South Farms Anaerobic Digester

Feasibility Study
Final Report

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Table of Contents

Tables

Executive Summary

Overview

Anaerobic digestion (AD) is one of the most established technologies for processing waste organics. This study investigated the feasibility of installing an Anaerobic Digester to produce renewable energy from available streams of organic waste (feedstock) within the University of Illinois Urbana-Champaign campus. This study assumed that one on-site digester would be installed in the University's South Farms. The best digester and energy conversion options were explored while considering UIUC's existing resources and operations, as well as the goals stated in the Illinois Climate Action Plan (iCAP).

Considerations

Following is a list of the considerations explored in this study:

- Feedstock sources and associated energy potential
- Digester technologies
- Feedstock collection strategies
- Potential digester sites
- Energy conversion technologies
- Environmental compliance and permitting
- Environmental attributes of waste-to-energy conversion
- Capital expenditures for the various digester and energy conversion options
- Operating expenses for the various digester and energy conversion options

Feedstock Sources

UIUC has numerous sources of organic waste that can be used as feedstock for a digester. The sources considered for this study are listed in the following table:

	Location	Material	Comments
1	Sheep & Beef Cattle Research Farm	Cow manure	Liquid and solid manure in pits and collected
2	Dairy Cattle Research Unit	Dairy farm cow manure	Open lot and wash in open lagoons
3	Campus Housing Foodservice Locations	Pre- and post- consumer food waste	UIUC Dining facilities, Illini Union, etc.
4	ISRL	Swine manure	Imported Swine Research
5	SRC	Swine manure	Moorman Swine Research
6	Grein	Swine manure	Finishing Pigs
7	Poultry	Chicken manure	Breeders & Layers
8	Campus Grounds Storage	Grass clippings, garden waste, arboretum, etc.	Landscaping residuals
9	Veterinary Medicine Facility	Waste and mortality disposal	Carcasses
10	Horse Research Farm, St. Mary's Road	Horse manure	Mares, foals, yearlings, some adult performance animals

It was determined that animal manure waste streams should be collected and tested for biogas production potential. Waste samples of materials were collected, onsite, from the various facilities and sent to a laboratory to be evaluated for their energy production. Each of the feedstock sources was tested for its Biomethane potential (BMP.) These studies measured the amount of biogas produced by each type of waste material. Food waste BMP was estimated from known accepted values.

The total projected fuel potential from all available feedstock (animal manure - 100% collected, food waste – 100% collected, 33 weeks per year.   No losses in collection) is 4,325 MMBTU/year and is detailed in Table 5, on page 28.

Digester Technologies

There are a number of types of anaerobic digesters being used in the world, today. The most common are:

- Covered Lagoon
- Continuous Stirred-Tank Reactor Digester
- Fixed Film Digester
- Plug Flow Digester

The plug-flow, covered lagoon and fixed film designs work best with a single-sourced substrate, such as animal manure. It is a proven animal manure technology, but has limited success with co-digestion of food wastes. Anaerobic co-digestion (many different substrate) is best achieved when utilizing a Continuous Stirred-Tank Reactor (CSTR), which is the most popular AD technology, worldwide.

Feedstock Collection Strategies

Three potential methods of waste collection were considered. The first would use trucks that would be operated on a regular basis between the sites of the waste origin and the digester site. The second method would consist of a system of pumps and underground piping to move the wastes, that exist in liquid or liquid slurry form, from the various sources to the digester site. Truck transportation would be used to move the non-liquid wastes. The third method would be a hybrid of the first two methods.

Potential Digester Sites

Five possible sites were identified for the digester. All of the sites are co-located with a manure feedstock source.

Energy Conversion Technologies

Several options for obtaining energy from the biogas, produced by the digester, have been included in the study, with the advantages and disadvantages cited for all:

- Flare
- Internal Combustion Engine Generator
- Micro Turbine / Turbine
- Fuel Cell
- Natural Gas Pipeline Injection
- Compressed Natural Gas (CNG)
- Liquid Natural Gas (LNG)

Environmental Compliance and Permitting

The possible requirements by various governing agencies, including UIUC, the Illinois Environmental Protection Agency, and federal agencies operating under NEPA having jurisdiction over a project of this type, are included in the report.

Environmental Attributes of Waste-to-Energy Conversion

The benefits to the University, the local community, and the environment, in general, are described and include:

- Reduction of bio-waste
- Production of usable fuel in the form of biogas
- A reduction of overall noticeable odors to the campus and the surrounding community
- A soil amendment or conditioner product with no loss of valuable nutrients
- Possible offsets to existing energy or fuel expenses
- Possible carbon credits from methane capture

Capital Cost Summary

The capital expenditure (CAPEX) recommendations are driven by the most economical model and comprise the lowest total cost to produce biogas for the best outcome for the investment.

The digester is estimated to cost between $6.1- $8.1 million[1] for a continuous stirred-tank (CSTR) system. This cost is based on the amount of available organic materials, as reported by the campus stakeholders; and is assumed to be 100% collected with no losses 365 days per year, for the livestock waste. The food waste is assumed to be 100% collected with no losses, for the 33 weeks per year food service is in operation. There is additional standard equipment required for the digester system, including influent and effluent storage tanks, coarse fiber separation and storage, and a drying drum for solid effluent, would add another $1,063,000. Various options for the use of the biogas, could be added to the system; cost estimates of each are detailed in the capital cost summary.

Operational Cost Summary

Operational expenditures (OPEX) are estimated to be 8% of capital expenditures (CAPEX) annually.

[1] This number represents construction cost only. For total project cost, add 35-40%.

Sample Item	Anticipated Expenditure Items
Vacuum Trucks	Engine maintenance (oil changes, tune up), periodic complete cleaning, servicing of vacuum system, disinfection
Wheel Wash	Spray head decalcification, pressure systems tests
Pipeline	High powered flushing to clear out, or using powered rotational blades to clean the line
Shed	Paint, repair (much of this is associated with weather based damage)
Macerator/Chopper	Tune up, sharpening of blades
Pre-Mix tank	Pump servicing, calibration of mixers
Thickening pit	Pump servicing, calibration of screens and mixers
Thickening pit pasteurizer	Periodic heat calibration, burner testing and maintenance
Pasteurizer (animal mortality waste)	Periodic heat calibration, burner testing and maintenance
Incoming feedstock pump	Pump maintenance (cleaning, lubing, bearing replacements)
Digester	Inspection of construction integrity, inspection of discharge system, anticipated maintenance of mixers, heating elements and all connections, controls
Information Technology	Configuration changes, software/firmware upgrades,
Solids separation	Periodic maintenance of moving parts (grease, lube, sharpen); replacement as necessary
Liquid separation	Periodic maintenance of moving parts (grease, lube, sharpen); replacement as necessary

Summary and Recommendations

Our recommendations are based on data collected from individual campus stakeholders that would, most likely, contribute organics to a campus-based Anaerobic Digester facility. The goal of any plan will maximize project participation with minimal changes in those stakeholders' operations and practices.

- SeaHold is recommending anaerobic co-digestion of many different substrates and using a Continuous Stirred-Tank Reactor (CSTR) as the most effective and flexible technology for the UIUC co-digestion project to achieve the most success.

- Initial planning for waste collection and delivery to the digester should be for a truck routing system, as an interim step, requiring a lower capital investment, with a long-term Campus Organics Waste (COW) collection line planned for the future, which would provide economical, safe collection and delivery of organics to the digester. This collection line would reduce and potentially eliminate any biohazard and cross-contamination from trucks and equipment collection from research facilities and working farms. Moving in steps from trucks to sewer lines, as engineering and funding resources permit, would be a one path and option.

- The site located near the current Dairy Farm is the best choice for a new digester installation, considering the current arrangement of feedstock sources and campus infrastructure. Having the AD facility in close proximity to the dairy will save transport costs and improve the energy output. However, if the current Campus Master Plan is implemented with respect to the South Farms redevelopment, including the Dairy Farm moving to this area, then the site near the current Beef and Sheep Facility will be the most advantageous. If the Beef and Sheep site is selected for the digester installation, and the plan to relocate the animal research operations, per the Campus Master Plan, will be realized in the next few years, then using vacuum trucks to collect and transport the feedstock would be a flexible interim plan. The piped collection system could be phased in as animal research sites are moved into the vicinity of the Beef and Sheep Facility.

- The two best options for the AD system, that would create the greatest Life Cycle Cost, would be to either use the biogas for electrical generation via an internal combustion engine (ICE) generator (average 9.7 years, median 8.9 years) or to upgrade the biogas to compressed natural gas (CNG) vehicle fuel (average 13.6 years, median 12 years). This vehicle fuel can be used to power the campus vehicle fleet. SeaHold recommends the CNG option. The ICE option seems to have a slight advantage in terms of its projected returns period; however, since the numbers are only estimates, and with the annual revenue structure assumed to be flat, such a small difference is not meaningful. The advantage of the CNG option is that historically petroleum fuel prices rise faster than electricity prices, so the CNG option is more likely to have greater avoided fuel cost savings. The CNG option allows greater benefit from the avoided cost of petroleum rather than ICE whose benefit and value is based on electricity prices.

- With a Continuous Stirred-Tank Reactor (CSTR) system, the digester, by itself, is estimated to cost $6.1 - $8.1 million dollars[2]. This is based upon the results of the surveys and interviews done with known digester developers and manufacturers, coupled with the feedstock survey results, creating a baseline sizing. This dollar amount presumes that the total available organic waste for AD is 100% collected, with no losses. Similar recent projects with comparable feedstock types and amounts fall in this range. Additional typical equipment, including influent and effluent storage tanks, coarse fiber separation, and storage, and a thickening pond for the liquid effluent will add an additional $1,063,000. Depending on the choice of what to do with the produced biogas, the overall cost to implement the various choices could be an additional $2 to $4 mil.

[2] This number represents construction cost only. For total project cost, add 35-40%.

The following is a list of recommended next steps.

- Select a project effort champion for bringing the current university stakeholders skill and knowledge to the effort
- Conduct additional feedstock testing: be more longitudinal rather than cross-sectional.
- Start an internal feedstock testing laboratory
- Begin recipe testing for feedstock selection and considerations
- Audit and verify feedstock mass and volume
- Choose the actual digester location. The optimal location is the dairy farm. If the dairy farm is to be moved, it doesn't make sense to start any construction until after the dairy farm is moved
- Conduct more detailed engineering studies; based upon the results of the feedstock data, in order to develop a more specific AD system configuration
- Reach a consensus on the highest and best use of the biogas; then select fuel use and the form of energy to benefit the university. The selection must be weighted heavily to the environmental restrictions the university faces
- Consider the installation of a dedicated CHP at the digester site to address the parasitic loads of electricity and heat/steam.
- Address the public perception challenges. While the digester will be located on University property, good public relations goes a long way.

Validated and confirmed data leads to better engineering and materials balance estimates. This will further allow for increased accuracy and more useful design parameters yielding clearer development path options.

Technology Options
And Considerations

Technology Options & Considerations Overview

AD is a microbiological process that takes place in an environment that is absent of oxygen. The bacteria that live in the anaerobic environment are utilized to decompose the organic material (e.g. dairy manure, campus food waste, organics, etc.), and this process typically produces biogas, consisting of methane (CH_4), carbon dioxide (CO_2), and water vapor, with traces of hydrogen sulfide (H_2S), ammonia and siloxanes. Once the compounds of hydrogen sulfide, ammonia, and siloxanes are removed, the biogas can be used as a source to create fuels or electricity. Beyond the energy source options for the repurposed organic waste, the AD system creates a nutrient-rich byproduct called digestate, usable as a fertilizer or a soil amendment. The benefits of an AD system are numerous: The AD process diverts waste from storage lagoons, processing by waste water treatment plants, pollution basins and landfills, reduces odor, eliminates methane being released into the atmosphere, and creates valuable byproducts that provide nourishment as fertilizer for plants and conditioners for the soil. AD is part of the natural carbon and nutrient cycle.

The first step for many AD projects is the need to balance aerobic composting imbalances. Aerobic composting of waste is very well understood, but often results in the disproportionate composition of nitrogen and carbon nutrient loads. In addition, there is the likely perennial need of a dedicated environmentally controlled facility. This option is costly for a system with compost material as the only valuable yield. AD technologies can be run all year; and they yield fuel for energy, produce value added digestate (a ready soil amendment), and water for irrigation and nutrient extraction. Both aerobic and anaerobic facilities often generate revenue via “tipping” or gate fees. In any financial model, the University will benefit from the diversion of the organics, eliminating some of the landfill disposal fees. In this unique environment, the University is, in effect, a self-contained municipality that directs all organics to the AD system process. This is very similar to many of the European AD project models.

Anaerobic Digester Technologies

There are various technologies for converting fuel to energy. Below is a summary of some of the various technologies typically used for AD:

- Plug Flow Digester – A long, rectangular concrete tank with an air-tight cover, where manure flows in one end and out the other. Sometimes the tank is U-shaped, with the entrance and exit at the same end. Influent manure first enters a mixing pit, allowing solids to be mixed by adding water. Then, as manure is added, the “plug” of manure slowly pushes the older manure through the tank. The tank is typically heated to maintain a mesophilic (20 and 45 °C/68 and 113 °F) or thermophilic (45 and 122 °C/113 and 252 °F) environment, often using recovered heat from the biogas burner. The tank volume commonly holds 15 to 30 days’ worth of manure and waste water, or in other words, a hydraulic retention time (HRT) of 15-30 days. Plug flow digesters require 11 to 13 percent total solids in the manure and work well with scraped dairy manure.

- Continuously Stirred Tank Reactor - A Continuously Stirred Tank Reactor digester has a sealed, cylindrical concrete or steel tank, where manure is mechanically kept in suspension or “mixed” by a motor-driven impeller, pump, or other device. It is also referred to as a “continually stirred tank reactor.” The manure is typically heated to maintain a mesophilic or thermophilic environment, often utilizing recovered heat from the biogas burner. The tank commonly holds 15 to 20 days’ worth of manure and waste water, or 15 - 20 day HRT. Slurry manure, that is scraped or flushed with 3 to 10 percent total solids, works best in this system.

- Covered Lagoon Digester - An earthen lagoon fitted with a cover to contain and facilitate collection of biogas - the least expensive type of digester to install and operate. A covered lagoon is the least controlled system, with the lowest gas production and the longest retention time, due to its unheated environment. In northern climates, there may be no gas production in cold weather. Odor may not be totally eliminated due to incomplete digestion. Best suited for flush manure collection systems with total solids of 0.5 to 3 percent.

- Fixed Film Digester - A vertical concrete or steel tank that is filled with “biofilm”, a plastic media. The biofilm supports a thin layer of anaerobic bacteria and maintains a concentrated population of mesophilic or thermophilic methanogens, supporting a larger volume of biogas production and shorter HRT (six days or less) than the other digester types. The Fixed Film system works best with flushed manure with less than 5 percent total solids. Slowly degradable solids must be removed before the manure enters this type of digester.

Anaerobic co-digestion of many different substrates has achieved the most success when utilizing a Continuous Stirred-Tank Reactor (CSTR). This is the most popular, and proven, AD technology worldwide. Many single-sourced substrate AD technologies exist; a primary example is the plug-flow design for animal manure, a proven animal manure technology with some limited success with co-digestion of food wastes. It is our recommendation that the most effective and flexible technology for the UIUC co-digestion project is a CSTR system. CSTR systems are very large, heated insulated tanks, constructed of metal or concrete.

