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Feasibility Study of Biogas Generated Electricity for the Austin E. Knowlton Center for Equine Science at Otterbein University

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Abstract

Manure removal is an important issue for Otterbein University's Austin E. Knowlton Center for Equine Science. Evaluating alternative methods for manure removal at Otterbein is essential for both economic and green energy initiatives. Two companies who manufacture waste to energy systems, SEaB Energy and Bioferm Energy Systems, were contacted regarding the feasibility for the small-scale anaerobic digesters that they currently market (the Muckbuster and EUCOlino, respectively). Quasar Energy Corporation was also contacted as a possible off-site manure disposal option at their Zanesville large-scale dry digestion facility. Both the Muckbuster and EUCOlino options were determined to be economically infeasible for Otterbein University based on analysis on economic investment versus economic return. The Quasar Energy Corporation option could be economically feasible if Otterbein can provide storage for its manure for three-week intervals and invests in a front-end loader. Implications for this project are that Otterbein could potentially reduce its manure removal costs while supporting a green energy initiative, and that the Austin E. Knowlton Center for Equine Science is too small-scale for the small-scale anaerobic digesters that are currently available. An option for further research would be for an Otterbein University systems engineering major to design a custom made anaerobic digester for Otterbein's equine facility.

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Introduction

The process of converting animal manure and other organic waste into usable energy is a well-known science and has many beneficial implications. There are different ways to convert animal manure and organic waste into energy, the most prevalent being an anaerobic digester. The objective of this study was to determine the feasibility for Otterbein to invest in a small-scale anaerobic digester to convert the manure produced at Otterbein University's Austin E. Knowlton Center for Equine Science into electricity. The possibility of adding food waste from Otterbein's campus into the waste stream was also considered.

Anaerobic digestion was seen as early as the 10th century, where anecdotal evidence indicates that biogas was used to heat water in Assyria. In the 17th century, Jan Baptist Van Helmont first determined that flammable gasses could evolve from decaying organic matter. In 1776, Count Alessandro Volta concluded that there was a direct correlation between the amount of decaying organic matter and the amount of flammable gas produced. Lastly, Sir Humphry Davy determined that methane was present in the gases produced during the anaerobic digestion of cow manure in 1808 (Lusk, 2-2).

The first anaerobic digestion plant was built in Bombay, India, in 1859. Anaerobic digestion spread to England in 1895 (Lusk, 2-2). Anaerobic digestion is now prevalent in every continent besides Antarctica. According to the American Biogas Council, there are currently 2,100 sites in the United States producing biogas. There are 247 anaerobic digesters on farms, 1,241 wastewater treatment plants using an anaerobic digester (~860 currently use the biogas that they produce), 38 standalone (non-wastewater and non-agricultural) anaerobic digesters, and 645 landfill gas projects (American Biogas Council).

Operation of a Typical Anaerobic Digester System

There are two types of anaerobic digestion, wet anaerobic digestion and dry anaerobic digestion. In wet digestion, waste with a total solids content between 2-8% is used. Wet digestion is usually designed at one of three different temperature zones, psychrophilic, mesophillic, or thermophillic. Each zone relies on a different species of bacteria that flourish in each environment. Optimum temperature conditions for each zone are 15-20 degrees Celsius for psychrophilic, 30-40 degrees Celsius for mesophillic, and 50-60 degree Celsius for thermophillic. The temperature zone used depends on the available feedstock, project site logistics, cost of heating, and the end use of the digestate.

Wet digestion usually takes place in two possible reactors, plug flow reactors or continuously stirred tank reactors (CSTR). A plug flow reactor incorporates feed into one end and removes contents from the other. Plug flow reactors can have either a vertical or horizontal design. The main features of a CSTR system include the tanks, mixers, covers, and heating systems. One or two tanks are used for hydrolysis and methanization of the waste. Gas, mechanical, or hydraulic mixing techniques are used to mix the CSTR digester. Tank systems are usually made with concrete and steel. The cover for the digester can be either rigid or flexible depending on the system. Lagoons can be used for the digester, but this method is commonly used in warmer climates where temperature control isn’t needed. Heating systems are used to keep the digester at a steady, warm temperature for optimum gas yield and stable system operation. A combined heat and power unit (CHP) is usually used as a heating system. The input materials are mixed and pasteurized, then are fermented so that biogas is produced. The CHP provides heat for the fermentation tank so biogas can be used. The biogas is then moved to the

CHP, where electricity and heat are produced. The waste that is produced after fermentation can be used as fertilizer.

In dry digestion, waste with a total solids content between 15-30% is used. The higher solids content of the waste used in dry digestion means that it can be put into a waste pile rather than stored in a tank. The process of dry digestion starts by putting the waste into a sealed digester chamber that looks like a garage. The input materials do not need to be broken down or mixed prior to entering the digester. The input materials are then seeded and wetted with bacteria through recirculated water known as percolate. Digester heat is produced from the CHP. Optimum digester temperature is in the mesophillic zone (~95 degrees Fahrenheit). Hydrolysis and methanizaton of the waste is achieved in one or two different digesters. The waste is normally in the digester for 2-4 weeks. Biogas that is produced during the methanization of the waste is then used by the CHP, and the leftover waste can be further composted, cured, and used as a composted product (Introduction to Anaerobic Digestion).

The benefits of using an anaerobic digestion system are reducing CO_2 emissions, reducing the cost of electricity and heat at a facility, and eliminating the need to have animal waste removed from the facility. In 2014, anaerobic digesters on livestock farms reduced greenhouse gas emissions by 3 million metric tons of CO_2 equivalent ($MMTCO_2e$) (AgSTAR).

This feasibility study model was assessed on cost-saving analysis and beneficial reuse of waste. Should the results of this feasibility study show that there is a small-scale anaerobic digester that is suitable for Otterbein's manure production, food waste production, and electricity needs, Otterbein would save money related to manure removal, food waste removal, and electricity costs. There is also the possibility of net metering, in which energy generated is measured against the amount used. If Otterbein invests in an anaerobic digester and it produces more energy than the equine facility requires, Otterbein could put the extra energy back into the local energy grid and receive money for the extra energy.

The Austin E. Knowlton Center for Equine Science contains 52 stalls for horses. Currently, Otterbein is paying Kohler Farms to have the manure produced at the equine facility taken off site. The company takes the manure from the equine facility two to three times a week. The significance of this project is that it will determine if there is a small-scale anaerobic digester available that would be economically beneficial to use at Otterbein's equine facility, which would allow for potential of cost savings, revenue generation, and a green initiative for Otterbein.

Operational limitations that may reduce the feasibility of an anaerobic digester at Otterbein, include, but are not limited to, the following: generating enough manure at the equine facility, producing enough food waste to help supply the digester, the anaerobic digestion system not producing enough electricity to offset maintenance costs of the system, return on investment being too long due to the installation and maintenance costs for the digestion system, and not having enough horses at the equine facility year-round in order for the digester to continuously produce a beneficial amount of electricity.

If it is determined that it is not economically feasible for Otterbein to invest in a small scale anaerobic digester, then additional disposal methods will be analyzed to compare to the manure disposal method that Otterbein's equine facility currently uses.

Waste into energy is an important field that is continuously evolving due to advancements in technology. It is important for Otterbein to look into available options that could both potentially benefit Otterbein and reduce Otterbein's ecological footprint.

Methods

There are many things to consider when determining if it is economically feasible for Otterbein to invest in a small-scale anaerobic digester.

Costs

The utility bills for the Austin E. Knowlton Center for Equine Science for the past two fiscal years were obtained from the Business Office at Otterbein University to determine the electricity usage and cost at the equine facility. The manure removal bills for the past two fiscal years were obtained from Donna Rhodeback, administrator in the Biology and Earth, and Equine Science departments.

Equine Data

The average number of horses at Otterbein's equine facility was acquired from records provided by Wendy Hovey, administrative assistant at the equine facility. A manure production study was completed at the Austin E. Knowlton Center for Equine Science to determine the average amount of manure produced per horse per day at the equine facility. This data was then corroborated with historical data on equine manure production. Data obtained in the manure production study, historical data, and information on the average number of horses at the equine facility year round was used to calculate the average amount of manure produced at Otterbein's equine facility per year. A potential manure consortium was analyzed in the event that additional manure besides the amount produced at Otterbein's equine facility was needed to supply the digester.

Food Sources

Food waste production at Otterbein's cafeteria "The Nest" was determined after a discussion with Deborah Robinson, general manager for Bon Appétit at Otterbein University. Additional food waste options were analyzed for chain restaurants in the Westerville area in the event that a food waste consortium was needed to generate more input material for the anaerobic digesters.

Small-Scale Anaerobic Digester Research and Economic Return

Online research was completed to find companies that market a small-scale anaerobic digester. Feasibility forms were completed and returned to the companies, and information was provided on the costs associated with purchasing and maintaining the small-scale anaerobic digesters. Economic investment versus economic return was determined by estimating the total cost of the anaerobic digester system and computing the point at which the total benefits exceeds the total cost.

