Results

Calculating Food Waste Inputs

To find the food waste produced by UIUC during the different months of the year, we received data from Dawn Aubrey and Thurman Etchison on the amount of pre and post-consumer waste per meal swipe as well as the amount of dining hall swipes per month. As UIUC just started weighing their post-consumer waste in 2016, we averaged the values given to us from 2016 and 2017 for the different dining halls and found that about 0.326 lbs. of pre and post-consumer food waste are generated per meal. Then, using the data given to us on the amount of meal swipes per month, we were able to figure out the average amount of food waste generated per month. However, only a portion of this food waste is volatile solids, as much of it is water. We estimated that about 85% of this food waste is water based on the study published by Michael L. Westendorf, PhD. as well as our interview with Prof. Schideman (Westendorf 2007). Using this data, we calculated the average amount of total solids per month. Finally, to find the total amount of volatile solids per month, we found that the total solids in food waste is about 90% volatile solids based on our interview with Jackie Christensen and the study done by the EPA on the "Anaerobic Digestion of Food Waste" (EPA 2008). This allowed us to calculate the total amount of volatile solids generated at UIUC per month (See Appendix A).

$$\frac{\text{Total Amount of Volatile Solids Generated at UIUC per month}}{} = \frac{\text{lbs of Pre \& Post Consumer Waste}}{\text{Meal swipe}} * \frac{\text{Meal swipes}}{\text{month}} * \frac{.15 \text{ lbs total solids}}{\text{lb of consumer waste}} * \frac{.90 \text{ lbs volatile solids}}{\text{lb of total solids}}$$

<u>Calculating Methane Output of Anaerobic Digestion</u>

To determine how much additional methane can be generated by adding the food waste produced by UIUC, we first had to determine the capacity of the anaerobic digestion system at the UC Wastewater Treatment plant. Using the manual provided by Jackie Christensen, we were able to determine the maximum capacity of the system is 39,126 lbs of volatile solids per day (AECOM 2012). Then, using the 2016 Plant Summary provided by Jackie Christensen, we were able to find the average amount of volatile solids fed per day during each month (See Appendix B & C). Taking these values and subtracting them from the maximum capacity, we were able to calculate the average potential space remaining in the anaerobic digestion system per day during each month. After that, we converted our total amount of volatile solids generated at UIUC per month to the amount of volatile solids generated per day in order to compare it to the average potential space remaining in the anaerobic digestion system per day. By taking the average of both of these values, it's very clear that the UC Wastewater Treatment plant will have ample space for the current UIUC food waste since the average potential space remaining over all the months is 16,334 lbs of volatile solids per day while UIUC only generates an average of 291 lbs of volatile solids per day (See Fig. 2).