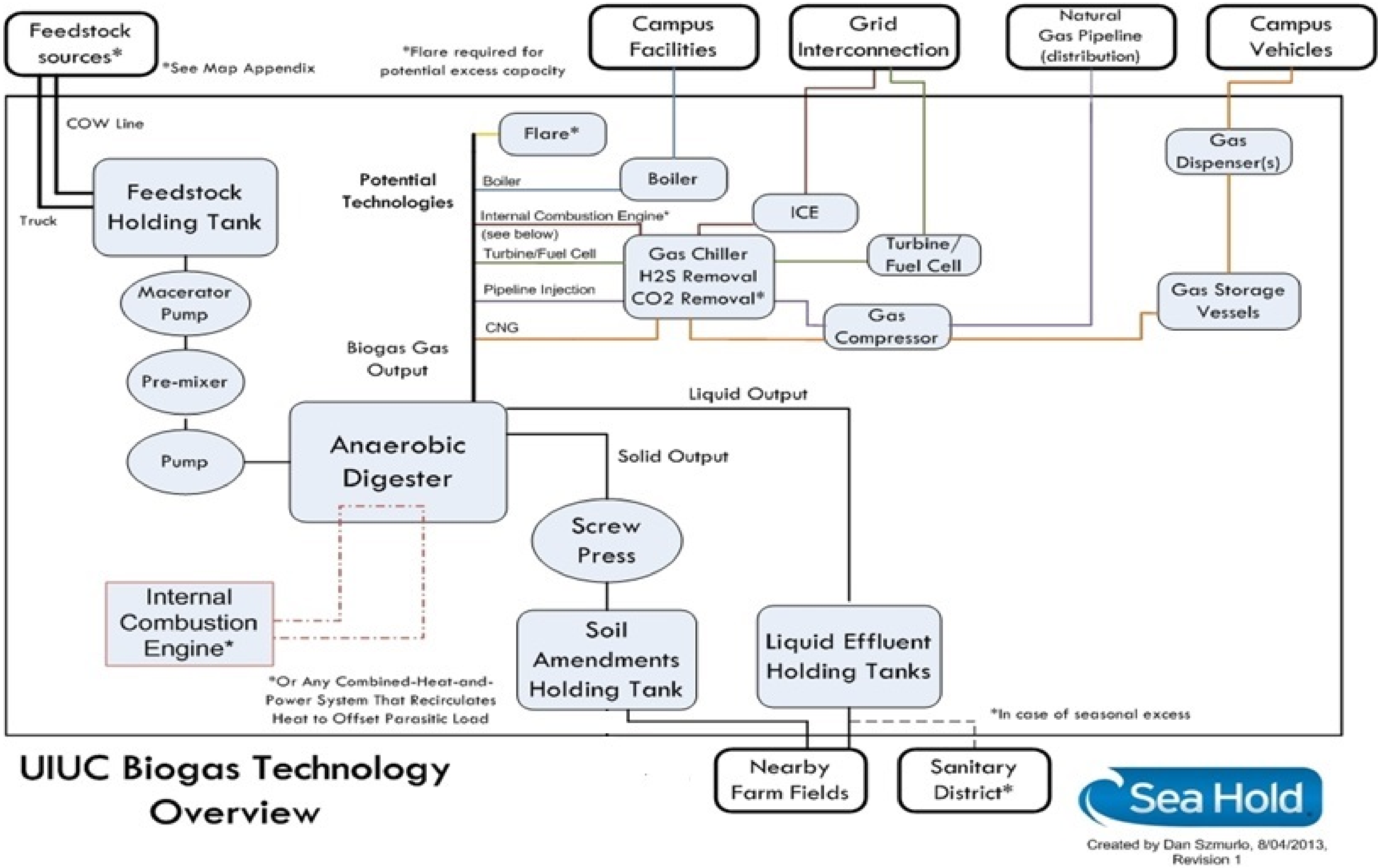
Brief Energy Output Production Overview

Biogas from an AD system has various use or off-take options. These include:

- Flaring – the direct burning of the biogas. With this option, there is no renewable energy value
- Internal Combustion Engine (ICE) - The ICE is a generator used to produce electricity
- Micro turbine - The micro turbine is a type of combustion turbine that produces both heat and electricity on a relatively small scale, using biogas as the fuel
- Fuel Cell - Fuel cells convert chemical energy from hydrogen-rich fuels into electrical power and usable high quality heat in an electrochemical process from methane
- Natural Gas Pipeline Injection – using biogas that has been “upgraded” to methane and putting it back into the natural gas utility grid

- Compressed Natural Gas (CNG) – methane is used as a replacement for vehicle fuel
- Liquefied Natural Gas (LNG) – methane gas that has been liquefied for ease of transport

Figure 1 depicts an overall AD system design, illustrating all of the options discussed.



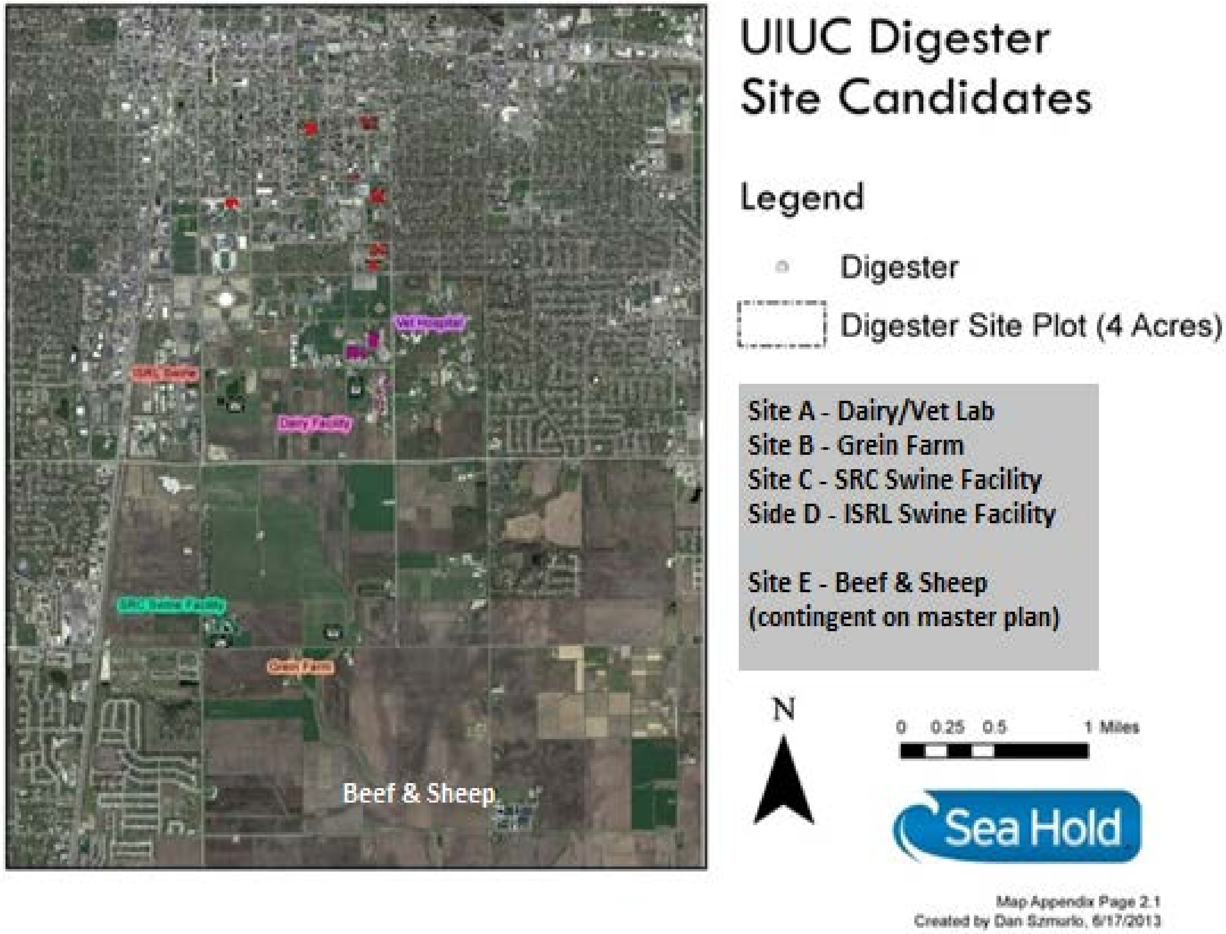
Site Options

SeaHold interviewed the various stakeholders by both telephone/email, and also gathered information during onsite visits. SeaHold prioritized the digester location, the transportation options, the collection options, and the storage and processing options. The following assumption set was utilized:

- Digester location should ensure the minimization of feedstock transportation, whether it is by truck or by pipeline.
- Digester location should be in close proximity to users of process discharge water. Digester effluent could be piped to nearby farm fields for irrigation. All proposed digester sites are located near farm fields to reduce ex-digester water pumping to fields.
- Proximity to existing utilities - electricity service, potable water, storm runoff, and sanitary sewer lines, as well as natural gas lines and connection infrastructure, should be considered, if pipeline injection of Biomethane or CNG use is an option.
- Offsetting the parasitic heat load should be considered to increase the total gross megawatt potential of the project. Utilizing other innovative technologies, such as solar concentrators, should be considered when determining digester location.

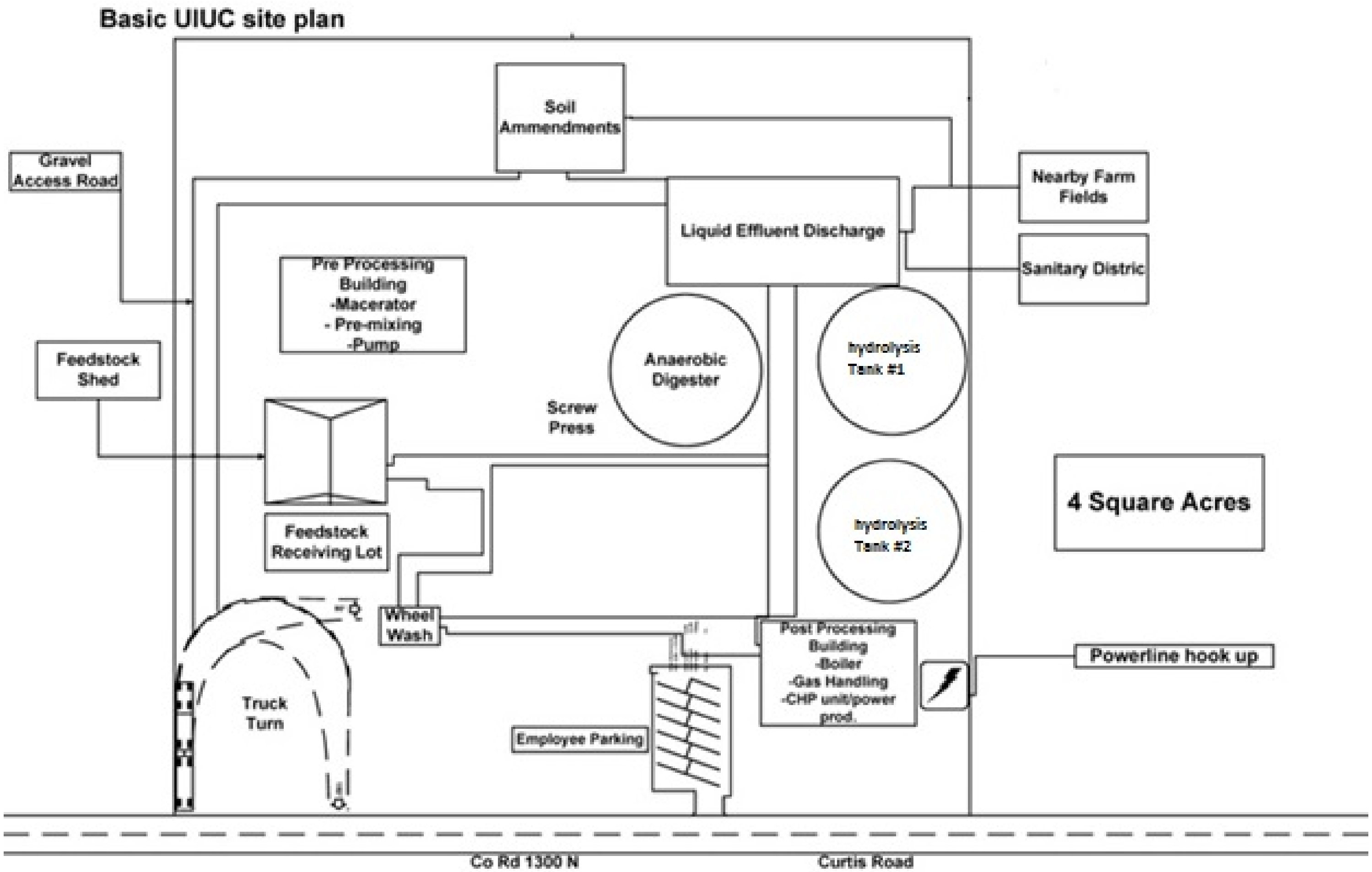
Conceptual Design and Project Sites Overview

The following map indicates the potential sites based upon our GIS mapping and analysis:


UIUC Digester
Site Candidates
Legend
Digester
Digester Site Plot (4 Acres)
Site A - Dairy/Vet Lab
Site B - Grein Farm
Site C - SRC Swine Facility
Side D - ISRL Swine Facility
Site E - Beef & Sheep
(contingent on master plan)
Beef & Sheep
N
0 0.25 0.5 1 Miles
Sea Hold
Map Appendix Page 2.1
Created by Dan Szmurlo, 6/17/2013

The diagram below represents a very basic configuration of an anaerobic digester:

Figure 2 - Conceptual Design



Campus Feedstock Sources And Potential Energy Testing

The organic waste streams produced at the UIUC campus represent the core of the implementation of an anaerobic digester. The varied types of waste streams (manure, food waste) is considered a co-digestion feedstock program. Although farm-based digesters typically only use manure, the most productive digester projects practice co-digestion of substrates. The UIUC campus offers a great variety of organic substrates for co-digestion with the university's sources of farm manure. The following sources of organic waste were investigated:

- Animal waste
  - Horse
  - Hog from several locations
  - Cow from dairy and beef farms
  - Poultry
- Food waste
  - Pre- and post-consumer waste from food service locations
- Animal carcasses from the Veterinary Diagnostic Facility
- Horticultural material (from Campus Grounds department)

Animal organic waste material consists of manure and other organics produced by the various animal science facilities. This material is primarily composed of manure, both liquid and solid (fecal material of cattle, sheep, horses, and swine), various bedding, and remains of deceased animals. Each animal science facility has a different strategy for collection and disposal of their waste streams.

The Swine facilities have highly operational liquid and solid waste collection systems. These systems will require additional engineering so that the liquids and solids can be delivered by truck or pipeline.

Dairy waste is valuable, as many of the required microbes (methanogens) are present in the fresh dairy cow manure. A campus AD system will benefit from the freshest supply of dairy cow manure. The present dairy farm operation is operating very well. The staff's expert skill and dedication to manage the dairy, as well as tending to their herd's care, are commendable. The liquid effluent discharge and solid waste storage is serviceable. With its dated layout and the physical plant and equipment repair that are needed, modernization of the dairy farm should be considered, especially in conjunction with designing a digester facility. A successful campus AD system requires bovine manure contribution, because the manure has important and inherent properties for the co-digestion of food waste. Having the AD facility in close proximity to the dairy will save transport costs and improve the energy output.

The Beef and Sheep facility has one of the most modern and functional waste collection systems in place, thus creating an opportunity for very high waste collection rates. The highly engineered and advanced solid and liquid waste separation and storage system, that currently exists, will require an investment to properly interconnect, prepare and deliver to a digester facility.

The Poultry farm is an outstanding example of stakeholder pride of operation. The Poultry operation was extremely well conceived and illustrates good farm management practices. The strong, passionate management of the operation is reflected in its layout and design and the quality and details of its construction. The animal waste from the Poultry facility should be carefully considered for inclusion in the AD system's substrate mix. The volumes are modest and are likely to be acceptable, but this manure is more challenging to process. This waste may require trucking in both the short and long term. Poultry waste is useful, but, again, the "recipe" for the digester would need to be researched and adjusted to accept it.

Pre-Consumer and Post-Consumer Waste - Pre-consumer is the food waste that the dining hall kitchens throw away, due to over-production, expiration, spoilage, trimming or handling issues. Post-consumer food waste is the food that the customer leaves on the plate after dining. In addition, grease traps could be installed at dining facilities to collect all Fats, Oils, and Greases (FOG), as well as interceptors and diverters at the dining facilities' food waste disposal lines.

Veterinary Mortality Waste - This organic material consists of the carcasses of animals that received treatment at the veterinary hospital. This material is divided into animals with normal mortality status and those categorized as hazardous and contagious. There will be an extensive processing investment to ensure bio-security for the campus when including this waste stream

Grounds Waste - This is the organic waste generated from the Grounds Maintenance department. Typical waste includes wood chips from trees, small wood twigs, leaves, weeds, and other plants. This material is composted and used as mulch in many decorative landscapes on campus. The only exception is the beds in front of the alumni center. The mulch used at the alumni center is purchased from an outside vendor, because it is more aesthetically pleasing than the mulch derived from campus grounds waste. This material is included in the main waste stream when replaced and is taken to the grounds storage facility for composting into mulch. All grounds material collected on campus is re-used on campus and, as such, was not deemed to be a likely feedstock source for the AD system.

The present study highlights the AD system's technology options and identifies the challenges of creating a system to incorporate the known campus waste organics and seasonality of the non-farm wastes. Further investigation and study are required to validate the substrates through verification of each stakeholder's actual volume, quality and long-term availability. This verification will be essential for design and engineering purposes. It should be noted that the dairy farm infrastructure and the beef and sheep facility should rank high on the list for investment in capital improvements, as they are the most economically compatible with the development of a UIUC AD system.

Collection Methodology

Campus stakeholders were interviewed for information regarding their organic waste streams. Onsite interviews were conducted with the stakeholders of the animal waste (beef cattle, dairy cattle, poultry, sheep, horse, and swine). Information was gathered that described the particular species population, including census count, current disposal practices, current disposal costs, and estimated waste poundage. The Dining Services department was interviewed to collect information about and clarify their pre- and post-consumer food waste. The Grounds Storage Facility and the Veterinary Diagnostic Laboratory were interviewed about their respective available organic waste.

The USDA guidelines were followed for collecting data for a university study.[3]

Sites to visit for volume, condition and state summary

Feedstock sampling was conducted at the following UIUC program sites:

Table 1 - Sampling Locations

Program	Address	Feedstock Condition
Horse Farm	501 St. Mary's Rd., Champaign, IL 61820	Manure
Dairy Farm	2301 S. Lincoln Ave., Urbana, IL 61802	Liquid and solid manure
ISRL Swine Facility	201 Hazelwood Dr., Champaign, IL 61820	Liquid manure
SRC Swine Facility	3502 S. First St., Champaign, IL 61820	Liquid manure
Beef and Sheep Facility	4900 S. Race St., Urbana, IL 61802	Slurry manure
Poultry Facility	4513 S. Race St., Urbana, IL 61802	Manure

The following program sites were not sampled, however the staff were interviewed to determine baseline/typical waste stream volumes:

Table 2 - Non-Sampled Locations

Program	Address	Feedstock
Dining Services	(vary across campus)	Pre- & post-consumer waste
Grounds Storage Facility	2306 S. Lincoln Ave., Urbana, IL 61802	Organic plant waste
Greins Farm[4]	811 E. Curtis Rd., Urbana, IL 61802	Manure
Veterinary Diagnostic Laboratory	2001 S. Lincoln Ave., Urbana, IL 61802	Animal carcass

The materials collected were comprised of liquids, solids and a combination of both liquids and solids.