Quasar Option

Quasar Energy Corporation was contacted as a potential third option for manure disposal from Otterbein's equine facility in the event that an anaerobic digester was determined to be infeasible for Otterbein.

Utility Bills for the Austin E. Knowlton Center for Equine Science

Utility bills for the Austin E. Knowlton Center for Equine Science were obtained and copied with permission from the Business Office at Otterbein University. The utility bills were collected for fiscal year 2014 and fiscal year 2015. The utility bills were collected in order to determine the total electricity usage and electricity cost that the Austin E. Knowlton Center for Equine Science was responsible for. Each utility bill accounted for one month of electricity, sewer, and water used at the equine facility. Total electricity usage was measured in kilowatt hours (kWh). Total electricity cost was measured in U.S. dollars.

Manure Removal Bills for the Austin E. Knowlton Center for Equine Science

The manure removal bills were obtained and copied with permission from Donna Rhodeback, administrative assistant for the Department of Equine Science. The manure removal bills were collected for fiscal year 2014 and fiscal year 2015. The manure removal bills were obtained in order to determine the cost of manure removal from the Austin E. Knowlton Center for Equine Science. Otterbein University was charged in U.S. dollars per trip for manure removal from the equine facility.

Average Number of Horses at Otterbein's Equine Facility Year Round

Wendy Hovey, administrative assistant at the equine facility, was contacted regarding the average number of horses at Otterbein's equine facility year round. It was determined that there are usually 49-52 horses at the equine facility between September 1st and April 30th and 36-40 horses at the equine facility between May 1st-August 31st. For calculating the total manure production per year at the equine facility, it was assumed that there are 50 horses at the equine facility between September 1st and April 30th and 38 horses at the equine facility between May 1st-August 31st.

Manure Production Study

A manure production study was completed from November 17th, 2015- November 22nd, 2015 at the Austin E. Knowlton Center for Equine Science. The manure of five horses (Noah, Ted, Quay, Flynn, and Dior) of varying stall habits (messy, clean, in-between) was weighed in the afternoon and evening to determine the average manure production per horse at the equine facility. Buckets that were used to hold the manure were weighed prior to the study. An assumed weight of 5.5 pounds was used for all of the buckets used to hold the manure, and that weight was deducted from the total manure weight as each bucket was weighed. The total average manure production over the five-day period was determined by averaging all of the manure production data. The manure production study did not account for the manure produced while the horses were outside in the dry pastures, but it was taken into consideration when determining the total manure production per day per horse when corroborated with historical manure production data. It was important to take into account the manure produced in the dry pastures because the manure is removed from those pastures daily in the summer and fall and as much as possible during the winter and spring, and is then unloaded into the roll-off at the equine facility. Even though the dry pasture manure was not quantified in the manure production study, it contributes to the total amount of manure produced at Otterbein's equine facility.

Online Historical Data of Average Horse Manure Production

Online historical data was used to corroborate the data obtained during the manure production study. An article published on Rutgers New Jersey Agricultural Experiment Station's website stated that a single horse can produce 50 pounds of manure per day (Smith). Another article published on the Virginia Cooperative Extension's website also stated that "on any given day, the average 1,000-pound horse will produce approximately 50 pounds of manure" (Kelly). The 50-pound value found online was higher than the average amount of manure determined per horse from the manure production study. However, the manure production study did not take into account manure taken from the dry pastures, therefore 50 pounds of manure per horse per day was used to determine the total amount of manure produced per day, per week, and per year at the equine facility.

Calculation of Manure Production per Year at the Austin E. Knowlton Center for Equine Science

Manure production per year was calculated using the assumption that there are 50 horses at the equine facility between September 1st and April 30th, 38 horses at the equine facility between May 1st-August 31st, and each horse produced 50 pounds of manure per day.

Food Waste Determination for Bon Appétit at Otterbein University

Bon Appétit, Otterbein's current dining service, was contacted regarding the average amount of food waste that is produced on Otterbein's campus. This data was used to determine if food waste from Otterbein's campus could potentially be used as an additional input material for the anaerobic digester. Deborah Robinson, general manager for Bon Appétit at Otterbein, was asked about the food waste produced on Otterbein's campus. Deborah was able to estimate that between 100-110 pounds of food waste is produced per day on Otterbein's campus and that Bon Appétit currently pays around $10,000 per year to have their food waste and trash removed.

Research into Companies that Market a Small-Scale Anaerobic Digester

Online research was completed to find companies that market a small-scale anaerobic digester. Bioferm Energy Systems, based in Madison, WI, and SEaB Energy, based in Southampton, Hampshire, UK, were two companies that market a small-scale anaerobic digester. Bioferm Energy Systems markets the EUCOlino and SEaB Energy markets the Muckbuster. Both companies were contacted, and feasibility forms were completed and returned to the companies so that information could be gathered about their small-scale anaerobic digesters.

SEaB Energy Corporation Feasibility Form for the Muckbuster

The Muck/Flexi Buster site survey form was completed to determine if it would be feasible for Otterbein to invest in their Muckbuster anaerobic digester. The information below explains how the data was determined when completing the feasibility form. The feasibility form was submitted to SEaB Energy Corporation upon completion.

Minimum, Average, Highest Temperature

The minimum, average, and highest temperature per year was determined using averages found online in corroboration with average temperatures experienced while living in Columbus (Historical Weather for 2015 in Columbus, Ohio, USA).

Ease of Access

It was determined that ease of access would not be an issue for delivery of the 40-foot container for the digester due to the layout of the equine facility.

Planning Permission and Electricity Connection Permission Requirement, Other Renewable Energy Technology Onsite, Odor Filter Requirement, Waste Processing License, and Applicable Government Tariffs

Tara Grove, Environmental Health and Safety Officer for Otterbein University, was contacted regarding whether planning permission was required or available, if electricity connection permission was required, and if Otterbein had a waste processing license or exemption certificate. It was determined that both the planning permission and electricity permission were required through the City of Westerville. There is no other renewable energy technology onsite and an odor filter is required. Otterbein does not currently have a waste processing license or exemption certificate. There would not be any applicable government tariffs unless the digester produced excess electricity.

Location, Available Area, Availability of Water and Lighting, Type of Soil, Total Site Area, Distance from Organic Waste Storage, and Distance to Electricity Supply

Three potential location options for the anaerobic digester at Otterbein's equine facility were considered, as seen in Figure 1.

Figure 1: Three Location Options for Anaerobic Digester at Otterbein's Equine Facility

In Figure 1, option two was determined to be the best place for the digester due to the available space and ability to have access to electricity, water, and external lighting.

The area available for installation was determined by measuring the area where option two is labeled. The length of the area was measured to be 20.8 meters long and the width of the area was measured to be 12.6 meters long, making the total area ~262 square meters.

The type of soil at the installation area is gravel.

Distance from organic waste storage was determined to be less than 10 meters because the manure produced at the equine facility is currently being stored less than 10 meters from option two in Figure 1.

Distance to electricity supply was determined to be less than 100 feet due to the close proximity of the option to location to the shed that has an electricity supply.

Current Organic Waste Disposal, Current Disposal Costs, and Current Waste Volume

Otterbein currently pays Kohler Farms to dispose of the organic waste produced at the equine facility. Current disposal costs were determined from the manure removal bills. Current waste volume was determined from the manure production calculation per year.

Availability of Waste Water Drains for Emergency, Availability of Single/Three Phase Supply, Availability of Pack Up Power, ADSL Connection, and Site Voltage, Frequency, and Phase Details

Tim Priest, Associate Director of Campus Operations at Otterbein University, was contacted regarding the information below. After contacting Tim, it was determined that:

- Waste water drains are not available
- Single/three phase supply is available
- Back up power is available through generator power
- ADSL connection is not available
- The site voltage is 120 volts, 208 volts, and 480 volts
- The frequency is 60 Hertz
- The phase details are single/three phase

Total Site Area

The total site area of the equine facility was determined to be ~3 hectares, which accounted for the green highlighted area in Figure 2 (Google Maps Area Calculator Tool).

Figure 2: Total Site Area of Otterbein's Equine Facility

Road Access, Availability of Liquid Fertilizer Storage Tanks, Cellular Phone Service, and Ventilation

Otterbein's equine facility has concrete in the front of the facility and gravel in the back of the facility. There are currently no available liquid fertilizer storage tanks at the equine facility. There is good cell phone service at the equine facility. Since the digester would be outside, ventilation is available.

Food Waste Details

Food waste details were determined based on the data given by Deborah Robinson. Refer to page nine for food waste determination.

Electrical Use and Cost

Electrical Use and Cost was determined based on the electrical bills provided by Otterbein University's Business Office.