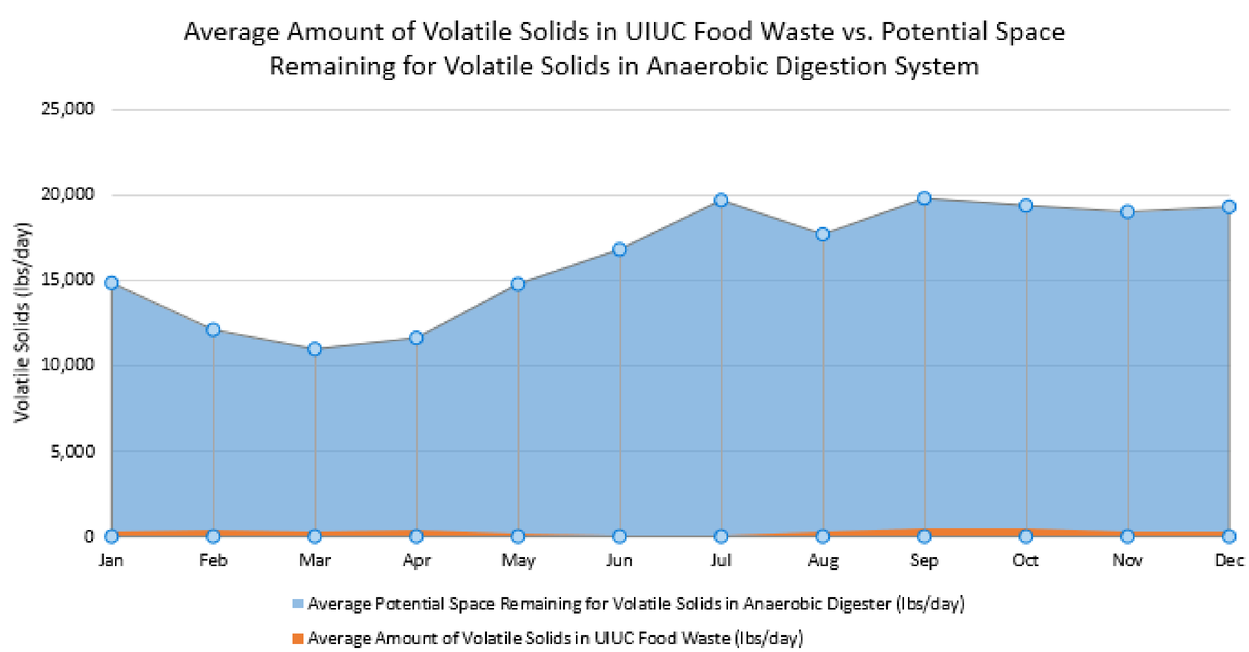

Fig. 2 Amount of volatile solids in UIUC food waste vs. potential space remaining for volatile solids in the anaerobic digestion system at UC Wastewater Treatment Plant (AECOM 2012)

Once determining that is it feasible for the UC Wastewater Treatment plant to take all of the UIUC food waste, we were able to calculate the additional output of methane generated by adding the UIUC food waste. In order to find this value, we used the data from the 2016 Plant summary on the cubic feet of methane generated per lb of volatile solid fed during each month (See Appendix B & D). We first were able to find the cubic feet of methane that is currently generated by multiplying the cubic feet of methane generated per lb of volatile solid fed during each month by the average amount of volatile solids fed per day during each month. This allowed us to find the current output of methane per day at the plant. Then, we repeated this process to find the additional methane that could be generated by taking the cubic feet of methane generated per lb of volatile solid fed during each month and multiplying it by average amount of volatile solids generated at UIUC per day during each month. We found that by adding in the UIUC food waste the plant would generate about 1% more methane than without the addition of the food waste (See Fig. 3).

$$\text{Additional Output of Methane Generated by adding the UIUC food waste} = \frac{\text{ft^3 methane}}{\text{lb of volatile solid fed}} * \frac{\text{lbs of volatile solids from UIUC food waste}}{\text{day}}$$