Between February 25, 2013 and February 28, 2013, materials were collected onsite from the various facilities. The SeaHold team members were Tom Hintz and Heather Pierce. AEI team members were David Guth and Michael Ziegler.

[3] Sources of university study material - http://www.epa.gov/agstar/tools/research/

[4] At the time the samples were collected, Greins Farm did not have any animals onsite; the facility will be repopulated soon. M. Katterhenry, Facility Manager(Personal Communication with Heather Pierce, February 27, 2013).

Testing Protocol of Co-Digestion Candidate Materials

The services of the University Of Wisconsin- Platteville Laboratory were engaged, which conducts reliable evaluation of materials for energy production, under the experienced direction of Dr. Timothy Zauche. For the UIUC feasibility study, UW-Platteville performed Biomethane Potential (BMP) studies for all of the substrates submitted. The lab also tested the materials for Chemical Oxygen Demand (COD) and Volatile Solids (VS). UW-Platteville used procedures presented by (Gunaseelan 1997)1993, "Biochemical Methane Potential of Biomass and Waste Feedstocks." Biomass & Bioenergy 5(1): 95-111; using the Automatic Methane Potential Testing System (AMPTSII) from Bioprocess Control. The COD analysis was performed using the Hach DRB 200 heating block with Hach COD reagent vials for 0-1500mg/L, mercury free. The samples were processed using the Automatic Methane Potential Testing System from Bioprocess Control.[5]

Biogas Projections from BMP Studies of Candidates

Biogas is a combustible gaseous fuel that is collected from the microbial degradation of organic matter in anaerobic conditions. Biogas is principally a mixture of methane (CH_4) and carbon dioxide (CO_2) along with other trace gases, such as H_2S (hydrogen sulfide). The energy content is based mainly on the combustion of the CH_4. For the purposes of this report, the values for CH_4 and CO_2 are presented below from samples processed in lab scale reactors:

Table 3 - Sample Composition as tested

Source	% CH_4	% CO_2
Horses	72%	28%
Dairy Solid	70%	30%
Imported Swine	75%	26%
Hog Finish	69%	31%
Hog - Manhole	84%	16%
Beef/Sheep	40%	60%
Poultry	38%	62%
Dairy Liquid	66%	34%
Recipe Mix	85%	15%
Average	**66%**	**34%**

Biogas Production

The laboratory provided extensive datasets. All of the calculations were extrapolated from the available samples tested. If a sample was not available for testing, “industry standards” proxy values were used for the biogas production. These are cited below the table. One of the

[5] http://www.bioprocesscontrol.com/products/ampts.aspx

datasets included an extrapolation for “projected CH_4 (methane) per ft^3 (cubic feet) per ton of material. The data was confirmed with the stakeholders, and all data was converted to standard measurements. The following dataset is indicative of the productivity of the feedstock that was tested:

Table 4 – Projected Gross Methane Production

Assay	Source	Projected Monthly Organic Material (ton)	Projected Yearly Organic Material (ton)	Projected CH4/ft^3 / Ton of Material	Projected Monthly CH4 (ft^3)	Projected Yearly CH4 (ft^3)
13001	Horses	91	1,095	768	70,080	840,960
13003	Dairy Solid	699	8,389	884	617,990	7,415,876
13010	Hog – Manhole	1,000	12,000	708	708,000	8,496,000
13011	Beef/Sheep	680	8,162	453	308,127	3,697,528
13012	Poultry	27	329	309	8,459	101,507
13015	Dairy Liquid	583	7,000	572	333,667	4,004,000
Proxy	Food Waste 33 weeks/yr	40	327	210	8,316	68,670
Proxy	Animal Carcass	88	1,060	9,406	831,074	9,972,888
	Total	**3208**	**38,362**	**13,310**	**2,885,712**	**34,597,428**

Horses - Penn State University - College of Agricultural Sciences/Agricultural Research & Cooperative Extension, "Horse Stable Manure Management". http://pubs.cas.psu.edu/freepubs/pdfs/ub035.pdf.

Dairy Solid - Daily animal manure production based on “ANAEROBIC DIGESTER – 366 Conservation Practice Information Sheet”. www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_026500.pdf.

Food Waste - “Increasing Anaerobic Digester Performance with Co-Digestion, September 2012”. www.epa.gov/agstar/documents/codigestion.pdf.

Animal Carcass - “Dairy Cow Mortality Management via Anaerobic Digestion”. http://www.epa.gov/agstar/documents/conf12/06d_Martin.pdf.

Fuel Projections - MMBTU – Measure of Fuel Potential

Energy consumption is expressed in BTUs to allow for consumption comparisons among fuels that are measured in different units. The MMBTU is the industry standard for biogas and energy. It is necessary to convert the cubic feet of methane (CH_4) first to BTU, then convert the BTUs to MMBTU:

- Total BTU methane = methane (CH_4) / ft^3 x 1000
- Total MMBTU methane = Total BTU methane / 1,000,000

Table 5 – Projected Gross Energy Values

Assay	Source	Projected Monthly BTU @ 1000BTU/ft^3	Projected Yearly BTU @ 1000BTU/ft^3	Projected Monthly MMBTU	Projected Yearly MMBTU
13001	Horses	70,080,000	840,960,000	70	841
13003	Dairy Solid	617,989,667	7,415,876,000	618	7,416
13010	Hog - Manhole	708,000,000	8,496,000,000	708	8,496
13011	Beef/Sheep	308,127,297	3,697,527,563	308	3,698
13012	Poultry	8,458,875	101,506,500	8	102
13015	Dairy Liquid	333,666,667	4,004,000,000	334	4,004
Proxy	Food Waste 33 weeks/year	8,316,000	68,670,000	8	69
Proxy	Animal Carcass	831,073,971	9,972,887,652	831	9,973
	Total	**2,885,712,476**	**34,597,427,715**	**2,886**	**34,597**

Gross Fuel Projections - Conversion Options

There are several options available for methane as fuel to be beneficial as an energy source:

- The first potential benefit is the capacity to convert the methane to electricity, by means of a "genset" (generator) or a fuel cell. Our preliminary analysis report reveals an annual Biomethane production capacity of 34,597 MMBTU. To compute the KW produced:
  - 34, 597 MMBTU x 292.9974[4] = 10,136,831 KWH per year
  - 10,136,831 KWH / 8,760 (hrs in year) = 1,157 KW of output (approx. 1.1MW gross electrical potential)

  Based on practical examples of internal combustion engines for electricity, engine sizing would be in the range of 500KW engine +/- 25%, before engineering and design. Engineering studies would provide a formal assessment of the actual project requirements for the digester and gas upgrading systems. These would be driven by materials balancing from the selected feedstocks.

  Electricity is one of the least efficient methods of utilizing this energy. This particular engine sizing recommendation is an estimate, pending a fully engineered project, and with appropriate material balancing analysis

Another option is to convert the BTU to vehicle fuel. The preliminary BTU production from the available Biomethane is 34,597,427,715. To compute the GGE (Gasoline Gallon Equivalents):

- 34,597,427,715 BTU / 114,000[6] BTU/GGE = 303,486 gallons of "regular" grade gasoline.

To put this into context, the 303,486 GGE will exceed the 279,570 gallons of gasoline dispensed on campus as CNG (compressed natural gas).

Natural gas from fossil sources is about 70-90% methane; Biomethane is 99% methane or about 900 to 1,000 BTUs per cubic foot. The examples above are pure fuel conversions to energy and do not take into account any kind of processing step loss, parasitic loads of any type or other system losses.

[6] http://alternativefuels.about.com/od/resources/a/gge.htm.

Collection, Transport, and Storage Options

Transport, collection, storage and processing options and recommendations

Three primary options for waste collection were explored. The first option would involve the use of vacuum trucks or trailers to collect and transport the waste from the feedstock sources to the digester location. The second is a South Campus pipeline system for pumping manure slurry from the various animal waste feedstock sources to the digester location, combined with dining facilities' food waste being collected by truck. The third option, is a hybrid of first two, as connecting the various sources may be expensive.

The existing animal research facilities were studied when considering the collection options.

Bovine manure is typically removed by trucking, both in farm communities and to digesters. Limiting the travel distance is very important because manure has high moisture content, and transporting water by truck is expensive. The dairy facility at UIUC currently removes manure by truck; however, the current handling practice is to store it in piles, until it is spread on farm fields. With its existing design, the dairy is not equipped to collect at higher than average manure rates. In order to collect greater than average rates of manure, the cows would need to spend more time on concrete than on dirt ground. Updating the dairy facility to improve the feeding process, improve the health of the herd, and automate the manure collection potential would be possible with modernized designs.

In contrast, the beef and sheep facility collects a much higher volume and percentage of waste, both liquid and solid, than a typical beefing operation. The effluent-under-the-pen collection system accounts for this higher volume. This system is possible when the livestock are kept in housing units rather than on a lot, where the animals are on dirt. However, the installed collection system needs to be improved so that it operates reliably and then can be adapted to feed the waste streams to the digester. The beef and sheep facility is believed to be currently sending the stored liquid nutrient water from the storage tanks to the farm fields via underground tiles (pipes). The liquid nutrient water is used to fertilize crops. Post-digested liquid and solid digestate fractions from an AD system would provide a nutrient fertilizer by-product that could be applied to vegetation, landscaping, and crops instead of commercial petrochemical-derived fertilizers. The utilization of these products would provide substantial savings. Locating a digester system near the dairy or beef and sheep facilities would be beneficial in lowering transportation costs, would reduce odor, and would provide a steady supply of fresh, naturally present methanogens. Digesters with bovine manure activate with less need for "seeding", as the methane producing microbes are already present in the manure.

Moving the swine waste by truck is also possible, but will require a vacuum truck system dedicated to each farm. Separating the liquid and solid waste via a new system to accommodate trucking may be needed. The goal would be to transport less water by truck. Collecting waste with the same vehicles or tanker trailers (either via vacuum trucks or via loaders and a trailer) from farm to farm substantially increases the risk for biohazard and cross-contamination. Since UIUC maintains a sizable investment in the ongoing research of animal populations, minimizing the risk of biohazards and contamination of animal populations is of particular importance. Preventative measures such as tire washes are common practice, but they do not provide a 100% guarantee of risk avoidance. Transport vehicle sanitizing spray stations and disinfection efforts would be needed, incurring additional investment and operational costs. We recommend moving the waste via alternate sewer lines to the digester. It is believed that much of the current waste stream is either piped to storage lagoons (ponds) or sent to the sanitary district sewer lines. The investment in piping the waste may protect the animal research farms, and the initial cost may be offset by lower sewer charges.

Transporting the food waste by truck is a viable option, and there is a highly organized and developed system already on the UIUC campus. This would divert the food waste that normally goes to the landfill or composting.

In the interim short-term scenario, trucking waste, compared with installing a dedicated sewer line, would require a lower capital investment while being flexible to allow for planned research facility relocations. Addressing all stakeholders' concerns and the fundamental biohazard concerns for research and animal population safety would require further review. Initially, the collection system might utilize a small fleet of dedicated trucks and trailers. Moving in steps from trucks to sewer lines, as funding resources permit, would be a viable investment option.

Based on the limited data and assumptions of this high level review, especially for expected capital costs, street routing, and estimated labor and fuel costs, we have presented gross estimates for trucking and collection lines. As a supplemental resource, we have provided a drawing for a dedicated piping option.

The University of Illinois Urbana-Champaign has unique constraints when considering the design of a system to move the various substrates to the digester location. The waste stream contributions from the farms are likely to be more consistent in volume and frequency than the waste streams produced by the student population, which changes during the year.

The bulk of feedstock material is animal based. These include various manure sources – horse, sheep, dairy cattle, beef cattle, swine and poultry. In addition, animal mortality wastes (carcasses) are available from the veterinary hospital. The veterinary hospital sourced feedstock is likely to be the most problematic for many reasons. Transporting animal mortality is a growing NIMBY issue, especially in a suburban or campus environment. Farm communities are more aware of the animal care and life cycles. Stock mortality is a reality. Having an AD facility processing carcasses for energy may not be readily accepted. The contribution to the gross energy output would be marginal. It was beyond the scope of this study to address these broader community issues. However, including the animal mortality into the UIUC AD feedstock protocol is worth exploring. Currently, commercial rendering facilities are incorporating unsalable organic materials (i.e. animal carcasses) into the energy yield of their AD systems. Therefore, evidence suggests that there is a market, and process designs are in place to accommodate the absorption of animal carcasses into an AD system's energy production balance.

Moving the organic waste of various animals from UIUC's research facilities is a sensitive matter, and the bio-security of each individual facility is a major concern. It is essential to maintain individual animal population health. The transfer of dangerous pathogens can result from any transport activity between facilities, as well as other sources not related to the digester effort on the transportation route. The trucking option will require dedicated trucks in order to minimize contamination risks. Commercial AD systems use extensive hot water spray zones.

These might be a plausible solution, but they will add time, labor, and additional infrastructure costs for each loading and unloading cycle.

Utilizing vehicles to move the organic material to the digester site exposes all of the animal facilities to the possibility of dangerous pathogen exposure. Implementing a truck-based system of material delivery will require a major change in the operations of all of the facilities. For example, spray-sanitizing stations or tire washes may need to be installed at each facility. Reaching sufficient stakeholder agreement for reducing or eliminating cross-contamination would be challenging. The implementation of the truck-based transportation model requires a significant yearly operating expense for labor, fuel and maintenance. Trucking is used more often in the commercial sectors where source collection locations and routes may change. In the campus environment, it is unlikely that the residence halls will be abruptly relocated, moved or closed. The stability of the organic waste creation sources and sites coincides more with a sewer investment collection option.

The economic trade-offs of trucking versus pipeline collection are the expected up-front NRE (Non-Reoccurring Engineering for capital projects design) for capital infrastructure investment and lower operating costs versus lower capital investment and higher operational costs. This high level study will illustrate the options, but each option will need to be reexamined after a project layout has been defined.

Capital costs for the trucking option are greater than they would be for a commercial effort. More attention must be given to the aforementioned biohazards. In order to operate in a safe and preventative manner, it is likely that the trucking option will require “truck washes” to disinfect the vehicles upon entry and exit of each facility, in addition to training the sanitation personnel and training the vehicle operators. Also, the disposal of the residual chemical disinfectant may require an additional storage facility and government permitting and authorization.

Transport of the substrate material using a dedicated pipeline should be considered as a potentially more economically attractive transport design model. Bio-security concerns would be dramatically reduced and might even be eliminated. No vehicles containing potentially pathogen-laden material would contaminate the site. There would be fewer concerns about diesel and exhaust fumes. The COW line option would lower the carbon footprint on an ongoing basis. The pipeline would require an initial higher CAPEX investment to build, however. But, it would not be subject to the disruptions in service associated with seasonal weather changes. Also, the pipeline’s carbon intensity is likely to be much lower than collection by vehicles burning fuel.

Pumped Pipeline Waste Delivery

Overview

This scenario will assume that each of the six major waste-producing farm locations will be connected via an underground pipeline Campus Organics Waste line (COW line) that will be used to pump the slurry from five of these locations to the sixth location where the digester resides. When comparing these two scenarios, it will also be assumed the temporary waste collection method (e.g., scraping procedure, holding tank, etc.) at each individual site will be the same for both scenarios.

Additionally, there are six farm locations where a majority of the digestate will be sourced. Therefore, under the second collection scenario COW line, each of the locations will be analyzed with regard to pumping equipment and infrastructure cost differences between locations. This analysis will be factored in to the recommendation for digester site location. Since all of the other sites (food waste, horse farm, etc.) will be manually collected via vacuum truck in both scenarios, there are no comparisons made between these sites.

Each location would have a dedicated pumping station designed to pump the slurry from the holding tank to the digester location once every specified number of days. The number of days between each pumping would be dependent on a standardized UIUC process, or simply based on the holding capacity of installed holding tanks. It is assumed that the size of the holding tank would be the same as in scenario #1. Rather than a vacuum truck, each tank would utilize a vertical slurry pump to extract the slurry from the tank, along with base mounted centrifugal pumps in a series, to provide the pressure necessary to transport the slurry through the pipeline to the digester location. Each centrifugal pump would have a bypass, and the pumps would be installed so that they provide N+1 redundancy.

With regard to the actual operation of these pumps, the pumping from each site will be intermittent and strategically staged; for example, two sites would not be pumping simultaneously through the shared COW line. The waste traveling through the pipeline would be directed toward the digester location via opening and closing 2-position control valves. The location of the farm site currently pumping its waste would dictate which valves are open and which are closed.