Bioferm Energy Systems Feasibility Form for the EUCOlino

The Bioferm Feasibility Form was completed to determine if it would be feasible for Otterbein University to invest in their EUCOlino anaerobic digester. The information below explains how the data was determined when completing the feasibility form. The feasibility form was submitted to Bioferm Energy Systems upon completion.

Amount of Manure Produced per Year

The amount of manure produced per year at Otterbein's facility was calculated based on the parameters stated in the "Calculation of Manure Production per Year at the Austin E. Knowlton Center for Equine Science" section on page nine.

Volume, Density, Total Solids Content, Volatile Solids Content, and Organic Strength of Manure

The volume, density, total solids content, volatile solids content, and organic strength of the manure was determined using an article from Ohio State University's Extension website (OSU Extension Fact Sheet).

Acquisition Cost of Manure and Food Waste

The acquisition cost of the manure is zero because the digester would be at the equine facility. The acquisition cost of the food waste from Otterbein would be the loading and transportation cost to move the food waste from Otterbein to the equine facility, and was going to be calculated if it was determined that Otterbein's food waste was needed for the EUCOlino.

Haul Away Cost of Manure and Food Waste

The haul away cost for the manure was calculated based upon the manure removal bills obtained from Donna Rhodeback. The haul away cost of the food waste was based upon Deborah Robinsons $10,000 per year estimate.

Current Amount and Cost of Electricity, Current Heat Use, and Anticipated Buy Back Rate

The final questions on the Bioferm feasibility form focused on electricity and heat use at Otterbein's equine facility.

- Current amount and use of electricity were determined based on the electrical bills for the equine facility obtained from Otterbein University's Business Office.
- The current heat use is electricity.
- The anticipated buy back rate for electricity was not determined because buy back electricity was not anticipated due to the high electricity usage at the equine facility.

Manure Consortium: Locating and Contacting Local Barns

A list of local barns was provided by Dr. Sheri Birmingham to be used in this research project. The list provided the names, addresses, and phone numbers for each barn. Twenty-six local barns were called and voicemails were left if no one answered the phone. The people representing each local barn on the list were asked the following three questions:

1. On average, how many horses are usually staying at your barn?
2. What is the current use of the manure produced at your barn?
3. If Otterbein invested in a small-scale anaerobic digester in the future, could Otterbein use your manure for the digester?

The responses to the questions were recorded for the eleven barns that responded. The distance to each barn in miles and minutes was determined using the Maps Application on the iPhone. If a barn did not respond to the survey, the number of horses at that barn was determined using the barn's website if it stated how many stalls the barn had or assumed to have a capacity of holding 20 horses.

Food Waste Consortium: Determining Average Amount of Food Waste Produced per Restaurant

A food waste consortium was considered to get additional food waste as an input material for an anaerobic digester if it was determined that Otterbein did not produce enough manure and food waste to adequately power the digester. To determine how much food waste a single restaurant produces, online sources were used. A 2014 report completed by the Business for Social Responsibility and prepared for the Food Waste Reduction Alliance found that in the restaurant sector, survey respondents generated 33 pounds of food waste per thousand dollars of revenue. The report also stated that 84.3% of the food waste produced in the restaurant sector is disposed of, 14.3% is recycled, and 1.4% is donated (Business of Social Responsibility).

Food Waste Consortium: Determination of Model Restaurant to use in Consortium and Average Revenue

Olive Garden was used as a model chain restaurant to use in the food waste consortium. To determine the average revenue of an Olive Garden restaurant, online research was completed from the Darden website, as Darden is the company that owns Olive Garden. Darden's 2015 annual report states that Olive Garden produces 4.5 million dollars in average unit sales (Darden 2015 Annual Report, iii).

Food Waste Consortium: Determination of Average Food Waste Produced per Olive Garden Restaurant

The $4.5 million in average unit sales was used as the revenue generated per Olive Garden restaurant. The 4.5 million dollars was used with the 33 pounds of food waste generated per thousand dollars of revenue to determine the total amount of food waste produced per Olive Garden restaurant per year. 84.3% of the total amount of food waste was calculated, and that final number was used as the food waste available per chain restaurant that could be used for the anaerobic digester.

Quasar Energy Corporation

Quasar Energy Corporation has large-scale waste recycling systems, including a wet digestion facility in Columbus, OH and a dry digestion facility in Zanesville, OH. Quasar Energy Corporation was contacted as a potential third option in the event that it wasn't feasible for Otterbein to invest in an anaerobic digester. This option would be compared to Otterbein's current manure disposal method. After reaching out to Quasar via email for more information, Mitch Long, Biomass Account Executive for Quasar, provided information regarding potential options for having Otterbein's manure taken to one of Quasar's facilities. The best option was to have Otterbein's manure taken to Quasar's Zanesville dry digestion facility because the shavings and straw discarded with the manure would not need to be separated. The shavings and straw would need to be separated in order to be used at Quasar's Columbus wet digestion facility. A draft business contract was drawn up by Quasar to have Otterbein's manure picked up by Quasar and taken to the Zanesville facility.

Parameters for Economic Investment Versus Economic Return

Economic investment was calculated using the cost of each anaerobic digester, installation cost, and maintenance cost, which was provided by Bioferm Energy Systems and SEaB Energy. Economic return was estimated by combining the electricity and manure removal savings. Electrical savings was calculated by comparing the amount of electrical output each anaerobic digester could produce in kilowatt-hours (kWh) and multiplying that by $.1105 per kWh. $.1105 per kWh was determined by taking the total cost of electricity for fiscal years 2014 and 2015 separately, dividing those numbers by the total kWh usage for each fiscal year, and then averaging those two numbers to get the total average cost per kWh. Manure removal savings was determined by averaging the manure removal costs for fiscal years 2014 and 2015.

Results

The electricity usage and cost for Otterbein's equine facility, the manure removal costs, the manure production study data, the total manure production calculation, the Muckbuster and EUCOlino feasibility forms, the manure consortium data, and the food waste consortium data were all needed to complete this study. Costs for the Muckbuster and EUCOlino were determined from information given from SEab Energy and Bioferm Energy Systems, respectively. Return on investment was determined based upon the costs associated with the digesters versus savings on electricity and manure removal. Costs were determined for having Otterbein's manure taken to Quasar's Zanesville facility.

Electricity Usage and Cost for Fiscal Years 2014 and 2015 at the Austin E. Knowlton Center for Equine Science

Electricity usage and cost for fiscal years 2014 and 2015 were analyzed for Otterbein's equine facility. The total electricity usage and cost was determined by taking the sum of the monthly electricity usage and cost for each fiscal year. Table 1 shows the electricity usage and cost for fiscal year 2014. Table 2 shows the electricity usage and cost for fiscal year 2015.The total cost of electricity for fiscal year 2014 was $39,159.20 for 359,760 kilowatt hours (Table 1). The total cost of electricity for fiscal year 2015 was $40, 876.11 for 364,800 kilowatt hours (Table 2).

Month	Cost ($)	Usage (kWh)
6/11-7/10	1680.74	14000
7/10-8/4	1509.11	11600
8/4-9/5	1675.01	13920
9/5-10/3	1557.74	12280
10/3-10/30	1804.83	15320
10/30-12/3	3484.27	33600
12/3-1/1	4407.61	43280
1/1-1/31	6718.95	68600
1/31-3/2	6233.69	63240
3/2-4/1	4279.48	38880
4/1-4/30	2134.53	17520
4/30-6/1	1755.6	12680
6/1-7/1	1917.64	14840
Total	**39159.2**	**359760**

Table 1: Electricity Cost and Usage Fiscal Year 2014

Month	Cost ($)	Usage (kWh)
7/1-7/31	1842.62	13840
7/31-8/31	1971.65	15560
8/31-9/30	1884.63	14400
9/30-10/31	2157.7	18040
10/31-12/1	4022.64	37040
12/1-1/1	4823.05	45760
1/1-2/1	6234.44	60680
2/1-3/1	7177.73	72120
3/1-3/30	4414.96	38920
3/30-5/1	2584.95	20800
5/1-6/1	1798.6	12760
6/1-7/1	1963.14	14880
Total	40876.11	364800

Table 2: Electricity Cost and Usage for Fiscal Year 2015

<u>Manure Removal Cost Data</u>

Table 3 shows the manure removal costs for fiscal year 2014. The total manure removal cost for fiscal year 2014 was $25,670, amounting to an average monthly cost of $2,139.17. Table

4 shows the manure removal costs for fiscal year 2015. The total manure removal cost for fiscal year 2015 was $26,690, amounting to an average monthly cost of $2,224.17. The average manure removal cost for fiscal years 2014 and 2015 was $26,180.