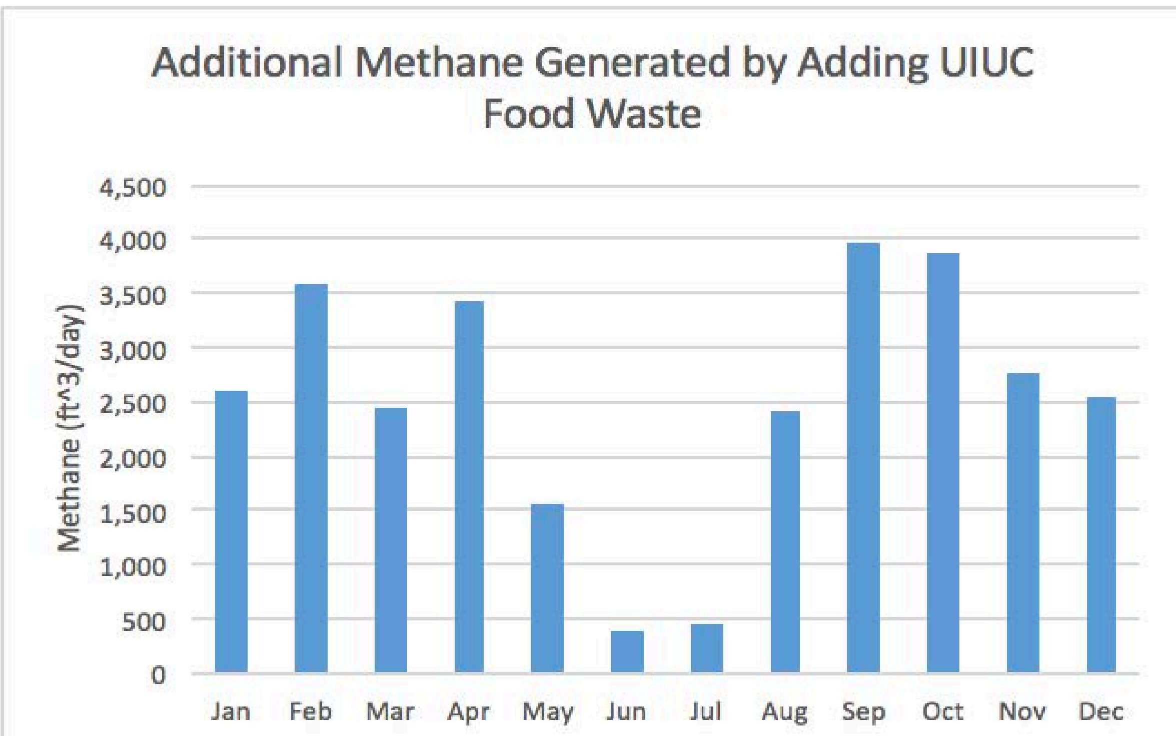

Fig. 3 Fluctuations in methane generated by adding UIUC food waste to the anaerobic digestion system at the UC Wastewater Treatment Plant during the different months of the year

Calculating Energy Output

Using our calculated values for the current methane generated per day during each month as well as the additional theoretical methane generated per day during each month by adding the UIUC food waste, we were able to calculate the current and additional energy outputs. To find the current energy output, we multiplied the current methane generated per day during each month by 1000 BTU/ cu. ft of methane to find the current energy output in BTU. Then, we converted this value to kWh by multiplying by 0.000293071 kWh/ BTU. We found that the current energy potential of the methane generated by the anaerobic digestion system is, on average, 57183.1 kwH per day. We then repeated this process to find the additional energy output by adding the UIUC food waste. We multiplied the additional methane created per day during each month by 1000 BTU/ cu. ft and 0.000293071 kWh/ BTU to find the additional energy output in BTU. We found that the energy potential of adding the food waste is, on average, 734.1 kWh (See Appendix E).

$$\begin{array}{c}\textit{Additional Energy Generated}\\ \textit{from UIUC food waste}\end{array} = \frac{\begin{array}{c}\textit{ft\^{}3 methane generated}\\ \textit{from UIUC food waste}\end{array}}{\textit{day}} * \frac{\textit{1000 BTU}}{\textit{ft\^{}3 methane}} * \frac{\textit{0.000293071 kWh}}{\textit{BTU}}$$

<u>Calculating Revenue</u>

To find the additional revenue of the plant, or in other words, the savings of the UC Wastewater Treatment plant on power purchased, we found the market price of methane to be $3.06/ MMBTU and then converted it to $0.0104/ kWh (U.S. Energy Information Administration 2017). We multiplied this value by each of the values for the additional energy output per day during each month to find the amount of money saved per day over the various months. On average, we found the plant would save about $7.66/ day on power (See Appendix F & Fig. 4).

$$\begin{array}{c}\textit{Revenue Generated from}\\ \textit{additional Methane Produced}\\ \textit{from UIUC food waste}\end{array} = \frac{\textit{\$3.06}}{\textit{MMBTU}} * \frac{\textit{BTU}}{\textit{0.000293071 kWh}} * \frac{\textit{kWh generated from food waste}}{\textit{day}}$$

In addition to that, we calculated the cost saved by eliminating the EnviroPure systems. We found that each of the six EnviroPure systems on campus uses 0.32 kWh/ hr based on the data given to us by Thurman Etchison (See Appendix G). We found the total power needed to operate the EnviroPure systems by multiplying 0.32 kWh/ hr times 24 hours times 6 systems to determine 46.08 kWh are needed per day to run the EnviroPure systems. We then multiplied this number by $0.0104/ kWh to find roughly about $0.48 is saved per day by eliminating the EnviroPure systems.