Once the waste holding tank is emptied past a certain level, the pump would then switch over to pumping water through the pipeline to "flush" the pipeline system out, to prevent solids from settling in the pipe. The duration of the water flush would be controlled by a pipeline volume calculation from each site, water quality sensor at the digester site, or manually controlled by an individual at the digester site observing the slurry content at the COW line exit.

Below is a summary of the approximate pump requirements that would be needed, based on digester location, along with general specifications and requirements for the associated infrastructure.

General Pump Requirements

Site A - Digester Located At Dairy Facility:
ISRL Swine Facility - 800 GPM @ 300 Ft. H_2O
SRC Swine Facility - 800 GPM @ 300 Ft. H_2O
Grein Farm - 800 GPM @ 300 Ft. H_2O
Beef & Sheep - 800 GPM @ 400 Ft. H_2O
Poultry Facility - 800 GPM @ 400 Ft. H_2O

Site B - Digester Located At Grein Farm:
ISRL Swine Facility - 800 GPM @ 300 Ft. H_2O
Dairy Facility - 800 GPM @ 300 Ft. H_2O
SRC Swine Facility - 800 GPM @ 300 Ft. H_2O
Beef & Sheep - 800 GPM @ 300 Ft. H_2O
Poultry Facility - 800 GPM @ 300 Ft. H_2O

Site C - Digester Located At SRC Swine Facility:
ISRL Swine Facility - 800 GPM @ 375 Ft. H_2O
Dairy Facility - 800 GPM @ 300 Ft. H_2O
Grein Farm - 800 GPM @ 300 Ft. H_2O
Beef & Sheep - 800 GPM @ 300 Ft. H_2O
Poultry Facility - 800 GPM @ 300 Ft. H_2O

Site D - Digester Located At ISRL Swine Facility:
Dairy Facility - 800 GPM @ 300 Ft. H_2O
SRC Swine Facility - 800 GPM @ 375 Ft. H_2O
Grein Farm - 800 GPM @ 300 Ft. H_2O
Beef & Sheep - 800 GPM @ 500 Ft. H_2O
Poultry Facility - 800 GPM @ 500 Ft. H_2O

Site E - Digester Located At Beef & Sheep Facility:
ISRL Swine Facility - 800 GPM @ 500 Ft. H_2O
Dairy Facility - 800 GPM @ 400 Ft. H_2O
Grein Farm - 800 GPM @ 300 Ft. H_2O
SRC Swine Facility - 800 GPM @ 300 Ft. H_2O
Poultry Facility - 800 GPM @ 300 Ft. H_2O

Piping Design

Each of the five scenarios would require approximately 25,250 total feet of 8" PVC pipe. Pressure class 305 psi PVC pressure pipe with restrained joints would be used and installed underground with at least 3' of cover. A majority of the pipe installation would be under unpaved areas, with street crossings being the exception.

Control Valves

For each scenario, 11 - 8" PVC DDC Butterfly Control Valves

- Industrial grade
- Two position with end switches
- Pressure rating to match pipeline
- Control and power wiring run in underground conduit
- IP based controller at each building
- 4 new accessible manholes (10’ x 10’ x 6.5’) would be created at the valving location

A detailed cost estimate for the pumped pipeline scenario can be found in Appendix C. There would be little difference in cost among the five proposed digester sites, with the total cost for any site approximately $5.1 million.[7]

Collection Radius Review and Considerations

Using the physical locations of the relevant facilities, the approximate coordinates for longitude and latitude positions, and GIS (Geographic Information Systems) layers provided by AEI, a robust set of tables and maps to illustrate and highlight the prospective AD operations was created. These illustrations can be utilized as tools to aid in the initial planning for a truck routing system and COW line options. Trucking the material may prove to be an interim step for collection.

The available site location data from UIUC was used to determine the following collection radiuses. These radius tables reflect the distances between available feedstock materials and the proposed digester locations. The datasets and illustrations show that it would be more practical and economical to develop digester locations nearest the relevant farm locations. These illustrations are based upon 100% collection of the animal manure waste and collection of the food waste (33 weeks per year) with no losses.

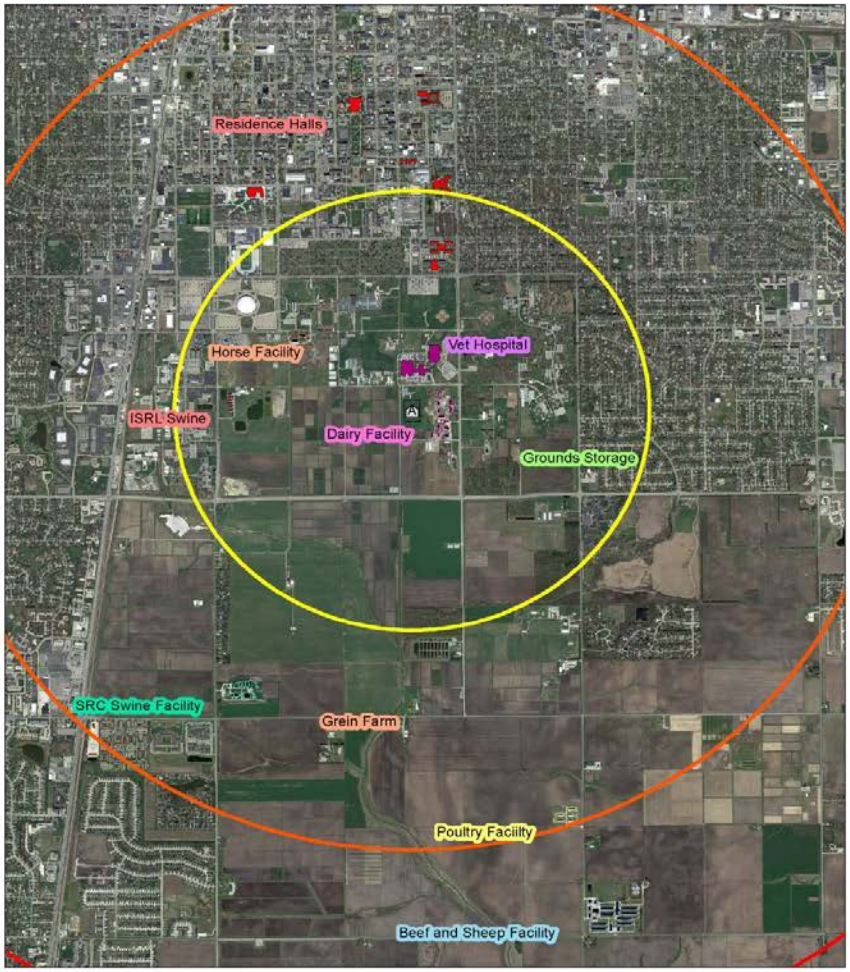
[7] This number represents construction cost only. For total project cost add 35-40%.

Table 6 - Collection Radius Review

Site Candidate ID	Proposed Digester Site Location	Within 1 mile radius of Site Candidate	Miles	Within 2 mile radius of Site Candidate	Miles	Within 3 mile radius of Site Candidate	Miles
Site A	**Dairy Facility/Vet Med Campus**	Grounds Storage	0.4	Busey-Evans (res halls)	1.0	Poultry Facility	2.0
		Florida Avenue (res halls)	0.6	Ikenberry Dining Hall (res halls)	1.1	Beef and Sheep Facility	2.5
		Horse Farm	0.6	Illinois Street (res halls)	1.3		
		Pennsylvania Avenue (res halls)	0.6	Illini Union (res halls)	1.3		
		ISRL Facility	0.8	Grein Farm	1.5		
		Lincoln Avenue (res halls)	0.9	SRC Facility	1.6		
Site B	**Grein Farm**	SRC Facility	0.7	Beef and Sheep Facility	1.2	Florida Avenue (res halls)	2.0
		Poultry Facility	0.8	Grounds Storage	1.2	Pennsylvania Avenue (res halls)	2.1
				Dairy Facility/Vet Center	1.5	Ikenberry Dining Hall (res halls)	2.4
				ISRL Facility	1.6	Lincoln Avenue (res halls)	2.4
				Horse Farm	1.8	Busey-Evans (res halls)	2.5
						Illini Union	2.8
						Illinois Street (res halls)	2.8

Site Candidate ID	Proposed Digester Site Location	Within 1 mile radius of Site Candidate	Miles	Within 2 mile radius of Site Candidate	Miles	Within 3 mile radius of Site Candidate	Miles
Site C	**SRC Swine Facility**	Grein Farm	0.7	ISRL Facility	1.4	Florida Avenue (res halls)	2.1
				Grounds Storage	1.5	Pennsylvania Avenue (res halls)	2.2
				Poultry Facility	1.5	Ikenberry Dining Hall (res halls)	2.3
				Dairy Facility/Vet Center	1.6	Lincoln Avenue (res halls)	2.5
				Horse Farm	1.6	Busey-Evans (res halls)	2.5
				Beef and Sheep Facility	1.8	Illini Union (res halls)	2.8
						Illinois Street (res halls)	2.9
Site D	**ISRL Swine Facility**	Horse Farm	0.4	Florida Avenue (res halls)	1.0	Poultry Facility	2.4
		Dairy Facility/Vet Center	0.8	Pennsylvania Avenue (res halls)	1.1	Beef and Sheep Facility	2.8
		Ikenberry Dining Hall (res halls)	0.9	Grounds Storage	1.1		
				Busey-Evans (res halls)	1.3		
				Lincoln Avenue (res halls)	1.3		
				SRC Facility	1.4		
				Illini Union	1.4		
				Illinois Street (res halls)	1.6		
				Grein Farm	1.6		
Site E	**Beef & Sheep Facility**	Poultry Facility	>.1	Dairy Facility/Vet Center	1.5	ISRL Facility	2.8
				SRC Facility	1.8	Horse Farm	2.8

All map documents were created with the use of ArcGIS 10.1. The projected coordinate system for all map documents is NAD 1983 State Plane Illinois East FIPS 1201.