July 1st, 2013- June 30th, 2014 (Fiscal Year 2014)					
Month	Cost ($)	Total Cost/ Month ($)	Month	Cost ($)	Total Cost/ Month ($)
July			**January**		
30th-6th	340		29th-4th	510	
7th-13th	340		5th-11th	510	
14th-20th	340		12th-18th	510	
21st-27th	340		19th-25th	510	
		1360	26th-1st	510	
August					2550
28th-3rd	340		**February**		
4th-10th	510		2nd-8th	510	
11th-17th	510		9th-15th	510	
18th-24th	510		16th-22nd	510	
25th-31st	510		23rd-1st	510	
		2380			2040
September			**March**		
1st-7th	510		2nd-8th	510	
8th-14th	510		9th-15th	510	
15th-21st	510		16th-22nd	510	
22nd-28th	510		23rd-29th	510	
		2040			2040
October			**April**		
29th-5th	510		30th-5th	510	
6th-12th	510		6th-12th	510	
13th-19th	510		13th-19th	510	
20th-26th	510		20th-26th	510	
27th-2nd	510		27th-3rd	510	
		2550			2550
November			**May**		
3rd-9th	510		4th-10th	510	
10th-16th	510		11th-17th	510	
17th-23rd	510		18th-24th	510	

Table 3: Manure Removal Cost for Fiscal Year 2014

Table 3, Cont'd

24th-30th	510		25th-31st	510	
		2040			2040
December			**June**		
1st-7th	510		1st-7th	510	
8th-14th	510		8th-14th	510	
15th-21st	510		15th-21st	510	
22nd-28th	510		22nd-28th	510	
		2040			2040
Total Cost for Fiscal Year 2014 ($)=			25670		
Average cost per month ($)=			2139.17		

July 1st 2014-June 30th, 2015 (Fiscal Year 2015)					
Month	Cost ($)	Total Cost/ Month ($)	Month	Cost ($)	Total Cost/Month ($)
July			**January**		
29th-5th	510		4th-10th	510	
6th-12th	510		11th-17th	510	
13th-19th	510		18th-24th	510	
20th-26th	510		25th-31st	510	
27th-2nd	510				2040
		2550			
August			**February**		
3rd-9th	510		1st-7th	510	
10th-16th	510		8th-14th	510	
17th-23rd	510		15th-21st	510	
24th-30th	510		22nd-28th	510	
		2040			2040
September			**March**		
31st-6th	510		1st-7th	510	
7th-13th	510		8th-14th	510	
14th-20th	510		15th-21st	510	
21st-27th	510		22nd-28th	510	
		2040			2040
October			**April**		
28th-4th	510		29th-4th	510	
5th-11th	510		5th-11th	510	
12th-18th	510		12th-18th	510	

Table 4: Manure Removal Cost for Fiscal Year 2015

Table 4, Cont'd

19th-25th	510		19th-25th	510	
26th-1st	510		26th-2nd	510	
		2550			2550
November			**May**		
2nd-8th	510		3rd-9th	510	
9th-15th	510		10th-16th	510	
16th-22nd	510		17th-23rd	510	
23rd-29th	510		24th-30th	510	
		2040			2040
December			**June**		
30th-6th	510		31st-6th	510	
7th-13th	510		7th-13th	510	
14th-20th	510		14th-20th	510	
21st-27th	510		21st-27th	510	
28th-3rd	510		28th-29th	170	
		2550			2210
Total Cost for Fiscal Year 2015 ($)=			26690		
Average cost per month ($)=			2224.17		

<u>Manure Production Study Data at Otterbein's Equine Facility</u>

Table 5 shows the results of the manure production study that was completed at Otterbein's equine facility. The total amount of manure produced per day was determined based on the sum of the morning and evening manure production values for each horse. Figure 3 shows a graphical representation of the manure production study data.

Unit: lbs	Horse				
Day	Noah	Ted	Quay	Flynn	Dior
1					
AM manure	38	15.5	11.5	33.5	36.5
PM manure	7.5	5.5	13.5	3.5	5.5
Total	45.5	21	25	37	42
2					
AM manure	63	18.5	9.5	49	14.5
PM manure	11.5	6.5	11.5	5.5	15.5
Total	74.5	25	21	54.5	30
3					
AM manure	41	10.5	18.5	43.5	73
PM manure	0	13.5	12.5	0	0
Total	41	24	31	43.5	73
4					
AM manure	82	18.5	34.5	18.5	-
PM manure	0	17.5	12.5	0	21.5
Total	82	36	47	18.5	-
5					
AM manure	76.5	9.5	46	47	45.5
PM manure	4.5	20.5	13.5	4.5	7.5
Total	81	30	59.5	51.5	53

Table 5: Manure Production Study Data

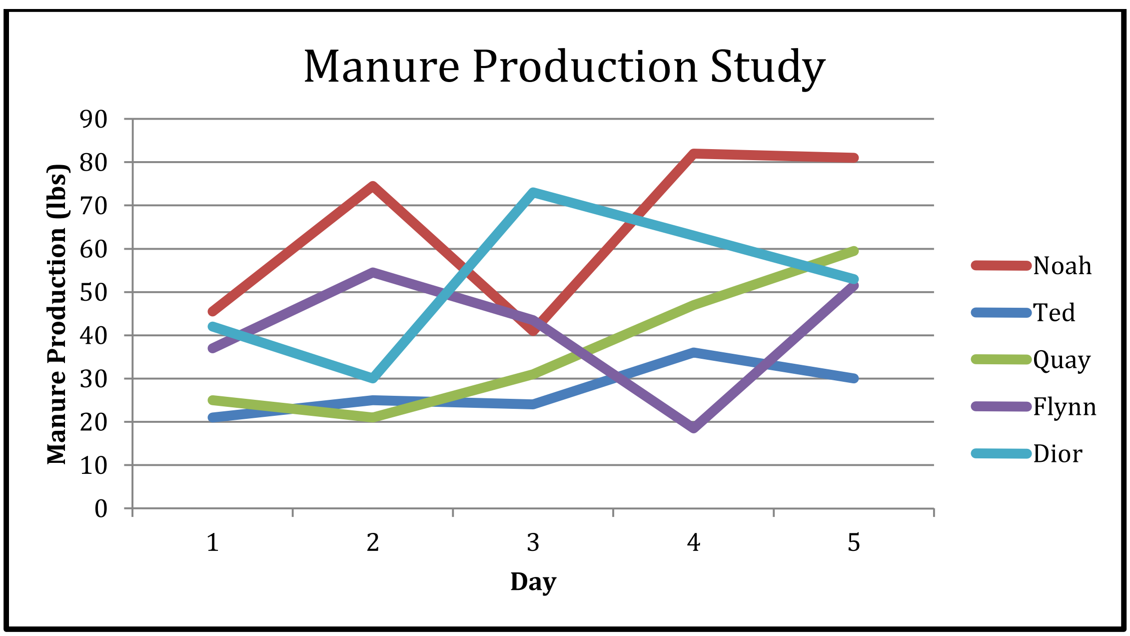


Figure 3: Manure Production Study Graph

Manure Production Study: Average Amount of Manure Produced Per Day Per Horse

The daily manure production values from Table 5 were used in Table 6 to determine the average amount of manure produced per day over the five-day period. The total manure production average per day from all five horses in the study was determined to be 43.6 pounds.

Unit: lbs	Horse				
Day	Noah	Ted	Quay	Flynn	Dior
1	45.5	21	25	37	42
2	74.5	25	21	54.5	30
3	41	24	31	43.5	73
4	82	36	47	18.5	63
5	81	30	59.5	51.5	53
Average	64.8	27.2	36.7	41	49.5
Total Average/ Day	**43.6**				

Table 6: Average Amount of Manure Produced Per Horse

Calculation of Total Amount of Manure Produced Per Year at Otterbein's Equine Facility

Determination of the total manure production per year at Otterbein's equine facility was based on the calculations below.

1. September 1^{st}- April 30^{th}: 49-52 horses
   - ~50 horses over 8 months
     - 8 months= 240 days
     - 50lbs manure/horse/day
   - 50 horses*50lbs/day*240 days= 600,000lbs manure= 300 US tons (1.25 US tons/day)
2. May 1^{st}-August 31^{st}: 36-40 horses
   - ~38 horses over 4 months

    - 4 months= 125 days
    - 50lbs manure/horse/day
- 38 horses*50lbs/day*125 days=237,500lbs manure= 119 US tons (.95 US tons/day)

3. 12 Month Total
    - 600,000+237,500= 837,500lbs manure/year
    - 837,500lbs= ~419 US tons/year

Bioferm Feasibility Calculations

Determination of the volume, density, total solids content, volatile solids content, BOD_5, and dry matter content of the equine manure for the Bioferm feasibility form are shown below.