$$\begin{array}{c}\textit{Cost Saved on Electricity}\\ \textit{from Eliminating EnviroPure}\\ \textit{Systems}\end{array} = \textit{6 EnviroPure systems} * \frac{\textit{0.32 kwH}}{\textit{hr}} * \frac{\textit{24 hr}}{\textit{day}} * \frac{\textit{\$0.0104}}{\textit{kWh}}$$

Furthermore, we found how much biomix was needed for each system and found 1.51 gal/ day was needed to operate all of the systems. Using the data given to us by Thurman Etchison, each 15 gallon barrel costs $1233 thus allowing us to find $124.12 is saved per day on biomix by eliminating the EnviroPure systems. Adding this to the amount of energy saved on power, we concluded about $124.60 is saved per day by eliminating the EnviroPure systems.

$$\begin{array}{c}\textit{Cost Saved on Biomix from}\\ \textit{Eliminating EnviroPure}\\ \textit{Systems}\end{array} = \frac{\textit{1.51 gallons of biomix}}{\textit{day}} * \frac{\textit{\$1,233}}{\textit{15 gallon barrel of biomix}}$$

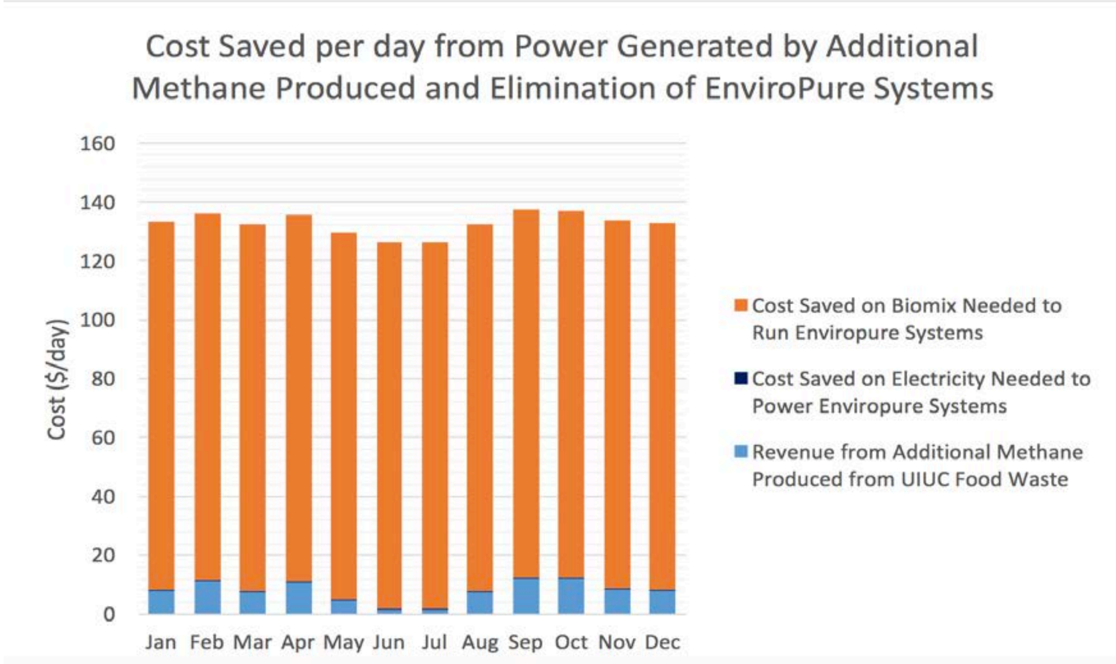

Fig. 4 Cost saved per day from the elimination of the EnviroPure Systems and the revenue generated from the additional methane created by adding the UIUC food waste to the anaerobic digestion system

Discussion

With the large amount of additional space that the Urbana-Champaign Wastewater Treatment Plant has in their anaerobic digestion systems, the University could look into other forms of high strength waste to increase the methane output. Some possibilities of high-strength waste sources could be food waste from other dining halls, such as the private certified housing, and manure as well as other organic matter byproducts from the campus farms. In addition, if the UC Wastewater Treatment Plant wanted to produce more energy from the food waste, they could install a hydrothermal liquefaction system, which will generate an increased energy output in comparison to an anaerobic digesting system.