Radial Analysis in Conjunction with Site Candidate A

Legend

- 1 mile radius
- 2 mile radius
- 3 mile radius

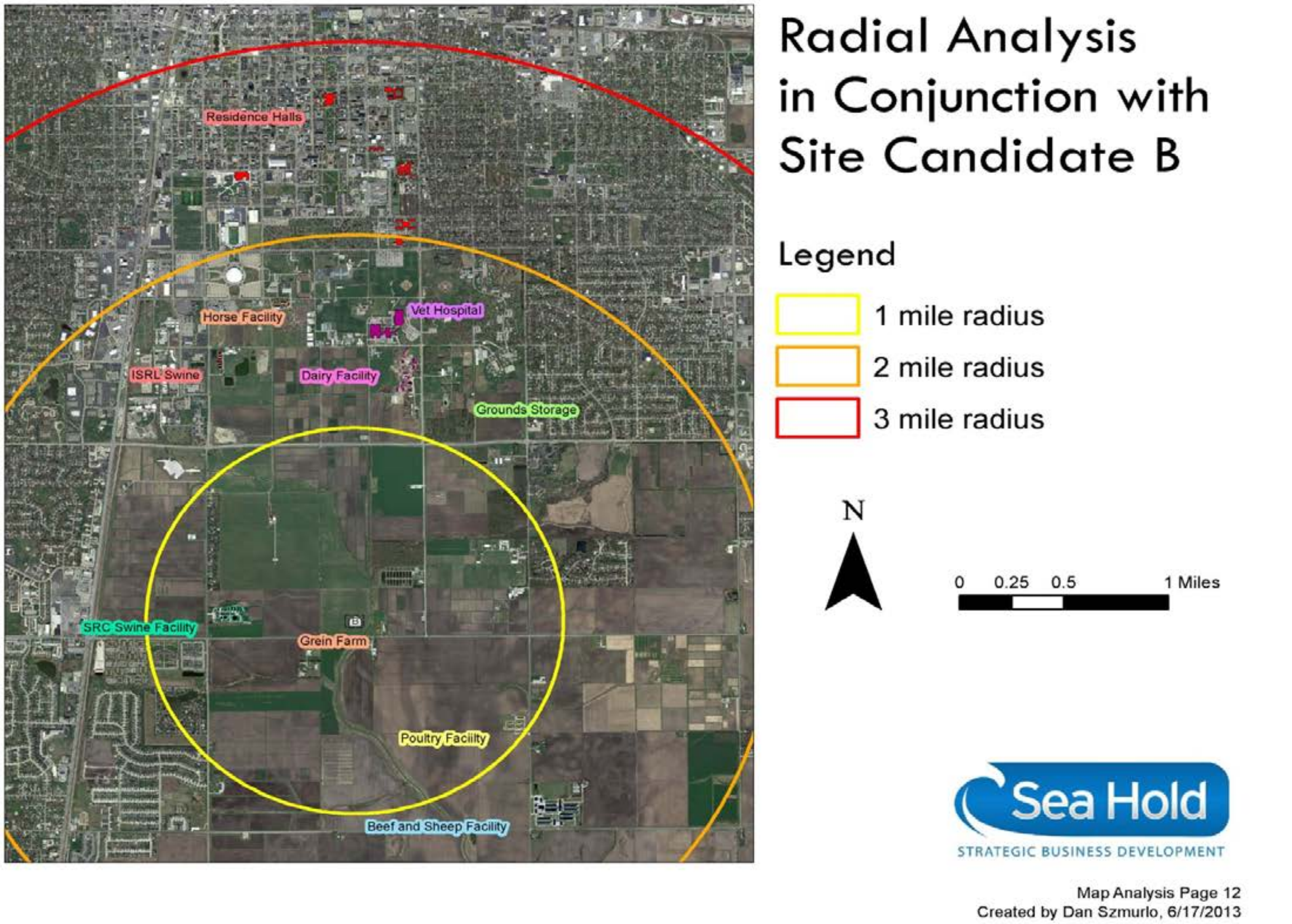
N

0 0.25 0.5 1 Miles

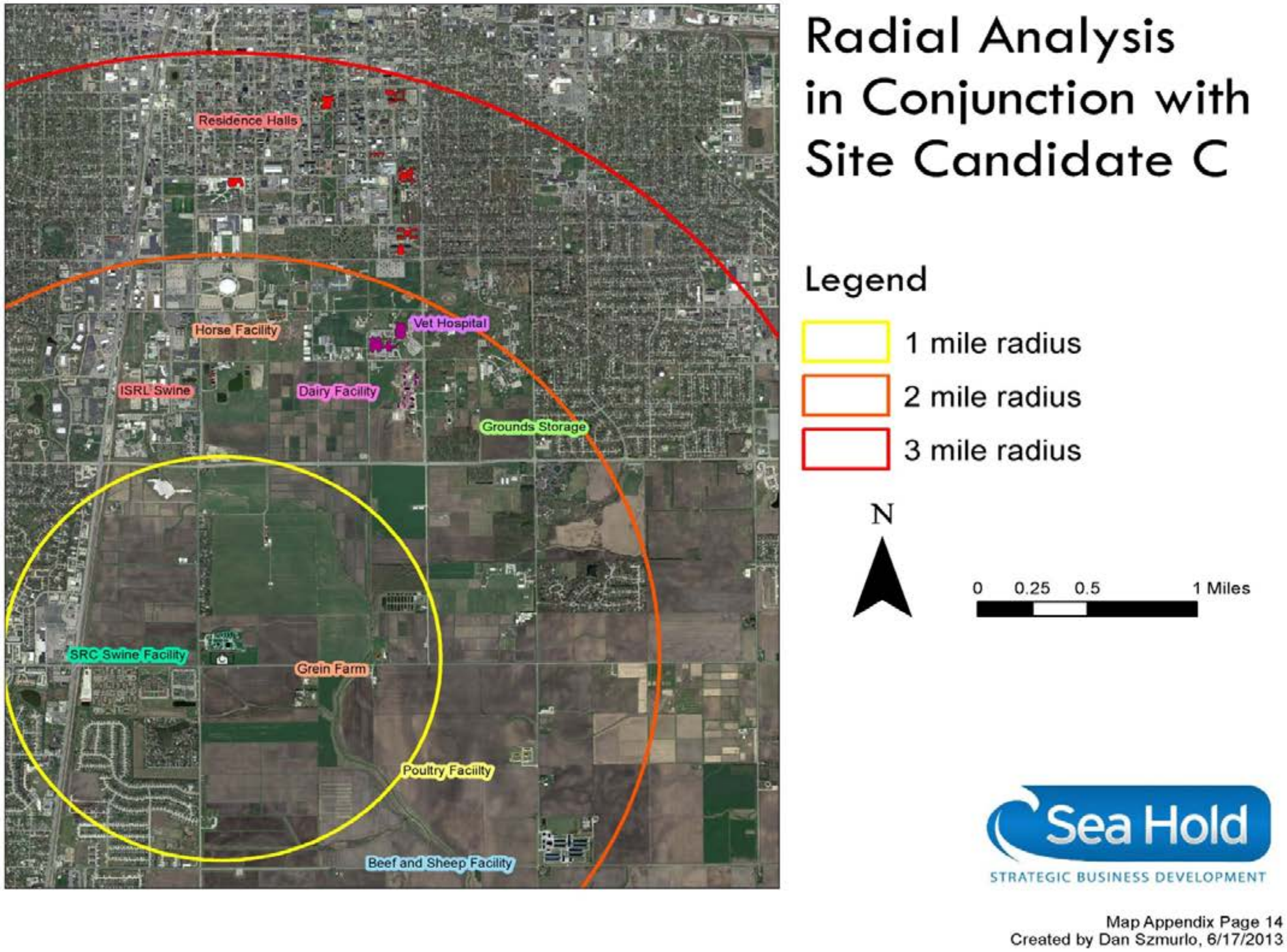
Sea Hold
STRATEGIC BUSINESS DEVELOPMENT

Map Appendix Page 10
Created by Dan Szmurlo, 6/17/2013

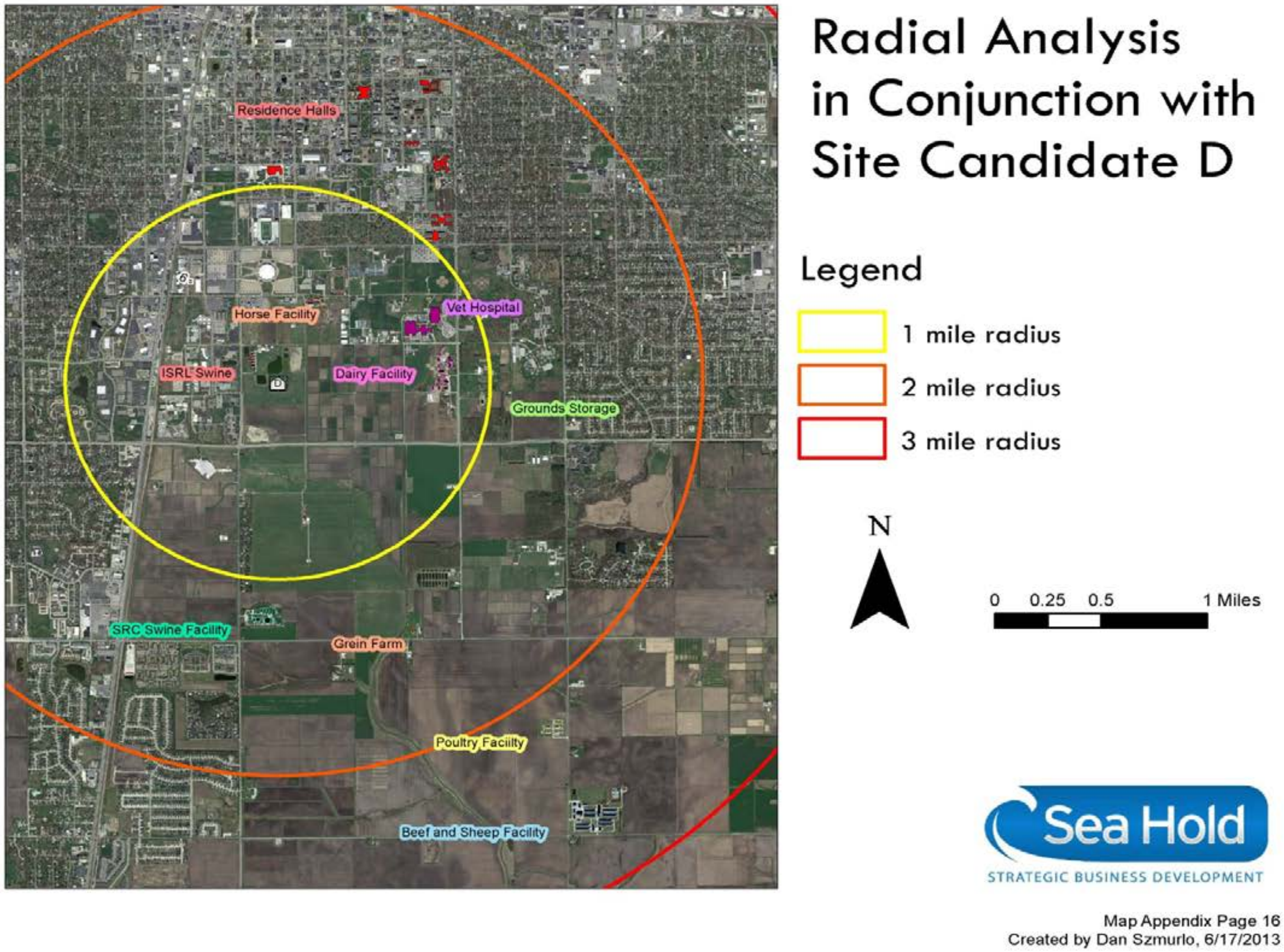
Dairy Facility / Vet Med Campus


Radial Analysis in Conjunction with Site Candidate B
Residence Halls
Horse Facility
Vet Hospital
ISRL Swine
Dairy Facility
Grounds Storage
SRC Swine Facility
Grein Farm
Poultry Facility
Beef and Sheep Facility
Legend
1 mile radius
2 mile radius
3 mile radius
N
0 0.25 0.5 1 Miles
Sea Hold
STRATEGIC BUSINESS DEVELOPMENT
Map Analysis Page 12
Created by Dan Szmurlo, 6/17/2013

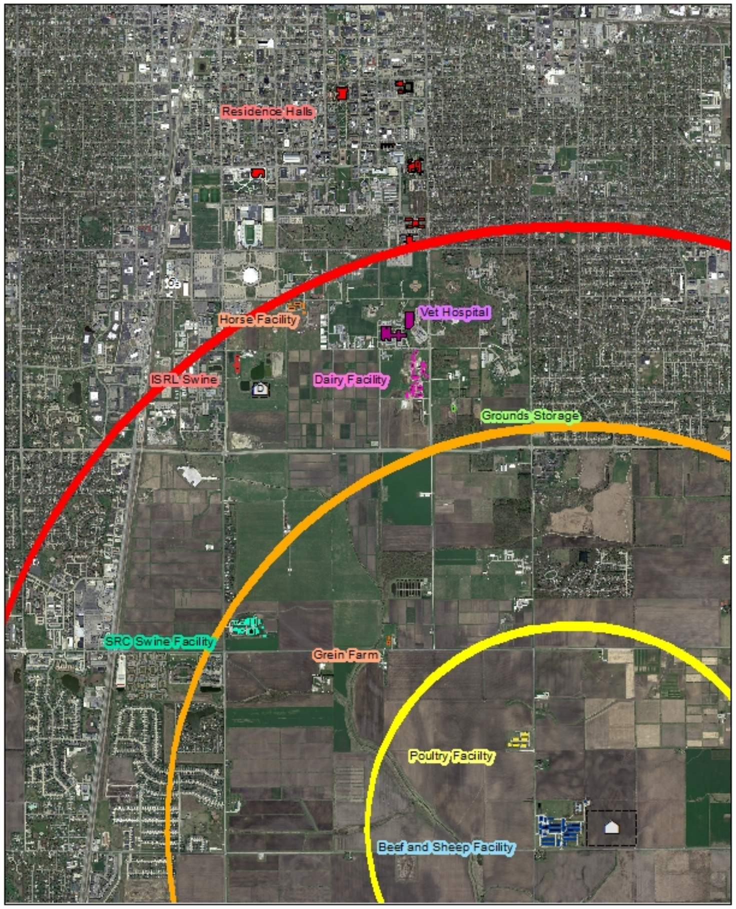
Grein Farm



SRC Swine Facility



ISRL Swine Facility



Radial Analysis in Conjunction with Site Candidate E

Legend

1 Mile Radius
2 Mile Radius
3 Mile Radius

N

0 0.25 0.5 1 Miles

STRATEGIC BUSINESS DEVELOPMENT

Map Appendix Page 17
Created by Dan Szmurlo, 2/07/2014

Beef and Sheep Facility

Environmental Attributes & Sustainability

Environmental Attributes

The environmental attributes and financial incentive opportunities associated with the proposed UIUC AD project are outlined below. It is important to keep in mind that the financial benefits and cost avoidance opportunities that may apply to the proposed AD project are contingent upon the organic waste material selected for use in the AD, the baseline waste methodology circumvented by the installation and operation of an anaerobic digester, and the gas production technology designed to utilize the AD-generated biogas. Methane capture from animal waste often yields “carbon credits,” which have economic value.

It would be essential to balance the environmental, energy, efficiency and educational goals of UIUC stakeholders when employing an AD system. Anaerobic digestion systems easily absorb student population growth and seasonality (the school year cycle), expansion of food crop farming efforts (additional vegetation waste), expansion of animal populations for research efforts, and energy crops for forage to feed animals or the digester. This would provide UIUC with options to address research and applications to achieve its carbon neutral goal. Diverting university campus organics has the potential to demonstrate best practices and solutions for integrating sustainability options. Balancing the investment and returns from an AD effort supports the entire campus community. The waste organics processed by an AD system are recycled and yield methane gas (for fuel) and soil amendments (improving soil till and nutrient balance for growing crops), which derive from the natural carbon cycle. The value-added products from AD systems provide a decreased dependence on fossil fuels and chemical fertilizers to support the campus community. The nutrient recovery (for farming), and the fuel and energy yields have the ability to support the project investment and address sustainability and the carbon neutrality goals. Our scope of work addresses the anticipated capital investment and operational costs. Diverting campus-generated organic waste will lead to balancing the overall mission and goals of UIUC’s iCAP program.

Carbon Credit Opportunities

The Climate Action Reserve (CAR), is a premier market-based GHG reduction program, operates a rigorous carbon-trading platform exclusively in the United States. The proposed UIUC AD project may be eligible to register for issuance of Climate Reserve Tonnes (CRT) through the Climate Action Registry. The CRTs awarded to an eligible AD project owner are saleable and can generate a financial benefit stream through the Climate Action Registry system or Voluntary carbon markets. The Table below identifies substrates where the proposed UIUC AD project may be eligible through CAR:

Table 7 - Climate Action Reserve CRT Eligibility Table

Climate Action Reserve CRT Eligibility Table		
Substrate	**Eligible**	**Ineligible**
Dairy Waste	X – eligible for the Livestock Protocol	
Swine Waste (SRC, ISRL, Greins Farm)	X – eligible for the Livestock Protocol	
Horse Waste		X
Beef and Sheep Waste		X
Poultry Waste		X
Food Waste (i.e. Dining Halls Waste)	X – eligible for the OWD protocol	
Veterinary Mortality Waste	*Unknown at this time*	
Grounds Waste		X

The calculation of the actual number of CRTs eligible for marketing is dependent upon the following factors: the registration and acceptance of the project, having the project "verified" to be certain it adheres to the standards of the eligibility protocol, and the issuance of the credits.

Waste-to-Energy Benefits

The UIUC has a commitment to sustainability. The benefits of using an AD to produce energy are well known and are compatible with the waste disposal needs of campus stakeholders. AD systems will help reduce waste volumes and produce biogas. For the University of Illinois at Urbana-Champaign, the ability to process animal waste from the horse, dairy, beef and sheep, swine and poultry facilities will provide solutions for numerous concerns. AD provides a reduction in overall odors, as well as a process for returning vital nutrients to the soil. The biogas produced can be used to provide "green" fuel and heat for the individual facility and UIUC's broader campus community. Using manure and its methane capture will allow the UIUC AD project to qualify for participation in various types of environmental attribute programs. Additionally, the AD process will generate valuable organic soil amendments that the crop farms at UIUC will be able to use, thus reducing fossil fuel derived nutrients. Dependence on chemical fertilizers and its associated cost will be reduced. And the solid fraction digestate material is a soil amendment that can be used in campus landscaping.

Anaerobic digesters produce a material after the gas is created - a mixture of solids suspended in a very thick liquid solution. This solution is rich in nutrients such as ammonia, phosphorus, and potassium, along with important trace elements. When treated as a part of the AD process, the solution is weed-, seed- and pathogen-free. A value-added byproduct, the solution is a soil conditioner used as compost or an amendment to the soil. Post AD processing provides stable and odor free compost, which can be stored without the issues associated with raw manure. The compost will not attract flies, rodents or the attention of neighbors.

When using an AD processing system, the organic nitrogen in the manure converts to ammonium. It is this ammonium that is available for uptake by plants. As a dried product, it is easily stored and applied as a fertilizer. The remaining “digester fiber” (fibrous solids) can be used as an ingredient in fiberboard and other composite materials.

High quality compost allows farmers and other users to decrease their reliance upon petrochemical sources of fertilizers and nutrients, at a significantly reduced cost. Excess heat from the AD and processing of biogas can be used for heating and drying materials and digestate.

The digester process, when operated properly, converts most of the odor-causing volatile acids to biogas. This reduces the noxious smells and complaints generated by traditional solid or liquid storage practices.

AD systems reduce the potential for surface and ground water contamination. These nutrients move into the digester’s effluent, and then into the resulting compost product, thus reducing the potential for water pollution. As a result, compost generated as a byproduct of AD contributes beneficial, stable and balanced nutrients when applied to soil.

Using an AD system allows the potential methane gas to be effectively captured and channeled. This fuel can be used to replace fossil fuels and helps to reduce climate change. The carbon from this natural methane is recycled and is part of the natural carbon cycle of plants and consumption by animals and humans. There is potential for UIUC to earn methane capture credits - a potential source of financial benefit for improving organic waste management practices.

All of the various biogas options have “soft costs/benefits”.

Biogas Option	Environmental and Public Perception Advantages	Environmental and Public Perception Disadvantages	Soft Benefits (in addition to CAPEX)	Soft Costs (in addition to CAPEX)
Flare	• Reduction of methane emissions from campus animal waste facilities	• No production of renewable energy • Could be perceived as waste of gas by students and public • Environmental impact of gas flaring not well understood by public		• No financial benefit besides avoided tipping fees
Internal Combustion Engine	• Reduction of methane emissions from campus facilities • Reduction of coal usage to provide electricity to campus buildings, resulting in reduction in CO_2,SO_2, NOx, and mercury emissions	• Undesirable emissions from burning of raw biogas (although not well known by public and relatively less intensive than coal emissions) • Low public and media exposure	• Decreased coal expenditures	• Quarterly to monthly oil replacement and labor charges • Breakers • Disposal of petrochemicals • Noise levels

Biogas Option	Environmental and Public Perception Advantages	Environmental and Public Perception Disadvantages	Soft Benefits (in addition to CAPEX)	Soft Costs (in addition to CAPEX)
Micro Turbine Fuel Cell	• Reduction of methane emissions from campus facilities • Reduction of coal usage to provide electricity to campus buildings, resulting in reduction in CO_2,SO_2, NOx, and mercury emissions	• Low public and media exposure	• Decreased coal expenditures	• Quarterly to monthly oil replacement and labor charges • Breakers • Disposal of petrochemicals
Natural Gas Pipeline Injection	• Reduction of methane emissions from campus facilities • Production of renewable natural gas to be supplied to campus or third party • High public and media exposure • CO_2 tail gas can be fed to ethanol-producing algae	• If gas is sold to a third party, negative public opinion could form – “Is University in the education business or the energy production business?”	• Decreased gas utility expenditures or generated gas profits • Increased ethanol production when used with algae	• Gas testing costs

Biogas Option	Environmental and Public Perception Advantages	Environmental and Public Perception Disadvantages	Soft Benefits (in addition to CAPEX)	Soft Costs (in addition to CAPEX)
Compressed Natural Gas	• Reduction of methane emissions from campus facilities • Production of clean renewable fuel for campus buses and trucks • High public and media exposure (advertise on buses) • CO_2 tail gas can be fed to ethanol-producing algae		• High potential for technology and financial partnership with third party • High potential for further research and student participation opportunities • Increased ethanol production	• Vehicle conversion costs • Vehicle advertisement costs
Liquefied Natural Gas	• Reduction of methane emissions from campus facilities • Production of renewable natural gas to be supplied to campus or third party • CO_2 tail gas can be fed to ethanol-producing algae		• High potential for technology and financial partnership with third party • High potential for further research and student participation opportunities • Increased ethanol production when used with algae	

Environmental Permitting Considerations

Suitability and Permissibility Research

An accurate delineation of the AD project's timeline is essential to project reliable capital and operational investment costs. Initially, the potential environmental regulatory framework and permitting requirements must be identified. Therefore, this segment of the feasibility report discusses the major local, state, and federal regulatory and permitting issues likely to impact the development of an anaerobic digester on the UIUC campus. It is important to note that the scope of this report reflects a general overview of potential permitting time frames, regulatory guidelines, and fee structures. Specific permits, time tables, and associated fees are dependent upon the selection of specific design models.

Municipal/County Level Environmental Permitting Structure

The requirement of a land pollution control permit and/or a local siting permit is contingent upon whether or not the developers of the proposed UIUC AD project decide to accept feedstock originating from external (i.e. off-campus) sources or if the end use of by-products generated from a campus-community digester are sent off-campus. If local siting and/or land pollution control permits would be required, then the Safety and Compliance division at UIUC recommends that the project developers build 30 to 180 days into the project development period for pre-application preparation meetings and relevant signature approvals. In addition, it is likely that the proposed AD project will be categorized as a solid waste facility or composting facility.