Volume

1 horse= 6.06 gallons/day

- September-April
    - 6.06 gallons/day*50 horses=303 gallons/day
- May-August
    - 6.06 gallons/day*38 horses=230 gallons/day

Density

63 lbs/ft^3

Total Solids Content

1 horse= 15 lbs TS/day

15 lbs TS/day divided by 50lbs manure/day= .30*100= 30% TS

Volatile Solids Content

1 horse= 10 lbs VS/day

10 lbs VS/day divided by 50 lbs manure/day=.20*100= 20% VS

BOD_5

1 horse= 1.7 lbs/day BOD_5

(6.06 gallons/day)*(3.79 L/1 gallon)= 22.97 L/ day

(1.7 lbs/day)*(453592mg/1 lb)= 771107 mg/day

771107mg/22.97L= 33570 mg/L

Dry Matter

79.5% water so 100-79.5= 20.5% DM

Completed EUCOlino Feasibility Form

The completed EUCOlino feasibility form from Bioferm Energy Systems can be seen in Appendix A. The completed feasibility form was sent to Bioferm Energy Systems for feasibility analysis.

Completed Muckbuster Feasibility Form

The completed Muckbuster feasibility form from SEaB Energy can be seen in Appendix B. The completed feasibility form was sent to SEaB Energy for feasibility analysis.

Muckbuster Data Given By SEaB Energy

SEaB Energy provided the data given below in Table 8 for the Muckbuster small-scale anaerobic digester. This data was based on 1.25 tons of horse manure per day (peak season waste volume) plus 50 kg of food waste per day taken from Otterbein's campus.

Muckbuster 48 Costs	Pounds (£)	U.S. Dollars ($)
System (Mouth + Digester Tanks + 8kw CHP)	201,738.97	286,859.70
Installation (not including labor)	7,500	10,664.51
Maintenance	13,571/yr	19,297.08/yr
Operating System License	900/yr	1,279.74/yr
Two Year Standard Warranty	Free	Free
First Year Total Cost	223,709.97	**318,101.03**
Yearly Cost After First Year	14,471	**20,576.82**

Table 7: Muckbuster Costs Provided by SEaB Energy

Electricity available to site, kWh/Year	44,373
Parasitic electrical requirement- kWh/Year	12,000
Total electrical production qualifying for FiT, kWh/Year	**56,373**
Heat Available to site, kWh/Year	105,737
Parasitic Heat Requirement - kWh/Year	7,008
Total heat production qualifying for RHI, kW/annum	**112,745**

Table 8: Data Provided By SEaB Energy for Muckbuster Electricity and Heat Production

SEaB Energy requires that the manure used in the digester be free of shavings or straw, and that the Muckbuster has a 20-year lifetime before it needs to be replaced. The shavings and straw that is removed with the manure is currently not separated from the manure for disposal. The fact that the Muckbuster cannot take in straw or shavings poses a potential problem for this option. The 20-year lifetime of the Muckbuster is important when determining return on investment for the anaerobic digester.

Return on Investment for Muckbuster

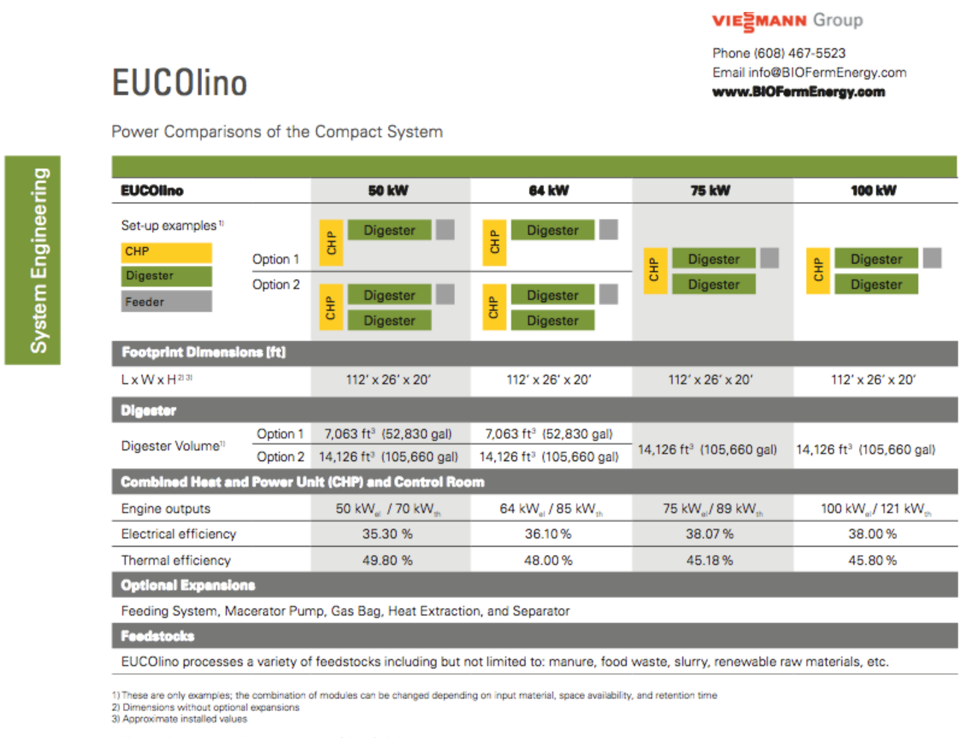
Return on investment for the Muckbuster was determined by comparing the costs associated with the Muckbuster to the electricity and manure removal savings per year. Table 9 shows the return on investment for the Muckbuster. Calculations for the Muckbuster return on investment can be seen in Appendix C. Table 9 does not include the ~$36,440.44 that Otterbein would have to continue paying each year for electricity that is not provided by the Muckbuster. The return on investment for the Muckbuster was calculated to be 33 years, as seen in Table 9.

Year After Purchase	Cost ($)	Return ($)	Total ($)
1	-318101.03	29757.22	-288,344
2	-20576.82	29757.22	-279,163
3	-20576.82	29757.22	-269,983
4	-20576.82	29757.22	-260,803
5	-20576.82	29757.22	-251,622
6	-20576.82	29757.22	-242,442
7	-20576.82	29757.22	-233,261
8	-20576.82	29757.22	-224,081
9	-20576.82	29757.22	-214,901
10	-20576.82	29757.22	-205,720
11	-20576.82	29757.22	-196,540
12	-20576.82	29757.22	-187,359
13	-20576.82	29757.22	-178,179
14	-20576.82	29757.22	-168,999
15	-20576.82	29757.22	-159,818
16	-20576.82	29757.22	-150,638
17	-20576.82	29757.22	-141,457
18	-20576.82	29757.22	-132,277
19	-20576.82	29757.22	-123,097
20	-20576.82	29757.22	-113,916
21	-20576.82	29757.22	-104,736
22	-20576.82	29757.22	-95,555
23	-20576.82	29757.22	-86,375
24	-20576.82	29757.22	-77,195
25	-20576.82	29757.22	-68,014
26	-20576.82	29757.22	-58,834
27	-20576.82	29757.22	-49,653
28	-20576.82	29757.22	-40,473
29	-20576.82	29757.22	-31,293
30	-20576.82	29757.22	-22,112
31	-20576.82	29757.22	-12,932
32	-20576.82	29757.22	-3,751
33	-20576.82	29757.22	5,429

Table 9: Return on Investment for Muckbuster

EUCOlino Data Given by Bioferm Energy Systems

Bioferm stated that the ~420 tons of manure produced at Otterbein's equine facility would not be enough to power the EUCOlino. An additional 2,000 tons of manure or an additional 1,500 tons of food waste would be needed to help power the EUCOlino. Bioferm also stated that the average installation cost for the EUCOlino is a $1.2 million investment. A breakdown of this cost was not provided.


VIESMANN Group
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System Engineering

EUCOlino

Power Comparisons of the Compact System

EUCOlino		50 kW	64 kW	75 kW	100 kW
Set-up examples[1] (CHP, Digester, Feeder)	Option 1	CHP, Digester	CHP, Digester	CHP, Digester, Digester	CHP, Digester, Digester
	Option 2	CHP, Digester, Digester	CHP, Digester, Digester		
Footprint Dimensions [ft]					
L x W x H[2][3]		112' x 26' x 20'	112' x 26' x 20'	112' x 26' x 20'	112' x 26' x 20'
Digester					
Digester Volume[1]	Option 1	7,063 ft^3 (52,830 gal)	7,063 ft^3 (52,830 gal)	14,126 ft^3 (105,660 gal)	14,126 ft^3 (105,660 gal)
	Option 2	14,126 ft^3 (105,660 gal)	14,126 ft^3 (105,660 gal)		
Combined Heat and Power Unit (CHP) and Control Room					
Engine outputs		50 kW_{el} / 70 kW_{th}	64 kW_{el} / 85 kW_{th}	75 kW_{el} / 89 kW_{th}	100 kW_{el} / 121 kW_{th}
Electrical efficiency		35.30 %	36.10 %	38.07 %	38.00 %
Thermal efficiency		49.80 %	48.00 %	45.18 %	45.80 %
Optional Expansions					
Feeding System, Macerator Pump, Gas Bag, Heat Extraction, and Separator					
Feedstocks					
EUCOlino processes a variety of feedstocks including but not limited to: manure, food waste, slurry, renewable raw materials, etc.					