Conclusions

Our group has determined that combining the food waste from the University of Illinois with the biosolids in the anaerobic digestion system at the Urbana-Champaign Wastewater Treatment Plant would be economically beneficial for both the wastewater treatment plant and the university, while having social and environmental benefits. We quantified the increase in methane production to be around 1%. This would save the wastewater treatment plant on average $7.66 per day on the amount of power purchased.

By diverting the food waste from the EnviroPure systems, the University of Illinois would be able to save money by shutting off their EnviroPure systems. By shutting off the EnviroPure systems, the university would save a total of $124.60 on electricity and biomix per day. In addition, the university would be reaching out to the local community and supporting the initiative to reform food waste into a new useable form of energy to generate electricity. This will also open up even more opportunities for students interested in waste management and renewable energy to become more involved in these topics while helping out the community around us.

Acknowledgements

We would like to thank Dr. Lance Schideman for assisting us with our understanding on hydrothermal liquefaction and anaerobic digestion, along with giving us advice through meeting with us and proofreading out report throughout this process. We would like to thank Jackie Christensen, Director of Operations of the Urbana Champaign Sanitary District, for emailing us the anaerobic digestion system manual and the data the treatment plant has collected on their anaerobic digestion systems, along with having a conference call with us to clarify uncertainties we had. We would like to thank Dawn Aubrey, the Associate Director of Housing for Dining, for meeting with us and providing data on the food waste recorded on campus along with the data on the average amount of meal swipes each dining hall receives per month. We would like to thank Thurman Etchison, the Assistant Director of Dining Equipment and Facilities, for meeting with us and providing us the data on the EnviroPure system that the campus currently uses. Lastly, we would like to thank the all of the TA's, Kathleen Hawkins, Kunal M. Patel, and Michael Neal, the Course Director, Professor Jeffery Roesler, along with the writing coach for this course Mary Hays, for assisting us by giving advice and proofreading our report throughout this process.

References

AECOM. (2012). “Chapter 13.” *Operations Manual*, Urbana and Champaign Sanitary District, Urbana and Champaign.

Environmental Protection Agency (EPA). (2017). “Reducing the Impact of Wasted Food by Feeding the Soil and Composting.”

Environmental Protection Agency (EPA). (2017). “Basic Information about Landfill Gas.”

Environmental Protection Agency (EPA). (2015). “The Benefits of Anaerobic Digestion of Food Waste at Wastewater Treatment Facilities.”

Environmental Protection Agency (EPA). (2008). “Anaerobic Digestion of Food Waste.” East Bay Municipal District.

Hall KD, Guo J, Dore M, Chow CC (2009). “The Progressive Increase of Food Waste in America and Its Environmental Impact,” PLoS ONE.

Lesikar B. J., Garza O. A., Persyn R.A., Keinimer A. L., and Anderson M. T. (2016). “Food-Service Establishment Wastewater Characterization.”

Snowden-Swan L. J., Zhu Y., Jones S. B., Elliott D. C., Schmidt A. J., Hallen R. T., Billing J. M., Hart T. R., Fox S.P., and Maupin G. D. (2016). “Hydrothermal Liquefaction and Upgrading of Municipal Wastewater Treatment Plant Sludge: A Preliminary Techno-Economic Analysis.” Pacific Northwest Laboratory.

United States Department of Agriculture (USDA). (2017). *USDA,*“How much food waste is there in the United States and why does it matter?” <https://www.usda.gov/oce/foodwaste/faqs.htm> (October 12, 2017).

United States Department of Agriculture (USDA). (2016). “Percent of Consumer Expenditures spent on food, alcoholic beverages, and tobacco that were consumed at home, by selected countries.”

University Housing (2017). “Sustainability in Dining.” *University Housing*, <http://www.housing.illinois.edu/dining/about-dining/sustainability> (October 10, 2017).

U.S. Energy Information Administration (2017). “Natural Gas Weekly Update.” <https://www.eia.gov/naturalgas/weekly/>.

Waste 360. (2016). *Waste 360*, “EnviroPure Systems Helps University of Illinois Reduce Food Waste.” <http://www.waste360.com/food-waste/enviropure-systems-helps-university-illinois-reduce-food-waste> (October 10, 2017).