If local siting is required, the UIUC Safety and Compliance office specified that it may take up to 90 days per permit for siting application approval. In addition to other local siting application materials, the proposed AD project developers would also be required to conduct a formal public notice and hearing, which might take up to 90-180 days beyond the six month local siting application period. The cost of a public hearing process is estimated at \$10,000 to \$40,000.[8]

State Level Environmental Permits and Regulatory Compliance Matters

The Illinois Environmental Protection Agency anticipates that an UIUC AD project will require permitting that reflects compliance with the Illinois Environmental Protection Act (IEPA). The 35 Ill. Adm. Codes 807 and 830 do apply for solid waste and composting facilities, respectively. Regardless of whether or not the proposed AD project developers decide to include organic waste collected from external sources (e.g. organic waste from unaffiliated university local farms, groceries, etc.), the proposed project will require approval from the Illinois Environmental Protection Agency's land, air, and water bureaus. According to the UIUC Safety and Compliance office, the Illinois Environmental Protection Agency bureaus can take up to 90 days to review the application materials. Upon issuance of the applicable environmental permits, construction of the AD project may commence. After the construction of the AD plant is completed, the project developers must apply for an operational/occupancy permit, which can

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8 Per personal communication with Illinois Environmental Protection Agency Air Bureau Engineer Bob Smet, a public hearing can cost between \$10,000 and \$40,000 to conduct. (Personal Communication, May 22nd, 2013).

take up to 45 days to review before issuance and subsequent AD plant operation may commence.

The UIUC Safety and Compliance office will review the applications for completeness, obtain the appropriate university signatures, and submit all applications to local, state, and federal regulatory bodies.

Illinois Environmental Protection Agency Air Bureau Permitting

As a separate body corporate and politic of the State of Illinois, it has long been well established that the University is not subject to city codes and ordinances."[9] The University of Illinois Urbana-Champaign Facilities and Services Department has a Safety and Compliance division, which acts as a liaison between UIUC and relevant regulatory agencies. Due to the size and scope of the proposed UIUC AD project, it is highly probable that the Illinois Environmental Protection Agency will require environmental permits that meet local, state, and federal air, water, and land codes

The Illinois Environmental Protection Agency's Air Bureau requires permitting for total potential emissions generated by the proposed AD project. The complexity and time period associated with issuance of an air permit is contingent upon the technology the proposed AD developers select for the UIUC AD plant, and the cost associated with the necessary air permits will likely range between $10,000 and $20,000. For example, if the UIUC project developers select to incorporate a combined heat and power (CHP) engine system to generate electricity, the emissions off-take will be higher than if a genset system, fuel cell technology option, or the purchase of a gas upgrading unit, that allows the biogas to be purified and used for Biomethane through pipeline injection, were selected.

According to the Illinois Environmental Protection Agency's Air Bureau, it is imperative that the UIUC total campus emissions remain below the Illinois "New Source Review/Prevention of Significant Deterioration (PSD) trigger limits" -

- Below 40 tons per NO_X (oxides of nitrogen)
- Below 100 tons per CO (Carbon Monoxide)
- Below 40 tons per SO_X (oxides of sulfur)
- Below 75,000 tons per GHG (Green House Gas)

In addition to the potential emissions from heat combustion, the proposed AD project must also consider the potential emissions produced from an installed flare. Although routine flaring is not anticipated, a flare will be installed as a precaution in the unlikely event that an installed turbine or gas engine used to generate electricity malfunctions, and the gas in the anaerobic digester must be eliminated by means of a flare.

Regardless, the Illinois Air Bureau must verify that the potential total campus emissions from a flare do not exceed any individual pollutant or total GHG emission listed in the above specified

[9] Per UI Legal Counsel

thresholds. Based on the threshold limits, it is expected that the emissions produced from the proposed AD project will fall comfortably within compliance of Illinois regulatory parameters.

Illinois Environmental Protection Agency Land Bureau Permitting

If waste is accepted from off-site sources and/or by-products are distributed or taken off-campus, then the local siting approval and construction and operation permits discussed in the section on municipal and county level permitting and compliance structure will likely be required. However, except for the potential costs associated with fulfilling local siting requirements, there are no state level land bureau fees.

Illinois Environmental Protection Agency Water Bureau Permitting

In conjunction with any land construction permit requirements, the proposed AD project developers should anticipate applying for a Public Water Supply Construction Permit from the IEPA. The IEPA is allowed 90 days to review the construction permit application before issuing a permit to begin construction. After construction is complete, an IEPA Public Water Supply Operating Permit will be needed. Water samples will be required with the submission of the operating permit application. The IEPA is allowed an additional 90 day review time for water supply operating permit applications before issuing an operating permit. If the proposed AD project pumps 50,000 gallons or more per day of potable water, then the Illinois Environmental Protection Agency's Water Bureau will require additional permitting. However, it is unlikely that the proposed AD project will exceed the 50,000 gallons of water per day threshold. In addition to the potable water main connection, the proposed AD project developers will need to apply for and obtain a sanitary service connection through the Urbana-Champaign Sanitary District. The fee range for a sanitary service connection is $355 per population equivalent with a minimum fee of 3.5 PE ($1242.50). If the proposed AD project qualifies for an industrial waste water use permit, it is recommended that the industrial permit be obtained.

The Illinois Environmental Protection Agency's Water Bureau will require a Storm Water Pollution Prevention Plan (SWPPP). A SWPPP must be able to project the quantity of soil displacement that will transpire due to construction of the AD system and how that displacement will translate into specific volumes of any type of contamination into local water streams. SWPPP and NPDES permits are required if the area of soil disturbance is greater than 1 acre. The IEPA NPDES construction permit application must be submitted 30 days prior to soil disturbance.

If there will be any discharging to a local waterway, there will be additional permitting required by the NPDES. This is regardless of the classification of the discharge and end product or waste. Additionally, this will trigger land pollution control permits, local siting approval, and additional permit cost exposure.

Illinois Endangered Species Protection Act and the Illinois Natural Areas Preservation Act

An EcoCAT natural resource review should be initiated to assess the project's potential adverse effect on any Illinois endangered and threated species and sites listed on the Illinois Natural Areas Inventory.

Federal Level Environmental Permits and Compliance Regulations

The National Environmental Policy Act (NEPA) requires that federal agencies determine if a proposed action will significantly impact the environment and germane social and economic activities. However, unless federal funds are considered or the proposed AD project's emissions exceed national thresholds, federal level applications and permitting are not anticipated to apply to the UIUC AD project.

Economics

The focus has been on proven, well-documented and well-deployed conversion technology solutions. The final selection of any particular AD system and its technology and/or energy output is subject to its ability to meet the goals and capacities of UIUC campus participants. The overall financial investment of any project will be subject to stakeholder willingness to accommodate the challenges of an accounting or “costing” model for their organic waste management needs. The direct cost savings and/or cost avoidance for an installed campus AD system is to lower the amount of effluent transported to the local sanitary district. Facilities discharging to the sanitary district lines incur a charge to UIUC. For the AD operations using fresh water, there may be sewer fees built into the fresh water delivery charge. The food waste and other organics not disposed of via trucks and landfill now become another source of “cost” savings to support the cost of the digester. If the AD system’s residual water fraction exceeds the existing irrigation ponds’ capacity, then new “ponds” or discharge solutions will be needed. The only charge for storing the water fraction will be additional ponds, if needed, and/or pumping costs for delivery. If the AD system process produces excess water beyond the needs of campus landscape and crop irrigation needs, then sanitary district discharge is likely. If the storm sewer system is able to accommodate the post-digestion water fraction, then there may not be a charge. These steps require further investigation. Once a system has been designed and engineered, the water balance will be determined.

CAPEX Summary and Equipment List

High level capital cost estimates are driven by the options, which include selection of technology, collection, and the organic waste processing paths. These estimates are presented as investment scenarios. In order to increase revenue and return on investment, the AD system must generate value-added benefits via processing and advancement in infrastructure. The capital costs and investment estimates may include a contingency for soft costs, as well as some nuanced costs that are difficult to estimate at this high level. The infrastructure estimates are likely to be greater than their actual costs, because the quotes provided by suppliers and vendors did not take specific technology and design preferences into account. As AD plant design, technology, and infrastructure decisions are made, the estimated investment costs can be determined.

Several design paths and alternative technologies are presented in this study. Further analysis of numerous project elements is also recommended. In order to incorporate UIUC’s total waste production, it may be worth considering a “dry” fermentation of MSW (garbage combined with mixed organics). Using the organic waste-to-energy process as a platform for interdisciplinary educational opportunities and the advancement of state-of-the-art AD applications may also be a valuable residual of the AD effort.

Interestingly, very few universities have campus AD systems, and even fewer have taken advantage of the opportunity to incorporate an interdisciplinary approach in their broader educational missions. Although the development of a stand-alone AD system is a viable option, utilizing this project to expand UIUC’s scope in research and training in field agricultural sustainability practices is an excellent long-term educational enrichment opportunity for the UIUC community. University campuses and many other public and private sector agencies and organizations are currently exploring ways to reduce their carbon footprint with zero carbon emission goals. Therefore, advancements in this field are becoming more and more valuable as the U.S. improves its sustainable energy profile. Many aspects of these broader sustainability themes are represented in the AD process.

Our capital expenditure (CAPEX) recommendations are driven by the most economical model and comprise the lowest total cost to produce biogas for the highest return and lowest cost of ownership. The transportation fuel production path appears to return the highest value added product. The campus's natural gas infrastructure seems capable of accepting CNG fuel into the pipelines. Through meetings with the UIUC Utilities & Energy Service and Facilities and Services representatives, we have learned about the general pipeline system operation. Further study will be required to confirm whether the Biomethane volumes fall within the capacity limits, as well as to confirm the quality of the Biomethane. There is limited regional experience in natural pipeline injection practices and sales, because the required infrastructure is uncommon in the area. However, fracking efforts are expanding throughout the United States and into non-traditional fossil fuel energy-producing regions. Compared with other regions, UIUC's electrical rates are relatively low. Without a robust RPS (Renewable Portfolio Standard) to support higher demand and competitive pricing for electricity derived from organic sources (biogas), the economic case for using all of the biogas to generate electricity is weak. We suggest that an electrical production system be designed which allows for the AD project site to be "off" the grid and generate a sufficient parasitic heat load for the digester. An advantageous and novel solution would be to tie into the heat loads from other sources and use technologies, such as solar, thermal, and transfer, to heat the digester.

Our CAPEX cost and pricing estimates are based on the expert opinions of cutting edge, industry leaders. We also used and projected data from other campus digester developers. Project technology options and their corresponding capital equipment are included in these estimate figures. Not all technology options are available from multiple sources or in capacities that match the project. For example, there are only a few viable fuel cell suppliers, and some digester designs are patented (i.e., Plug Flow). Sources of organic substrate mixes and the resulting total solid (TS) content help to determine the most likely reactor technology and size. Choosing the "right" reactor design generally occurs after a dedicated recipe mix is selected. Due to the high probability that UIUC will utilize a co-digestion design method, the scope was narrowed to two prominent North American-based technology suppliers. Typically, the highest product yields for advanced co-digestion efforts are produced by the CSTR (Continuous Stirring Reactor) technology options. There are several different operating temperature ranges within this technology class. The project's capital costs have been estimated, using the 38,362 ton annual production figure identified through onsite interviews, and communications with the various campus stakeholders.

Capital Cost Estimate Table Overview

Technology and equipment estimates, based on information from industry experts and research, are listed in the table below for the following options:

- Anaerobic Digesters (Continuous Stir Tank Reactor)
- Standard Equipment (influent/effluent storage tanks, coarse fiber separation and storage, drying drum for effluent solids)
- Pasteurizer
- Additional Pre-Processing Equipment
- Truck Transportation Equipment
- Electricity Off-Take Options
- Gas Injection Off-Take Options
- Vehicle Fuel Off-Take Options

Note: The numbers below represent high-level budgetary estimates. The estimates below are based on the collected and summarized data regarding the available organics for processing. This total currently is 105 tons per day. This total assumes 100% collection efficiency of the waste streams, 365 days per year (33 weeks per year for food services)

Table 8 - Digester Options Estimates[10]

	CSTR Estimate	Typical Components	Comments
Digester	$8,125,000	Concrete tanks, pads, flexible cover, control mechanism	Creating biogas from the organic material
Standard Equipment	$1,063,000	Manure transportation, pre-processing equipment (solids/liquids separator), pumping and collection materials	Transportation and pre-processing of materials for digester
Biogas Fuel Use Equipment Estimates			
Flare	$30,000	These costs represent the total to procure and install the various biogas fuel options.	
ICE	$1,600,000		
Micro turbine	$3,750,000		
Turbine	$4,900,000		
Fuel Cell	$6,000,000		
CNG	$800,000		
LNG	$1,300,000		

[10] This number represents construction cost only. For total project cost, add 35-40%.

CAPEX Summary

Note: All figures, below, are estimated, approximate costs.[11]

The digester alone is estimated to cost $8.125 mil for a continuous stir tank (CSTR) system. Standard equipment, including influent and effluent storage tanks, coarse fiber separation and storage, and a drying drum for solid effluent, should cost $1,063,000. If the feedstock includes animal remains, a pasteurizer costing $300,000 will be necessary. Additional pre-processing equipment should add $400,000, and truck transport equipment should cost $160,000, although these numbers are not included in the CAPEX calculations. Flaring gas will not require additional equipment.

OPEX Summary

Based on experience, we have gauged operational expenditures to be 8% of capital expenditures (CAPEX) annually.

[11] This number represents construction cost only. For total cost, add 35-40%.

Some typical expenses associated with the operation of an anaerobic digester include:

Sample Item	**Anticipated Expenditure Items**
Vacuum Trucks	Engine maintenance (oil changes, tune up), periodic complete cleaning, servicing of vacuum system, disinfection
Wheel Wash	Spray head decalcification, pressure systems tests
COW line	High powered flushing to clear out, or high speed mechanical blade cleaning
Shed	Paint, repair (much of this is associated with weather based damage)
Macerator/Chopper	Tune up, sharpening of blades
Pre-Mix tank	Pump servicing (overhaul, bearings), calibration of mixers
Thickening pit	Pump servicing (overhaul, bearings) calibration of screens and mixers
Thickening pit pasteurizer	Periodic heat calibration, replacement burners
Pasteurizer (animal mortality waste)	Periodic heat calibration, replacement burners
Incoming feedstock pump	Pump maintenance (cleaning, lubing)
Digester	Inspection of construction integrity, inspection of discharge system, anticipated maintenance of mixers, heating elements and all connections, inspection and repair of flexible membrane
Information Technology	Configuration changes, equipment upgrades, software troubleshooting
Solids separation	Periodic maintenance of moving parts (grease, lube, sharpen)
Liquid separation	Periodic maintenance of moving parts (grease, lube, sharpen)

Summary of Technology Options including Construction Costs[12]

Fuel Use Option Flare	Construction Estimates	Construction Time	Permitting Time	Permitting Obstacles	Advantages	Disadvantages
CSTR Digester	$8,125,000	4-6 months once permitting is completed	90 to 180 days	Municipal/County/State Hearings & Reviews	Reduction of methane emissions on campus	No production of renewable energy
Standard Equipment	$1,063,000					
Flare	$30,000					
Sub Total	**$9,218,000**					
Fuel Use Option Micro Turbine	**Construction Estimates**	**Construction Time**	**Permitting Time**	**Permitting Obstacles**	**Advantages**	**Disadvantages**
CSTR Digester	$8,125,000	4-6 months once permitting is completed	90 to 180 days	Municipal/County/State Hearings & Reviews	Reduction of methane emissions on campus Efficient Power Production	Will require quarterly maintenance Low Public Understanding
Standard Equipment	$1,063,000					
Micro turbine	$3,750,000					
Sub-Total	**$12,938,000**					

12 The numbers in the table are construction cost estimates only. To estimate total project cost, add 35–40%.

Fuel Use Option Turbine	Construction Estimates	Construction Time	Permitting Time	Permitting Obstacles	Advantages	Disadvantages
CSTR Digester	$8,125,000	4-6 months once permitting is completed	90 to 180 days	Municipal/County/State Hearings & Reviews	Reduction of methane emissions on campus Efficient Power Production	Will require quarterly maintenance Low Public Understanding
Standard Equipment	$1,063,000					
Turbine	$4,900,000					
Sub-Total	**$14,088,000**					
Fuel Use Option ICE	**Construction Estimates**	**Construction Time**	**Permitting Time**	**Permitting Obstacles**	**Advantages**	**Disadvantages**
CSTR Digester	$8,125,000	4-6 months once permitting is completed	90 to 180 days	Municipal/County/State Hearings & Reviews	Reduction of methane emissions on campus Reduction of Coal usage Classic Electricity Production	Emissions Concerns
Standard Equipment	$1,063,000					
ICE	$1,600,000					
Sub-Total	**$10,788,000**					

Fuel Use Option CNG	**Construction Estimates**	**Construction Time**	**Permitting Time**	**Permitting Obstacles**	**Advantages**	**Disadvantages**
CSTR Digester	$8,125,000	4-6 months once permitting is completed	90 to 180 days 90 to 180 days	Municipal/County/State Hearings & Reviews	Reduction of methane emissions on campus Renewable Vehicle Fuel	Vehicle Conversion Costs
Standard Equipment	$1,063,000					
*CNG	$800,000					
Sub-Total	**$9,988,000**					

Fuel Use Option CNG	**Construction Estimates**	**Construction Time**	**Permitting Time**	**Permitting Obstacles**	**Advantages**	**Disadvantages**
CSTR Digester	$8,125,000	4-6 months once permitting is completed	90 to 180 days	Municipal/County/State Hearings & Reviews	Reduction of methane emissions on campus	Anticipated conversion of equipment
Standard Equipment	$1,063,000					
LNG	$1,300,000					
Sub-Total	**$10,488,000**					

Project Comparisons

Project	Feedstock	Daily Tons	Yearly Tons	#	Reactor Size Gallons	Use	Amount	Note	Cost
Vermont Technical College	Manure, energy crops, pre and post-consumer food waste	63	22995	2	1 EA 135,000 1 EA 410,000	Co-generation	2,8 million kWH	Electricity is sold to grid, heat is put back to campus; excess is flared	$4,000,000
Ohio State OBIC	Manure, food waste, fog	96	35000	1	1 EA 550,000	electricity	600 kW		$6,000,000
Michigan State University[13]	manure, food waste	47	17000	1	1 EA 450,000	Co-generation	2.8 million kWh	Electricity, heat to digester, eventually CNG	$5,000,000
Fiscalini	manure, whey, expired cheese, energy crop	100	36500	2	2 EA 860,000	Co-generation	710 kW	heat is used to heat digester, and cheese plant	$4,000,000
North State Rendering	Animal mortality waste, grease trap waste	100	36500	2	2 EA 244,500 1 EA 611,000	Co-generation	710 kW	Electricity, heat to digester, eventually CNG	$8,000,000

[13] http://www.meridian.mi.us/vertical/sites/%7B1800D46E-0900-43BD-B3FA-10A5660870B1%7D/uploads/MSU_AD_2013_Read-Only.pdf

Appendix A

Appendix A – Glossary

Abiotic: Having an absence of life or living organisms.