1) These are only examples; the combination of modules can be changed depending on input material, space availability, and retention time
2) Dimensions without optional expansions
3) Approximate installed values

* All values shown are approximate and current as of date of printing

Figure 4: Bioferm EUCOlino Data

Bioferm provided information on four different engines (50 kW, 64 kW, 75 kW, and 100 kW) that could be used in the EUCOlino depending on the availability of the organic waste as seen in Figure 4. It was not stated what the minimum amount of input materials was for each engine.

Bioferm stated that the EUCOlino has a 20-year lifespan.

Food Consortium Cost Breakdown for the EUCOlino Based on Olive Garden Sized Chain Restaurants

- Olive Garden
  - 2015 $4.5 million average unit sale
  - ~33 lbs of food waste per $1,000 of company revenue
  - $4,500,000/$1,000= 4,500*33= 148,500 lbs of food waste per year
  - 84.3% disposed of per source: 148500(.843)= 125, 186 lbs (62.6 tons) of food waste disposed of per year
  - Equals 343 lbs of food waste disposed of per day (.1715 ton per day)
    - Need at least 1,500 tons of additional food waste per year for EUCOlino
      - 1,500/62.6= **~24 restaurants like Olive Garden**

Manure Consortium Data and Cost Breakdown for the EUCOlino

An extra 2,000 tons of manure would be needed in addition to Otterbein's ~420 tons of manure to power the EUCOlino. 2,000 tons of manure equals 4 million pounds of manure. To determine how many more horses would be needed to supply 4 million pounds of extra manure, horses were assumed to produce 50 pounds of manure per day.

- 50 lbs of manure per day * 365 days/ year = 18,250 pounds of manure produced per year per horse
- 4,000,000 pounds of manure per year/ 18,250 pounds of manure per horse per year= **~220** additional horse's manure needed for the EUCOlino

Table 10 shows the 26 local equine facilities that were contacted regarding the manure consortium. Eleven of the twenty-six equine facilities responded regarding the manure consortium. The number of horses at each equine facility was determined by talking to people representing each equine facility or by data provided on their websites. For each equine facility that did not respond to the survey and did not have data on their website about the number of stalls at their equine facility, it was assumed that they had a capacity to house 20 horses (numbers seen in blue in Table 10). To reach 220 additional horses whose manure had to be used for the EUCOlino, the number of closest barns that reached a minimum of 220 horses was determined. It was determined that the eight closest equine facilities (all within a 12 mile radius of Otterbein's equine facility) would be needed for the manure consortium, which would provide the manure of an additional 232 horses to be used for the EUCOlino. The eight equine facilities that were used are highlighted in yellow in Table 10.

Equine Facility	Distance (mi)	Time (min)	Number of Horses	Current Disposal Method	Interested in Consortium
Bay Crest Farm	13	25	23	pile--> spread on field	yes
North Star Stables	15	27	27	pile--> spread	yes
Liberty Farm	22	30	20	-	-
Black Gait Stables	11	20	20	compost in back pasture--> spread on field	yes
Foxridge Farms	11	19	30	pile in back--> taken	yes
Stones Throw Farm	5.5	12	30	haul out most and spread some	yes
New Albany- Granville EC	17	25	42	-	-
Dublin Stables	14	22	20	-	-
Sylvan Stables	20	34	13	topsoil company takes it	yes
Sid Griffith Equestrian Center	25	35	20	-	-
Bookmark Farms	20	26	33	spread or pile/ mixed with seed and spread on pastures	yes
The Friesian Empire	4.4	11	47	-	-
Redtail Ridge Farm	26	33	23	-	-
Red Rose Equestrian Centre	23	34	20	-	-
Blacklick Bend Farm	11	24	35	-	-
Hunters Court Farm	8.6	20	20	-	-
Timber Run Farm	25	32	20	-	-
Sugar Run	28	37	18	-	-
South Wind Stables	28	38	15-20	compost and spread	yes
Maple Leaf Equestrain Center	28	40	12	bin picked up weekly	yes
Shadowlake Farm	13	21	20	-	-
The Paddock Stables	24	35	26	pile	yes
Willow Way	12	24	20	-	-
Squires Glen Farms	6.6	15	30	spread in field everyday	yes
Lost Creek Equestrian Center	19	35	24	-	-
Stepping Stone Stables	15	27	20	-	-

Table 10: Local Equine Facilities Data

Return on Investment for EUCOlino

Return on investment for the EUCOlino could only be determined based on the $1.2 million installation cost. The largest engine (100 kW) was used to determine the maximum electricity savings possible for the EUCOlino. The 100kW engine generates 100 kW of electricity per day, or 36,500 kW of electricity per year.

Electricity and Manure Removal Savings

Electricity Savings: 36,500 kW * $0.1105 per kWh = $4,033.25 electrical savings per year

Manure Removal Savings: $26,180 per Year

Total: $4,033.25 + $26,180 = **$30,213.25 savings per year**

The $1.2 million installation cost was so high that the electricity and manure removal savings would not even be close to getting a profitable return of invest within the 20-year life span of the EUCOlino.

Quasar: Potential Option for Manure Removal

Quasar cannot pick up the roll-off that Otterbein currently uses to hold the manure produced at the equine facility to transport to their Zanesville waste recycling facility. Otterbein could hire an outside company to pick up the roll-off and transport it to Quasar’s Zanesville waste recycling facility, but Quasar thought that that option wouldn’t be economically feasible for Otterbein. The options that Quasar provides to pick up waste from facilities are tankers, vacuum trucks, dump trailers, and van trailers. The dump trailer option was determined to be the best potential option for Otterbein. The dump trailer option would involve Quasar bringing out a dump trailer to Otterbein's equine facility when Otterbein needs its manure picked up. A front-end loader would pick up the manure from a pile and fill the dump trailer. Either Quasar could bring a front-end loader with the dump trailer or Otterbein could use it's own front-end loader. The dump trailer holds up to 24 tons of waste.

Quasar Costs

In order to provide an estimated cost for Quasar to pick up Otterbein's manure and take it to the Zanesville facility, a similar contract between Quasar and a wastewater plant 43 miles away from the Zanesville facility was used. For that contract, each trip to the wastewater plant costs them $970, $400 for the dump trailer and driver fees, and $570 for Quasar to provide the front-end loader.

Quasar would charge a flat rate of $35 per ton of waste for disposal (see Appendix D). Since Otterbein's equine facility produces ~420 tons of manure per year, Otterbein would pay a flat rate of $14,700 per year for disposal.

Each dump trailer can hold up to 24 tons of waste. Since Otterbein produces 420 tons of manure per year, Quasar would have to make 18 trips to Otterbein's equine facility per year to remove all of the manure. 18 trips would account for the removal of 432 pounds of manure. Eighteen trips per year would break down to one trip about every three weeks. If Quasar had to provide the front-end loader, each trip would cost $970. 18 trips at $970 per trip would cost $17,460 per year. Adding the $14,700 flat rate to the $17,460 front-end loader, dump trailer, and pickup fee would cost Otterbein a total of $32,160 per year. Since Otterbein currently pays

Kohler Farms an average of $26,180 per year for manure disposal, the $970 trip option would be $5,980 more than what Otterbein current pays for manure disposal.

Another option would be for Otterbein to invest in a front-end loader so that Quasar would not need to provide one. This would lower the trip cost from $970 per trip to $400 per trip. 18 trips at $400 per trip comes out to $7,200 per year. The $14,700 flat rate plus the $7,200 dump-trailer and pickup fee would equal $21,900 per year. $21,900 is $4,280 cheaper than the average manure removal cost of $26,180 that Otterbein currently pays for.

A front end loader could cost anywhere from $150,000 up depending on if its new or used, what size front-end loader is needed, and who it is purchased from. Labor costs for the operator of the front-end loader would need to be considered due to the fact that only certified operators can maneuver a front-end loader.

Quasar Energy Group Draft Proposal

A draft proposal for the disposal of Otterbein's manure from the equine facility to Quasar's dry digestion facility in Zanesville can be seen in Appendix D.

Discussion

SEaB Energy, Bioferm Energy Systems, and Quasar Energy Group were all investigated as potential new options for manure disposal at Otterbein's Austin E. Knowlton Center for Equine Science. SEaB Energy markets the Muckbuster small-scale anaerobic digester, Bioferm Energy Systems markets the EUCOlino small-scale anaerobic digester, and Quasar Energy Group has large-scale waste recycling facilities near Otterbein. Each option was analyzed and a cost analysis was completed, and return on investment was determined for each option.