Westendorf, Michael L. (2007). “Food Waste to Animal Feed.” *Iowa State University Press*, pp. 114

Woo, M. (2012), “Sludge Stabilization Sustainability of Aerobic Digestion Processes.”

Xiu S., Shahbazi A. (2012). “Bio-oil production and upgrading research: A review,” Greensboro, NC.

Zastrow D. J., and Jennings P. A. (2013). “Hydrothermal Liquefaction of Food Waste and Model Food Waste Compounds.” Florida Institute of Technology, Melbourne, FL, USA.

Budget

All of our research and data collected to complete this project did not require any funds. We did not have a budget.

Appendices

Appendix A

Fluxuation of Food Waste During Seasons						
	Average Amount of Food Waste per Swipe (lbs)	2016	0.33209			
		2017	0.32008			
		Average	0.32608			
	Amount of Dining Hall Swipes per Month			Average Amount of Food Waste per Month (lbs)	Average Amount of Total Solids per Month (lbs)	Average Amount of Volatile Solids per Month (lbs)
		Jan	206634	67379.4	10106.9	9096.2
		Feb	282752	92200.1	13830.0	12447.0
		Mar	193873	63218.3	9482.7	8534.5
		Apr	269873	88000.5	13200.1	11880.1
		May	122695	40008.5	6001.3	5401.1
		Jun	31218	10179.6	1526.9	1374.2
		Jul	35534	11587.0	1738.0	1564.2
		Aug	190722	62190.8	9328.6	8395.8
		Sep	314278	102480.1	15372.0	13834.8
		Oct	306173	99837.2	14975.6	13478.0
		Nov	219108	71447.0	10717.0	9645.3
		Dec	199845	65165.7	9774.8	8797.4

Appendix B

System Capacity		
	Maximum Capacity of Volatile Solids (lbs/day)	39,126
VS Feed to AD (lbs/day)		
	Jan	24,280
	Feb	27,020
	Mar	28,150
	Apr	27,500
	May	24,350
	Jun	22,320
	Jul	19,440
	Aug	21,430
	Sep	19,330
	Oct	19,750
	Nov	20,110
	Dec	19,820
Average Potential Space Remaining (lbs/day)		
	Jan	14,846
	Feb	12,106
	Mar	10,976
	Apr	11,626
	May	14,776
	Jun	16,806
	Jul	19,686
	Aug	17,696
	Sep	19,796
	Oct	19,376
	Nov	19,016
	Dec	19,306
	Average	16,334

Appendix C

	:	RAW SLG.	:	Cu. Ft.
	:	From KK 1	:	Methane
2016	:	To Pri Dig	:	Generated
	:	LBS./ day	:	/ LBS
MONTH	:	VS Fed	:	VS Fed
---------------	--	----------------	--	------------------
January	:	24280	:	7.7
	:		:	
February	:	27020	:	8.2
	:		:	
March	:	28150	:	8.2
	:		:	
April	:	27500	:	8.4
	:		:	
May	:	24350	:	8.4
	:		:	
June	:	22320	:	7.2
	:		:	
July	:	19440	:	7.6
	:		:	
August	:	21430	:	7.0
	:		:	
September	:	19330	:	10.1
	:		:	
October	:	19750	:	10.1
	:		:	
November	:	20110	:	10.6
	:		:	
December	:	19820	:	10.1
=========	=	=========	=	==========
TOTAL	:	273500	:	

Appendix D

System Methane Output											
	Output Methane (ft^3/lbs VS Fed)				Current Output Methane Generated (ft^3/day)				Additional Potential Methane Generation (ft^3/day)		
		Jan	7.7			Jan	186956			Jan	2617.7
		Feb	8.2			Feb	221564			Feb	3582.0
		Mar	8.2			Mar	230830			Mar	2456.0
		Apr	8.4			Apr	231000			Apr	3418.8
		May	8.4			May	204540			May	1554.3
		Jun	7.2			Jun	160704			Jun	395.5
		Jul	7.6			Jul	147744			Jul	450.1
		Aug	7.0			Aug	150010			Aug	2416.1
		Sep	10.1			Sep	195233			Sep	3981.3
		Oct	10.1			Oct	199475			Oct	3878.7
		Nov	10.6			Nov	213166			Nov	2775.7
		Dec	10.1			Dec	200182			Dec	2531.7
		Average	8.63			Average	195117			Average	2504.8