Aerobic: Life or biological processes that can occur only in the presence of oxygen.

Anaerobic: Life or biological processes that occur in the absence of oxygen.

Anaerobic digestion: A biochemical process by which organic matter is decomposed by bacteria in the absence of oxygen, producing methane and other byproducts.

Backup rate: A utility charge for providing occasional electricity service to replace on- site generation.

Backup electricity, backup services: Power or services needed occasionally, for example, when on-site generation equipment fails.

Baghouse: A chamber containing fabric filter bags that remove particles from furnace stack exhaust gases. Used to eliminate particles greater than 20 microns in diameter.

Barrel of oil equivalent: A unit of energy equal to the amount of energy contained in a barrel of crude oil. Approximately 5.78 million BTU or 1,700 KWH. A barrel is a liquid measure equal to 42 gallons.

Base load capacity: The power output that generating equipment can continuously produce.

Best available control technology (BACT): That combination of production processes, methods, systems, and techniques that will result in the lowest achievable level of emissions of air pollutants from a given facility. BACT is an emission limitation determined on a case- by-case basis by the permitting authority, taking into account energy, environmental, economic and other costs of control. BACT may include fuel cleaning or treatment or innovative fuel combustion techniques. Applies in attainment areas.

Best management practices: A practice or combination of practices that is determined by a designated agency to be the most effective, practical means of reducing the amount of pollution generated by diverse, varying sources to a level compatible with water quality goals.

Bioaccumulants: Substances in contaminated air, water or food that increase in concentration in living organisms exposed to them, because the substances are very slowly metabolized or excreted.

Biochemical conversion process: The use of living organisms or their products to convert organic material to fuels, chemicals or other products.

Biochemical oxygen demand (BOD): A standard means of estimating the degree of pollution of water supplies, especially those which receive contamination from sewage and industrial waste. BOD is the amount of oxygen needed by bacteria and other microorganisms to decompose organic matter in water. The greater the BOD, the greater the degree of pollution. Biochemical oxygen demand is a process that occurs over a period of time and is commonly measured for a five-day period, referred to as BOD5.

Bioenergy: Renewable energy made available from materials derived from biological sources.

Biogas: A combustible gas derived from decomposing biological waste. Biogas normally consists of 50 to 60 percent methane.

Biological oxidation: Decomposition of organic materials by microorganisms.

Biomass: Organic matter available on a renewable basis. Biomass includes forest and mill residues, agricultural crops and wastes, wood and wood wastes, animal wastes, livestock operation residues, aquatic plants, fast-growing trees and plants, and municipal and industrial wastes.

Biomass fuel: Liquid, solid or gaseous fuel produced by conversion of biomass.

Biomass energy: See Bioenergy.

Biomass Industrial Process Heat Facility: A facility which manufactures products, using biomass resources as the fuel to generate thermal energy for the manufacturing process.

Biotechnology: Technology that uses living organisms to produce products such as medicines, to improve plants or animals or to produce microorganisms for bioremediation.

BOD: See Biochemical oxygen demand.

Boiler horsepower: A measure of the maximum rate of heat energy output of a steam generator. One boiler horsepower equals 33,480 BTU/hr output in steam.

Boiler: Any device used to burn biomass fuel to heat water for generating steam.

Bone dry: Having zero percent moisture content. Biomass heated in an oven at a constant temperature of 212 degrees F or above, until its weight stabilizes, is considered bone dry or oven dry.

Bone dry ton: See Oven dry ton.

Bottom ash: Noncombustible ash that is left after solid fuel has been burned.

British thermal unit (BTU): A unit of heat energy equal to the heat needed to raise the temperature of one pound of water from 60 degrees F to 61 degrees F at one atmosphere pressure.

BTU: An abbreviation for British thermal units. The amount of heat that is required to raise one pound of water one degree Fahrenheit.

Capacity: The maximum power that a machine or system can produce or carry safely. The maximum instantaneous output of a resource under specified conditions. The capacity of generating equipment is generally expressed in kilowatts or megawatts.

Capacity factor: The ratio of the average load on a generating resource to its capacity rating during a specified period of time. Or the amount of energy that the system produces at a particular site as a percentage of the total amount that it would produce if it operated at rated capacity during the entire year.

Capital Cost: Cost of construction of a new plant (including equipment purchase, design, and engineering) and expenditures for the acquisition of existing facilities.

Capacity Price: The electricity price based on the cost associated with providing the capability to deliver energy, primarily the capital costs of facilities.

CFM: Cubic feet per minute.

Char: The remains of solid biomass that have been incompletely combusted, such as charcoal when wood is incompletely burned.

Cogeneration: The sequential production of electricity and useful thermal energy from a common fuel source. Reject heat from industrial processes can be used to power an electric generator (bottoming cycle). Conversely, surplus heat from an electric generating plant can be used for industrial purposes or space and water heating purposes (topping cycle).

Coli form bacteria: Bacteria whose presence in waste water is an indicator of pollution and of potentially dangerous contamination.

Combined cycle: Two or more generation processes in a series or in parallel, configured to optimize the energy output of the system.

Combined-cycle power plant: The combination of a gas turbine and a steam turbine in an electric generation plant. The waste heat from the gas turbine provides the heat energy for the steam turbine.

Combined heat and power (CHP): An older term for what is now generally called cogeneration. The term is currently used in Europe and other foreign countries.

Combustion: Burning. The transformation of biomass fuel into heat, chemicals, and gases through the chemical combination of hydrogen and carbon in the fuel with oxygen in the air.

Combustion gases: The gases released from a combustion process.

Combustion air: The air fed to a fire to provide oxygen for combustion of fuel. It may be preheated before injection into a furnace.

Condenser: A heat-transfer device that reduces fluid from a vapor phase to a liquid phase.

Conservation: Efficiency of energy use, production, transmission or distribution that results in a decrease of energy consumption while providing the same level of service.

Conveyor: A mechanical apparatus for carrying bulk material from place to place, for example, an endless moving belt or a chain of receptacles.

Cost-effective: A term describing a resource that is available within the time it is needed and is able to meet or reduce electrical power demand at an estimated incremental system cost no greater than that of the least-costly, similarly reliable and available alternative.

Cyclone separator: A device used to remove particulate matter suspended in exhaust gases.

Digester: An airtight vessel or enclosure in which bacteria decomposes biomass in water to produce biogas.

Discount rate: A rate used to convert future costs or benefits to their present value.

Discounting: A method of converting future dollars into present values, accounting for interest costs or forgone investment income. Used to convert a future payment into a value that is equivalent to a payment made in the present.

Distribution: The transfer of electricity from the transmission network to the consumer.

District heating or cooling: A system that involves the central production of hot water, steam or chilled water and the distribution of these transfer media to heat or cool buildings.

Downdraft Gasifier: A Gasifier in which the product gases pass through a combustion zone at the bottom of the Gasifier.

Dry Ton: 2,000 pounds of material dried to a constant weight.

Dutch oven furnace: One of the earliest types of furnaces, having a large, rectangular box lined with firebrick (refractory) on the sides and top. Commonly used for burning wood. Heat is stored in the refractory and radiated to a conical fuel pile in the center of the furnace.

Electrical horsepower: See Horsepower.

Emissions: Waste substances released into the air or water.

Energy: The ability to do work.

Energy Price: The electricity price based on the variable costs associated with the production of electric energy (kilowatt-hours).

Federal Water Pollution Control Act: A federal law administered by the states. The act created the National Pollution Discharge Elimination System.

Feedstock: Any material which is converted to another form or product.

Fine: A very small particle of material, such as very fine sander dust or very small pieces of bark.

Firm power (firm energy): Power which is guaranteed by the supplier to be available at all times during a period covered by a commitment. That portion of a customer's energy load for which service is assured by the utility provider.

Flow rate: The volume of water or gas that moves through an area (usually pipe) in a given period of time

Fluidized-bed boiler: A large, refractory-lined vessel with an air distribution member or plate in the bottom, a hot gas outlet in or near the top, and some provisions for introducing fuel. The fluidized bed is formed by blowing air up through a layer of inert particles (such as sand or limestone) at a rate that causes the particles to go into suspension and be in continuous motion. Extremely hot bed material increases combustion efficiency through its direct contact with the fuel.

Fly ash: Small ash particles carried in suspension in combustion products.

Fossil fuel: Solid, liquid or gaseous fuels formed in the ground after millions of years by chemical and physical changes in plant and animal residues under high temperature and pressure. Oil, natural gas, and coal are fossil fuels.

Fuel: Any material that can be converted to energy.

Fuel cell: A device that converts the energy of a fuel directly to electricity and heat, without combustion.

Fuel-cell furnace: A variation of the Dutch oven design that usually incorporates a primary and secondary combustion chamber (cell). The primary chamber is a vertical refractory-lined cylinder with a grate at the bottom in which combustion is partially completed. Combustion is completed in the secondary chamber.

Fuel handling system: A system for gathering fuel, transporting the fuel to a storage pile or bin, and conveying the fuel from storage to the boiler or other energy conversion equipment.

Furnace: An enclosed chamber or container used to burn biomass in a controlled manner to produce heat for space or process heating.

Gal/d: Gallons per day.

Gas engine: A piston engine that uses gaseous fuel rather than gasoline. Fuel and air are mixed before they enter cylinders; ignition occurs with a spark.

Gasification: A chemical or heat process to convert a solid fuel to a gaseous form.

Gasifier: A device for converting solid fuel into gaseous fuel. In biomass systems, the process is referred to as pyrolysis distillation. See Pyrolysis.

Generator: A machine used for converting rotating mechanical energy to electrical energy.

Grid: An electric utility's system for distributing power.

Grid connection: Joining a plant that generates electric power to a utility system so that electricity can flow in either direction between the utility system and the plant.

Gross heating value (GHV): The maximum potential energy in the fuel as received. It reflects the displacement of fiber by water present in the fuel. Expressed as: GHV = HHV (1 - MC / 100).

Hammermill: A device consisting of a rotating head with free-swinging hammers, which reduce chips or hogged fuel to a predetermined particle size through a perforated screen.

Heat Rate: The amount of fuel energy required by a power plant to produce one kilowatt-hour of electrical output. A measure of generating station thermal efficiency, generally expressed in BTU per net KWH. It is computed by dividing the total BTU content of fuel burned for electric generation by the resulting net KWH generation.

Heating value: The maximum amount of energy that is available from burning a substance.

Higher heating value (HHV): The maximum potential energy in dry fuel. For wood, the range is 7,600 to 9,600 BTU/lb.

Horsepower (Electrical horsepower; hp): A unit for measuring the rate of mechanical energy output. The term is usually applied to engines or electric motors to describe maximum output.
1 hp = 745.7 Watts = 0.746 KW = 2,545 BTU/hr.

hp: See Horsepower.

Hydraulic load: Amount of liquid going into a system.

Hydrocarbon: Any chemical compound containing hydrogen, oxygen, and carbon.

Inclined grate: A type of furnace in which fuel enters at the top part of a grate in a continuous ribbon, passes over the upper drying section where moisture is removed, and descends into the lower burning section. Ash is removed at the lower part of the grate.

Induction generator: A variable speed multi-pole electric generator.

Infiltration: Leakage of ground water or surface run-off into a manure collection system.

Influent: Waste water going into the anaerobic digester.

Interconnection: A connection or link between power systems that enables them to draw on one another's reserve in time of need.

Interruptible load: Loads that can be curtailed at the supplier's discretion or in accordance with a contractual agreement.

Investment tax credit: A specified percentage of the dollar amount of certain new investments that a company can deduct as a credit against its income tax bill.

Investor-owned utility (IOU): A private power company owned by and responsible to its shareholders and regulated by a public service commission.

Kilowatt (KW): A measure of electrical power equal to 1,000 Watts. 1 KW = 3,413 BTU/hr = 1.341 horsepower.

Kilowatt hour KWH): A measure of energy equivalent to the expenditure of one kilowatt for one hour. For example, 1 KWH will light a 100-watt light bulb for 10 hours. 1 KWH = 3,413 BTU.

KW: See Kilowatt.

KWH: See Kilowatt hour.

LAER: See lowest achievable emissions rate.

Leachates: Liquids percolated through waste piles. Leachates can include various minerals, organic matter or other contaminants and can contaminate surface water or ground water.

Levelized life-cycle cost: The present value of the cost of a resource, including capital, financing and operating costs, expressed as a stream of equal annual payments. This stream of payments can be converted to a unit cost of energy by dividing the annual payment amount by the annual kilowatt hours produced or saved. By levelizing costs, resources with different lifetimes and generating capabilities can be compared.

Life-cycle costing: A method of comparing costs of equipment or buildings based on original costs plus all operating and maintenance costs over the useful life of the equipment. Future costs are discounted.

Load factor: Load factor is the ratio of average demand to maximum demand or capacity.

Load: (1) The amount of electrical power required at a given point on a system. Or (2) the average demand on electrical equipment or on an electric system.

Lowest achievable emissions rate (LAER): Used to describe air emissions control technology. A rate of emissions defined by the permitting agency. LAER sets emission limits for non-attainment areas.

Management plan: A plan guiding overall management of an area administered by a federal or state agency. A management plan usually includes objectives, goals, standards and guidelines, management actions, and monitoring plans.

MCWB: See Moisture content, wet basis.

Megawatt (MW): The electrical unit of power that equals one million Watts (1,000 KW).

Mesophilic: An optimum temperature for bacterial growth in an enclosed digester (25 degrees to 40 degrees C).

Methane: An odorless, colorless, flammable gas with the formula CH_4, which is the primary constituent of natural gas.

Methanogen: microorganisms that produce methane as a metabolic byproduct in anoxic conditions. They are classified as archaea, a domain distinct from bacteria. They are common in wetlands, where they are responsible for marsh gas, and in the digestive tracts of animals such as ruminants and humans, where they are responsible for the methane content of belching in ruminants and flatulence in humans.

Mill/KWH: A common method of pricing electricity. Tenths of a cent per kilowatt hour.

Mill: A tenth of a cent ($0.001).

Mitigation: Steps taken to avoid or minimize negative environmental impacts. Mitigation can include: avoiding the impact by not taking a certain action; minimizing impacts by limiting the degree or magnitude of the action; rectifying the impact by repairing or restoring the affected environment; reducing the impact by protective steps required with the action; and compensating for the impact by replacing or providing substitute resources.

MMBTU: One million British thermal units.

Moisture content, wet basis: Moisture content expressed as a percentage of the weight of biomass produced.

Net present value: The sum of the costs and benefits of a project or activity. Future benefits and costs are discounted to account for interest costs.

Nitrogen fixation: The transformation of atmospheric nitrogen into nitrogen compounds that can be used by growing plants.

Nonutility Generator (NUG): An all-encompassing term for independent power producers.

Opacity: The degree to which smoke or particles emitted into the air reduces the transmission of light and obscures the view of an object in the background.

Organic: Derived from living organisms.

Oven dry: See Bone dry.

Oven dry ton (ODT): An amount of biomass that weighs 2,000 pounds at zero percent moisture content.

Particulate: A small, discrete mass of solid or liquid matter that remains individually dispersed in gas or liquid emissions. Particulates take the form of aerosol, dust, fume, mist, smoke or spray. Each of these forms has different properties.

Particulate emissions: Fine liquid or solid particles discharged with exhaust gases. Usually measured as grains per cubic foot or pounds per million BTU input.

pH: A measure of acidity or alkalinity. A pH of 7 represents neutrality. Acid substances have lower pH. Basic substances have higher pH.

Pound: Pound mass (sometimes abbreviated lb. (m)). A unit of mass equal to 0.454 kilograms.

Pound of steam: One pound mass of water converted to steam.

Power conversion factors: (Rate of flow of energy) - Watts=3.413 BTU/hr. KW=1,000 watts=1.341 horsepower=3413 BTU/hr. Horsepower=745.7 watts.

Present value: The worth of future receipts or costs expressed in current value. To obtain present value, an interest rate is used to discount future receipts or costs.