SEaB Energy's Muckbuster option was potentially favorable because no additional manure would need to be added to Otterbein's manure for the digester, but Otterbein's food waste would need to be added to Otterbein's manure for the digester. After cost analysis and return on investment was completed, the 33-year return on investment was far too high to make the Muckbuster option economically feasible for Otterbein, especially since the Muckbuster only has a 20-year lifespan. Favorable economic return is usually considered two years. The 33-year return on investment didn't even take into account transportation costs to get the food waste from Otterbein's campus to Otterbein's equine facility, the $36,440.44 in electricity costs that Otterbein would continue to pay each year due to the low electrical output of the Muckbuster, or the fact that the Muckbuster wouldn't be able to take the shavings or straw that are removed with the manure from Otterbein's equine facility. Overall, the Muckbuster option was determined to be economically infeasible for Otterbein.

Bioferm Energy Systems EUCOlino option was also determined to be economically infeasible for Otterbein. Although the EUCOlino can take the shavings and straw that are removed with the manure, Otterbein doesn't produce enough manure to power the digester on its own. An additional 2,000 tons of manure or 1,500 tons of food waste would need to be added to

Otterbein's manure to help power the EUCOlino. The manure and food waste consortiums were analyzed as a way to get additional input waste material for the EUCOlino. Either the manure from eight local equine facilities within a 12-mile radius of Otterbein's equine facility or the food waste from 24 Olive Garden-like chain restaurants would have to be used in addition to the manure produced at Otterbein's equine facility to power the digester. It is understood that not all restaurants are the size of a traditional Olive Garden restaurant. Transportation to those facilities or restaurants, waste storage containers, and agreement to participate in the manure or food waste consortiums are all problems that would make the consortiums difficult to execute. The $1.2 million installation cost of the EUCOlino itself made this option economically infeasible due to the small return costs. All of these considerations make the EUCOlino economically infeasible for Otterbein.

Problems that arise when companies try to go green are initial investment costs of the product, the potential for a long return on investment, transportation costs, and a lack of small-scale digesters that can be economically feasible for actual small-scale operations like Otterbein's equine facility. The $318,101.03 investment cost for the Muckbuster and the $1.2 million investment cost for the EUCOlino are simply too expensive to make small-scale digesters a reality for small-scale farm operations. The high investment costs of the digesters lengthen the return on investment and therefore prevent companies from investing in their product. Going green is an economically friendly initiative, but it isn't practical to be applied to Otterbein University's manure disposal at this time.

The Quasar Energy Group option was the only option that could be potentially feasible for Otterbein. The only way that this option would be feasible would be for Otterbein to invest in a front-end loader so that Quasar would not have to bring one out for every trip. Otterbein would potentially save $4,280 per year on manure removal costs using this option, and the cost of the front-end loader would eventually be paid off due to the manure removal savings. Otterbein could also use the front-end loader for other things besides manure removal. Additional space would have to be allocated to store the manure at Otterbein's equine facility so that the manure produced there could be stored for three-week intervals in between manure removal trips from Quasar. The best option would be to store the manure on a concrete pad so that the front-end loader would be able to pick it up easily. This option could be economically feasible for Otterbein, and would make Otterbein a more green friendly university when it comes to waste management.

The importance of this research is that potentially cheaper options for manure removal for the Austin E. Knowlton Center for Equine Science were investigated and analyzed. Although the Muckbuster and EUCOlino were both determined to be economically infeasible, the Quasar option could be economically feasible for Otterbein. Analyzing these three options gives Otterbein University valuable information on other options for manure removal.

Further research that could be done based on the results of this research would be for a Systems Engineer student at Otterbein University to design a custom small-scale anaerobic digester for the Austin E. Knowlton Center for Equine Science. The Systems Engineer student could work together with other students in a consortium manner or this project could be included in a practicum course at Otterbein. The digester could be designed specifically for the amount of waste that is produced at Otterbein's equine facility. The custom digester would help save manure disposal costs, electricity costs, and would produce a green energy alternative to Otterbein's current manure disposal method. A custom digester would be a step forward in Otterbein's goal to become a more sustainable campus.

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Appendices

Appendix A

BIOFERM ENERGY SYSTEMS
VIESSMANN Group

Biomass Form

Client:							
Company:	Otterbein University		Contact Person:	Jillian Strimbu			
Street:	600 North Spring Street	City:	Westerville	State:	OH	Zip:	43081
Tel:	440-541-6627	Fax:		Email: jillian.strimbu@otterbein.edu			

Primary Motivation for AD (e.g. waste disposal, electricity production, environmental, etc):
Waste disposal/ electricity production/ environmental benefits

Biomass Availability:							
Type	Tons/Year Metric/Short	Volume (Specify Unit)	Density (Specify Unit)	Total Solids Content (%)	Volatile Solids Content (%)	pH	Organic Strength BOD or COD* (mg/L)
Horse manure	419 short tons per year (300 tons from September-April and 119 tons from May-August)	September-April: 303 gallons/day May-August: 230 gallons/day	63 lbs/ft³	30%	20%	6.5	BOD: 33,570 mg/L
Food (if needed)	18.25-20 tons/year						

Form.docx

Page 1 of 3

	BIOFERM ENERGY SYSTEMS VIESSMANN Group
Biomass Form	

[1] Please specify if you are using metric or short tons
[2] Please specify if you are using BOD or COD

Project Details:			
Feedstock	Acquisition Cost (Specify Unit)	Haul Away Cost (Specify Unit)	Tipping Fee (Specify Unit)
Horse Manure	None (On site)	$170 per trip (2-3 trips per week) ~$26,180 per year (last 2 fiscal years)	-----------
Food waste	Transport cost to equine facility (to be determined if necessary)	~$10,000 per year	

Project Details:			
Current Amount of Electricity Used (Specify Unit)	Fiscal year 2014: 11640- 68600 kWh (depending on the month)	Current Cost of Electricity ($/kWh)	Fiscal year 2014: $1509- $6718 (depending on the month)
	Fiscal year 2015: 12760- 72120 kWh (depending on the month)		Fiscal year 2015: $1758- $7178 (depending on the month)

	BIOFERM ENERGY SYSTEMS VIESSMANN Group
Biomass Form	

		Anticipated PPA (Buy-back) Rate ($/kWh)	not anticipating buy-back
Current heat use, specify electricity or gas	Electricity	Current Cost of heat ($/therm, $/MMBTU)	See electricity
Is there heat user within close proximity?	Yes		

Client information received by:	

Appendix B

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MUCK/FLEXI BUSTER SITE SURVEY FORM

PART 1 GENERAL INFORMATION OF THE SITE FOR INSTALLATION OF MUCKBUSTER™

a) Company name	Otterbein University
b) Responsible person contact name	Jillian Strimbu
c) Phone (Mobile)	
d) Email	
e) Nature of business	Potential customer
f) Urban or Rural Area	Urban
g) Minimum, Average, Highest temperature per year	Minimum: -10°F Highest: 100°F Average: 50°F
h) Ease of access to site for delivery of 40ft container (12.19mX2.44m). Availability of lifting equipment for container delivery.	Easy ease of access/ no lifting equipment on site
i) Site full Address	600 N Spring Road, Westerville, OH, 43081
j) Area available for installation (m2)	262 m2
k) Planning permission required/available?	Yes through the City of Westerville
l) Electricity connection permission required?	Yes through the City of Westerville
m) Waste processing license or exemption certificate obtained?	No
n) Type of soil at the installation area (wet soil, asphalt, concrete, gravel)	Gravel

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MUCKBUSTER™ SITE SURVEY FORM

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o) Total site area (ha)	~3 hectares
p) Current way of organic waste disposal (e.g. effluent pond, composting, animal feed, sale, landfill)	Pays a company to remove waste from facility
q) Current Disposal costs	Fiscal year 2014: $25,670/ Fiscal year 2015: $26,690 Usually $510 a week (3 trips at $170 per trip), sometimes $340 per week during the summer (2 trips at $170 per trip)
r) Distance from organic waste storage (m)	less than 10 meters
s) Will the fertiliser from (MUCKBUSTER®/MB400) be used on the site?	Yes
t) Current waste volume to be disposed kg/tonnes per day/week/month/year	~419 tons per year (380 tonnes) September-April: 37.5 tons/month (300 tons total) May-August: 29.8 tons/month (119 tons total)
u) Proposed use of biogas (water heating, electricity)	Electricity
v) Main reason for installation (cut carbon, local waste regulations,	Save money on electricity/ be more self-sufficient

PART 2 INFRASTRUCTURE

a) Availability of waste water drains for emergency	No
b) Availability of water supply	Yes
c) Distance to electricity supply connection (m)	Less than 100 feet
d) Availability of single/three phase supply	Yes, available
e) Is pack up power available? Provide details please.	Back up power is available through generator power
f) Site voltage (V) g) Frequeny (Hz) h) Phase details (please check for installations out of UK)	f) 120V/ 208V/ 480V g) 60Hz h) single/three phase