Appendix E

System Energy Output															
	Current Energy Potential of Methane Generated (BTU)				Current Energy Potential of Methane Generated (kWh)				Additional Power Generated by Adding Food waste (BTU/day)				Additional Power Generated by Adding Food waste (kWh/day)		
	Methane Energy Content: 1000 BTU/ ft^3	Jan	186956000		Methane Energy Content: 0.000293071 kWh/ BTU	Jan	54791.4		Methane Energy Content: 1000 BTU/ ft^3	Jan	2617674.1		Methane Energy Content: 0.000293071 kWh/ BTU	Jan	767.2
		Feb	221564000			Feb	64934.0			Feb	3581956.2			Feb	1049.8
		Mar	230830000			Mar	67649.6			Mar	2456030.0			Mar	719.8
		Apr	231000000			Apr	67699.4			Apr	3418815.6			Apr	1002.0
		May	204540000			May	59944.7			May	1554310.6			May	455.5
		Jun	160704000			Jun	47097.7			Jun	395462.7			Jun	115.9
		Jul	147744000			Jul	43299.5			Jul	450140.3			Jul	131.9
		Aug	150010000			Aug	43963.6			Aug	2416115.3			Aug	708.1
		Sep	195233000			Sep	57217.1			Sep	3981332.6			Sep	1166.8
		Oct	199475000			Oct	58460.3			Oct	3878653.9			Oct	1136.7
		Nov	213166000			Nov	62472.8			Nov	2775692.3			Nov	813.5
		Dec	200182000			Dec	58667.5			Dec	2531686.4			Dec	742.0
		Average	195117000			Average	57183.1			Average	2504822.5			Average	734.1

Appendix F

Revenue of Additional Methane Produced			
	Market Price of Methane ($/MMBTU)	$ 3.06000	
	Market Price of Methane ($/kWh)	$ 0.0104	
	Total Additional Revenue from Methane Generation ($/day)		
		Jan	$ 8.01
		Feb	$ 10.96
		Mar	$ 7.52
		Apr	$ 10.46
		May	$ 4.76
		Jun	$ 1.21
		Jul	$ 1.38
		Aug	$ 7.39
		Sep	$ 12.18
		Oct	$ 11.87
		Nov	$ 8.49
		Dec	$ 7.75
		Average	$ 7.66

Appendix G

Cost Saved by Eliminating Enviropure System			
	Power Needed for Each System (kWh/ hr)	0.32	
	Total Power Needed to Operate the Six Enviropure systems on Campus (kWh/day)	46.08	
	Cost Saved on Electricity ($/day)	$ 0.48	
	Biomix Needed for Each System (gal/day)		
		EPW720	0.24
		EPW480	0.16
		EPW1500	0.5
		EPW600T	0.2
		EPW750GT	0.25
		EPF480GT	0.16
		Total	1.51
	Cost of Biomix ($/15 gal barrel)	$ 1,233.00	
	Cost Saved on Biomix ($/day)	$ 124.12	
	Total Cost Saved ($/day)	$ 124.60	

Group Reflections

From our project, we learned how to cooperate and coordinate a project together. We managed to keep consistent dates and times to meet each week, which helped us very much to process all the data that we did. Outside of our group meetings, we were able to assign each other pieces of work to do outside our group project. The organization of continuous in person meetings, and outside of meeting work, around twice a week, helped us very much in creating an organized project.

Declaring the specific project parameters that we would be able to accomplish in the time limit given was one of the most difficult parts. Very late in our project, we decided to change what our objective would be based on what data we collected, so we had to redo our entire report in accordance with our new objective. We learned that setting out what a specific objective is in the beginning of the project is very important to producing a quality project. If we had the ability to do our project differently, we would add in more data that would help estimate all the costs concerning adding the food into the anaerobic digesting system, such as transportation.