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i) Road access and quality of paths (wet soil, asphalt, concrete, gravel)	Concrete (front of facility) to gravel (back of facility)/ truck accessible
j) Availability of liquid fertiliser storage tanks, volume (tonnes)	No
k) ADSL connection if yes distance in meters	No
l) Availability of External lighting	Yes
m) Availability of wash water	Yes
n) Cellular phone service (reception quality)	Good
o) Electrical connection	Yes
p) Ventilation	Yes
q) Odour filter requirement	Yes
r) Other information which may be relevant	
s) Other renewable energy technology onsite	No

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PART 3.1 FEEDSTOCK DETAILS

Type	Description	Disposal cost per tonne	Volume (weight) available per day	Seasonal availability (e.g. May-Aug)	Dry Matter (%)
a) Crops e.g. Maize, Silage					
b) Food waste e.g. Bread, Meat, Milk, Oil	Food waste from campus if needed (if manure isn't enough)	~10,000 per year	45-50kg/day	August-May	
c) Food processing waste e.g. fruit waste, vegetables , peelings,					
d) Leftovers from harvesting					
e) Grass clippings					
f) Other					

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PART 3.2 FEEDSTOCK DETAILS

Type of feedstock		Volume (weight) of waste per day	Dry Matter (%)
a) Cows			
b) Pigs			
c) Poultry			
d) Sewage sludge			
e) Other	Equine manure	September- April: ~1.25 tons/day May-August: ~.95 tons/day	20.5%

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PART 4 FEEDSTOCK DETAILS

Summary	Kg/day, tonnes/week, tonnes/year	Dry Matter (%)
PART 3.1 a)		
PART 3.1 b)	45-50kg/day, .315-.35 tonnes/ week, 16.4-18.2 tonnes/year	
PART 3.2 a)		
PART 3.3 b) PART 3.2 e)	September-April: 1134 kg/day, 7.9 tonnes/week May-August: 862 kg/day, 6 tonnes/ week Total: 380 tonnes/year	20.5%
Etc.		
Summary (PARTS 3.1 (a,b,c, etc) + 3.2 (a,b,c, etc)	September- April: 1179-1184 kg/ day, 8.25-8.29 tonnes/week May-August: 907-912 kg/day, 6.35-6.38 tonnes/week Total: 396-398 tonnes/year	

PART 5 ENERGY USAGE

Fuel	Heat used for	Average use month/year (e.g. kWh, kl, t, kg)	Monthly costs, currency
Gas			
Electricity cost 1		Fiscal year 2014: April-October: 14020 kWh/ month (average)	Fiscal year 2014: April-October: $1754/month (average)
Electricity cost 2		November-March: 49520 kWh/ month (average) Year total: 359760 kWh	November-March: $5024/month (average)
Electricity cost 3		Fiscal year 2015: April-October:	Fiscal year 2015: April-October: $2029/month (average)
Oil		15754 kWh/ month (average) November-March: 50904 kWh/ month (average)	November-March $5334/month (average)
Coal			
Diesel			
Other type of fuel			
Applicable Government tariffs	No, except if excess electricity is produced		

PART 6 ADDITITIONAL INFORMATION

Please consider only using manure to power the digester first. If there is not enough manure produced for the digester, then consider the food waste. If more waste is needed for the digester, please let me know.

PART 7 DETAILS OF PERSON FILLED THE FORM

Company name	Otterbein University
Full name of person filled the data	Jillian Strimbu
Contact details, phone, email, address	
Date	DAY MONTH YEAR 28/1/2016

Please supply any additional information if possible i.e. photos, plans, sketches for proposed installation.

Please send the a copy saved in PDF and DOC format of this form on info@SEaBEnergy.com

Appendix C

Electricity Savings Per Year

- kWh Saved per Year
  - Electricity Available to Site- Parasitic Electrical Requirement
  - 44,373-12,000= **32,373 kWh/yr**
- Cost per kWh
  - Fiscal Year 2014: Total Electricity Cost/ Total Electricity Usage

    ⇒ $39,159.20/ 359,760 kWh = $0.109/ kWh
  - Fiscal Year 2015: Total Electricity Cost/ Total Electricity Usage

    ⇒ $40,876.11/ 364,000 kWh= $0.112/ kWh
  - Average Cost per Kwh

    ⇒ Average the Cost per kWh for Fiscal Years 2014 and 2015

    ⇒ (0.109+ 0.112)/2 = **$0.1105/ kWh**
- Total Electricity Savings Per Year
  - Total kWh/year * Cost per kWh

    ⇒ 32,373 kWh/ year * $0.1105/ kWh = **$3,577.22 savings per year**

Manure Removal Savings Per Year

- Fiscal Year 2014 Manure Removal Cost= $25,670
- Fiscal Year 2015 Manure Removal Cost= $26,690
- Average Used for Manure Removal Savings per Year
  - (25,670+26,690) / 2 = **$26,180 per year**

Total Electricity and Manure Removal Savings per Year

Electricity Cost Savings per Year + Manure Removal Savings per Year

$3,577.22 + $26,180 = **$29,757.22 Total Savings per Year**

Costs Per Year

- Electricity Cost Per Year
  - Electricity Cost for Fiscal Year 2014: $39,159.20
  - Electricity Cost for Fiscal Year 2015: $40,876.11
  - Average Electricity Cost: (39,159.20+40,876.11)/ 2 = $40,017.66 per year
  - Average Electricity Cost – Electricity Savings from Muckbuster

    ⇒ $40,017.66 - $3,577.22 = **$36, 440.44 per year**
- First Year Cost
  - First Year Cost for Muckbuster: **$318,101.03**
- Yearly Cost After First Year
  - Yearly Cost for Muckbuster: **$20,576.82**

Total Cost/ Savings

- First Year
  - Total Cost: $318,101.03
  - Total Savings: $29,757. 22
  - Total: -$318,101.03 + $29,757.22 = **-$288.344**
- After First Year
  - Total Cost: $20,576.82

- Total Savings: $29,757.22
- Total: -$20,576.82 + $29,757.22 = **+$9,180.40**

Appendix D

quasar
energy group

QUASAR ENERGY GROUP PROPOSAL TO OTTERBEIN UNIVERSITY – EQUINE FACILITY

THIS TERM SHEET DOES NOT CONSTITUTE AN OFFER: PREPARED FOR A THESIS BY JILLIAN STRIMBU

Memorandum of Terms for Biomass Processing & Services

March 26, 2016

Parties	**quasar energy group, llc** (quasar) and Otterbein University Equine Facility (Otterbein)
Description	**quasar** shall accept and process horse manure biosolids originating from Otterbein at a quasar anaerobic digester located at 6400 Maysville Pike, Zanesville, Ohio.
Disposal Fees	**quasar** shall provide disposal services to Otterbein for a fee of $35.00 per ton.
Right to Cancel	**quasar** reserves the right to cancel this agreement and/or revise the proposed fee because of unsatisfactory test results, contamination, and other considerations.
Manifests	Otterbein agrees to use the **quasar** manifest in accordance with all instructions provided in writing or in person, including by **quasar's** Plant Operators.
Contamination	Otterbein shall make all reasonable efforts to ensure that the biomass is free of contamination by foreign objects, including, but not limited to metal, stone, plastic, and glass.
Scheduling Loads	Normal business hours are 7 a.m. – 4 p.m. Monday through Friday.
Transportation	Otterbein will provide transportation to the **quasar** anaerobic digester. Otterbein shall be responsible for all normal wear and tear while operating vehicles on **quasar** premises. Moreover, Otterbein certifies that all vehicles and drivers are fully and properly licensed.

NON-DISCLOSURE; CONFIDENTIALITY. OTTERBEIN agrees that it will hold in confidence all pricing; it will restrict the disclosure of pricing within its own organization to those persons who need to know pricing for the purposes of this Agreement, who have been informed of OTTERBEIN obligations under this proposal, and who are obligated to keep such pricing in confidence, provided that OTTERBEIN shall remain responsible for all breaches of this proposal by such persons; it will not disclose pricing to any third party without the prior written consent of quasar; and it will not use pricing except for the purposes specified in this Agreement.

INDEMNIFICATION. Both quasar and OTTERBEIN agree to defend, indemnify and hold the other party, its parent company and affiliates, their officers, employees, agents, and customers, harmless from any and all liabilities, including but not limited to violations of federal, state, or local laws, rules and ordinances, damage to property, injury, disability and death to persons; arising out of, related to, or resulting from its performance under this Agreement provided, however, nothing contained herein shall apply to any claim arising from or the result of such claiming party's negligence or willful misconduct. Under no circumstances shall either party be liable for special, consequential, incidental, or punitive damages to the other party.

AGREED and ACCEPTED BY

QUASAR ENERGY GROUP, LLC		**OTTERBEIN UNIVERSITY – EQUINE FACILITY**	
Signature:	____________	Signature:	____________
Name:	____________	Name:	____________
Title:	____________	Title:	____________
Date:	____________	Date:	____________