Process heat: Heat used in an industrial process rather than for space heating or other housekeeping purposes.

Producer gas: Fuel gas high in carbon monoxide (CO) and hydrogen (H_2), produced by burning a solid fuel with insufficient air or by passing a mixture of air and steam through a burning bed of solid fuel.

Psi: Pounds force of pressure per square inch.

Psig: Pounds force of pressure per square inch gauge (excluding atmospheric pressure).

Public utility commissions: State agencies that regulate investor-owned utilities operating in the state.

Pyrolysis: The thermal decomposition of biomass at high temperatures (greater than 400 degrees F or 200 degrees C) in the absence of air. The end product of pyrolysis is a mixture of solids (char), liquids (oxygenated oils), and gases (methane, carbon monoxide, and carbon dioxide) with proportions determined by operating temperature, pressure, oxygen content, and other conditions.

Quad: One quadrillion BTU (1015 BTU). An energy equivalent to approximately 172 million barrels of oil.

Rate schedule: A price list showing how the electric bill of a particular type of customer will be calculated by an electric utility company.

Recirculation: Returning a fraction of the effluent outflow to the inlet to dilute incoming wastewater.

Refractory Lining: A lining, usually of ceramic, capable of resisting and maintaining high temperatures.

Renewable energy resource: An energy resource replenished continuously or replaced after use through natural means. Sustainable energy. Renewable energy resources include bioenergy, solar energy, wind energy, geothermal power, and hydropower.

Return on investment (ROI): The interest rate at which the net present value of a project is zero. Multiple values are possible.

ROI: See Return on investment.

Saturated steam: Steam at the temperature that corresponds to its boiling temperature at the same pressure.

SCF: Standard cubic foot.

SCFM: Standard cubic foot per minute.

Shaft horsepower: A measure of the actual mechanical energy per unit time delivered to a turning shaft. 1 shaft horsepower = 1 electric horsepower = 550 ft-lb/second.

Slow pyrolysis: Thermal conversion of biomass to fuel by slow heating to less than 450 degrees C in the absence of oxygen.

Spreader stoker furnace: A furnace in which fuel is automatically or mechanically spread. Part of the fuel is burned in suspension. Large pieces fall on a grate.

Steam conversion factors: (approximations)
1 pound of steam = 1,000 BTU = .3 KW.
10,000 lbs/hr steam = 300 boiler horsepower.

Steam turbine: A device for converting energy of high-pressure steam (produced in a boiler) into mechanical power, which can then be used to generate electricity.

Stoichiometric condition: That condition at which the proportion of air-to-fuel is such that all combustible products will be completely burned with no oxygen remaining in the combustion air.

Sunk cost: A cost already incurred and therefore not considered in making a current investment decision.

Surplus electricity: Electricity produced by cogeneration equipment in excess of the needs of an associated factory or business.

Suspended solids: Waste particles suspended in water.

Therm: A unit of energy equal to 100,000 BTUs, used primarily for natural gas.

Thermal resource: A facility that produces electricity by using a heat engine to power an electric generator. The heat may be supplied by the combustion of coal, oil, natural gas, biomass or other fuels, including nuclear fission, solar or geothermal resources.

Thermochemical conversion process: Chemical reactions employing heat to produce fuels.

Total suspended particulates: All matter in solid or liquid form contained in a sample of air, regardless of the sample's particle size or chemical composition.

Transmission: The process of long-distance transport of electrical energy, generally accomplished by raising the electric current to high voltages.

Traveling grate: A type of furnace in which assembled links of grates are joined together in a perpetual belt arrangement. Fuel is fed in at one end and ash is discharged at the other.

TSP: See Total suspended particulates.

Turbine: A machine for converting the heat energy in steam or high temperature gas into mechanical energy. In a turbine, a high velocity flow of steam or gas passes through successive rows of radial blades fastened to a central shaft.

Turn down ratio: The lowest load at which a boiler will operate efficiently compared with the boiler's maximum design load.

Turnkey system: A system which is built, engineered, and installed to the point of readiness for operation by the owner.

Ultimate analysis: A description of a fuel's elemental composition as a percentage of the dry fuel weight.

VOC: See Volatile organic compounds.

Volatile organic compounds (VOC): Emissions of non-methane hydrocarbons, measured by standard methods.

Volatiles: Substances that are readily vaporized.

Waste streams: Unused solid or liquid by-products of a process.

Water-cooled vibrating grate: A boiler grate made up of a tuyere grate, surface- mounted on a grid of water tubes, interconnected with the boiler circulation system for positive cooling. The structure is supported by flexing plates, allowing the grid and grate to move in a vibrating action. Ashes are automatically discharged.

Watt: The common base unit of power in the metric system. One watt equals one joule per second, or the power developed in a circuit by a current of one ampere flowing through a potential difference of one volt. One Watt = 3.413 BTU/hr.

Wheeling: The process of transferring electrical energy between buyer and seller by way of an intermediate utility or utilities.

1 ft^3 = 28,316.80 ml
1 ft^3 gas = 28316.80 ml gas
1 ft^3 Methane (CH_4) = 1000 BTU
ft^3 = Cubic Foot
L = 1000 mL
mL = Milliliter
Ton (metric ton) = 2000 pounds

Biogas = $CH_4 + CO_2 + H_2S$ (Methane + Carbon Dioxide + Hydrogen Sulfide)
BMP = Biomethane Potential
BOD - Biological Oxygen Demand
BTU = British Thermal Unit (the heat required to raise the temperature of one pound of water by one degree Fahrenheit)
CH_4 = Methane
CO_2 = Carbon Dioxide
COD - Chemical Oxygen Demand
GGE = Gasoline Gallon Equivalents
H_2S = Hydrogen Sulfide
MMBTU = 1,000,000 British Thermal Units

COW Line = Campus Organic Waste line
Post-Consumer Food Waste = food that is left over on the food trays after eating
Pre-Consumer Food Waste = food waste generated from the preparation of various food items, spoiled food, outdated food, and overages from preparation
U/M = Unit of Measure

Note: All of the data for the projected organic material are expressed as conventional weights and not as BDT (bone dry tons).

Yearly available organics is calculated using confirmed stakeholder amounts (lbs/tons/gal) and is converted to tons.

Appendix B

Appendix B – SeaHold Sample Collection Protocol and Chain of Custody

SeaHold LLC collects samples using the following protocol:

As part of our routine collection process, we carry a number of supplies. These supplies include disposable gloves, a small bucket, a small "digger" type of shovel, "Nalgene" one-liter bottles, small screw top plastic containers, ice chest and ice, and Ziploc bags. We also carry collection logs, chain of custody logs, indelible markers, labels and various shipping forms (UPS and FedEx) for shipping samples to labs.

The collection of the samples occurs at various times during the day. The samples are collected from location sites, selected so the samples represent typical material that would be sent to an anaerobic digester.

Labels are affixed to the collection containers according to the schema identified.
The collector puts on disposable gloves.
The material sample is collected.
Manure samples are collected from locations typical of what would be fed to the digester.
Liquid manure samples are collected from locations typical of what would be fed to the digester.
The sample container is cleaned of excess material and bagged in a Ziploc, so the sample identification number is visible.
The unique number, physical location of the sample, time and date collected, and the source of the collection are recorded in the collection log.
The sample is placed in a pre-cooled ice chest. Additional ice is added to maintain a temperature not to exceed 58°F.

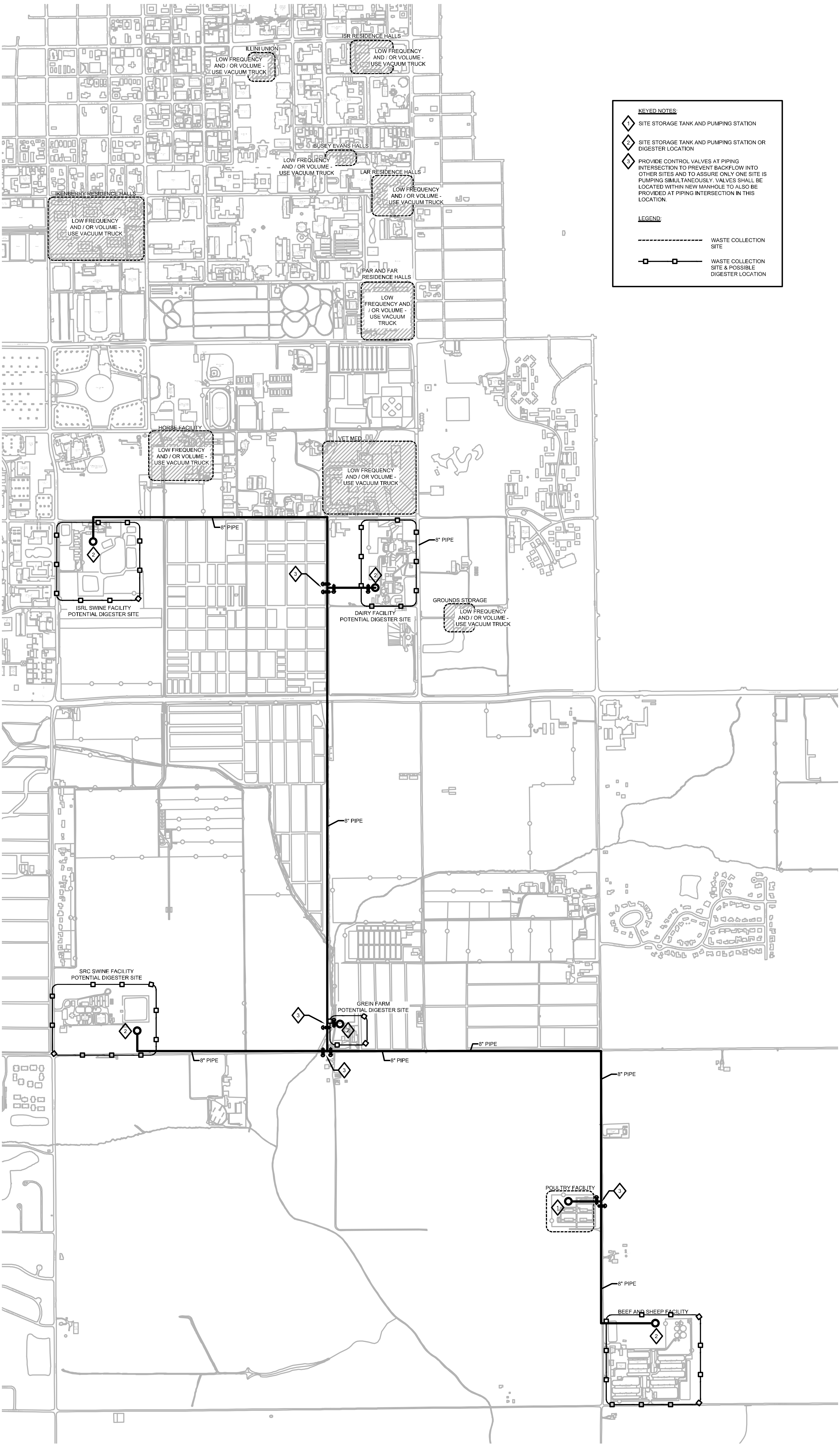
SeaHold LLC typically collects two samples of material in order to present a wider analysis profile, and reduce the degradation of the sample.

Photo 1 - Liquid Collection

Photo 2 - Solid Collection

Date/Time Collected	Collection Personnel	SeaHold ID#	Location Collected	Material Description	Testing Lab	Received By	Date/Time
2/25/2013 11:00am - 1:00pm	HP/TMH	UIUC-13001	Horse Farm	Horse Manure	UW Platteville	T. Zauche	3/1/2013
3/28/2013	Henry Hoehn	UIUC-13003	Dairy	Dairy Manure Solid	UW Platteville	T. Zauche	3/1/2013
2/26/13 7:30am - 9:30am	HP/TMH	UIUC-13005	ISRL Swine Facility	Swine Manure	UW Platteville	T. Zauche	3/1/2013
2/26/13 7:30am - 9:30am	HP/TMH	UIUC-13006	ISRL Swine Facility	Swine Manure	UW Platteville	T. Zauche	3/1/2013
2/26/13 10:30am - 12:30pm	HP/TMH	UIUC-13007	SRC Swine Facility Farrowing	Swine Manure	UW Platteville	T. Zauche	3/1/2013
2/26/13 10:30am - 12:30pm	HP/TMH	UIUC-13008	SRC Swine Facility Nursery	Swine Manure	UW Platteville	T. Zauche	3/1/2013
2/26/13 10:30am - 12:30pm	HP/TMH	UIUC-13009	SRC Swine Facility Finish	Swine Manure	UW Platteville	T. Zauche	3/1/2013
2/26/13 10:30am - 12:30pm	HP/TMH	UIUC-13010	SRC Swine Facility Manhole	Swine Manure	UW Platteville	T. Zauche	3/1/2013
2/26/13 12:30pm - 2:30pm	HP/TMH	UIUC-13011A	Beef & Sheep Facility	Beef & Sheep Manure	UW Platteville	T. Zauche	3/1/2013
2/27/13 6:30am - 7:30am	TMH	UIUC-13012	Poultry Facility	Poultry Manure	UW Platteville	T. Zauche	3/1/2013
2/26/13 12:30pm - 2:30pm	HP/TMH	UIUC-13013A	Beef & Sheep Facility	Beef & Sheep Manure	UW Platteville	T. Zauche	3/1/2013
3/28/2013	Henry Hoehn	UIUC-130115	Dairy	Dairy Manure Liquid	UW Platteville	T. Zauche	3/1/2013

Appendix C



1 **SCHEMATIC DIGESTER PIPING PLAN THROUGHOUT CAMPUS**

SCALE: 1" = 600'

University of Illinois - Urbana Champaign

Summary

South Farms

Anaerobic Digester Feasibility Study

AEI Project No. 12787-00
Estimate Date: 11-22-13 r1

Conceptual Cost Estimate (Construction Cost Only - Add 35 - 40% for Total Project Cost)

Description		Sub-Total Costs
Scenario #1 - Digester Located at ISRL Swine Facility Construction Cost	**$**	**5,117,000.00**
Scenario #2 - Digester Located at Dairy Facility Construction Cost	**$**	**5,131,000.00**
Scenario #3 - Digester Located at Grein Farm Construction Cost	**$**	**5,077,100.00**
Scenario #4 - Digester Located at SRC Swine Facility Construction Cost	**$**	**5,091,000.00**
Scenario #5 - Digester Located at Beef and Sheep Facility Construction Cost	**$**	**5,091,000.00**

University of Illinois - Urbana Champaign

Summary

South Farms

Anaerobic Digester Feasibility Study

AEI Project No. 12787-00
Estimate Date: 11-22-13 r1

Conceptual Cost Estimate

Description				Sub-Total Costs
Scenario #1 - Digester Located at ISRL Swine Facility				
Sanitary Piping - Direct Buried			$	4,231,200.00
Surface Demo & Site Restoration			$	490,800.00
Traffic and Pedestrian Control			$	131,400.00
Erosion Control			$	66,800.00
	Subtotal		**$**	**4,920,200.00**
	Subtotal Scenario #1 - Digester Located at ISRL Swine Facility Construction Cost		**$**	**4,920,200.00**
	General Conditions	4.0%	$	196,800.00
	Total Scenario #1 - Digester Located at ISRL Swine Facility Construction Cost		**$**	**5,117,000.00**

University of Illinois - Urbana Champaign

Summary

South Farms

Anaerobic Digester Feasibility Study

AEI Project No. 12787-00

Estimate Date: 11-22-13 r1

Conceptual Cost Estimate

Description			Sub-Total Costs
Scenario #2 - Digester Located at Dairy Facility			
Sanitary Piping - Direct Buried		$	4,244,700.00
Surface Demo & Site Restoration		$	490,800.00
Traffic and Pedestrian Control		$	131,400.00
Erosion Control		$	66,800.00
Subtotal		**$**	**4,933,700.00**
Subtotal Scenario #2 - Digester Located at Dairy Facility Construction Cost		**$**	**4,933,700.00**
General Conditions	4.0%	$	197,300.00
Total Scenario #2 - Digester Located at Dairy Facility Construction Cost		**$**	**5,131,000.00**

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Summary

South Farms

Anaerobic Digester Feasibility Study

AEI Project No. 12787-00
Estimate Date: 11-22-13 r1

Conceptual Cost Estimate

Description				Sub-Total Costs
Scenario #3 - Digester Located at Grein Farm				
Sanitary Piping - Direct Buried			$	4,217,800.00
Surface Demo & Site Restoration			$	490,800.00
Traffic and Pedestrian Control			$	106,400.00
Erosion Control			$	66,800.00
	Subtotal		**$**	**4,881,800.00**
	Subtotal Scenario #3 - Digester Located at Grein Farm Construction Cost		**$**	**4,881,800.00**
	General Conditions	4.0%	$	195,300.00
	Total Scenario #3 - Digester Located at Grein Farm Construction Cost		**$**	**5,077,100.00**

University of Illinois - Urbana Champaign **Summary**

South Farms

Anaerobic Digester Feasibility Study

AEI Project No. 12787-00

Estimate Date: 11-22-13 r1

Conceptual Cost Estimate

Description			Sub-Total Costs
Scenario #4 - Digester Located at SRC Swine Facility			
Sanitary Piping - Direct Buried		$	4,231,200.00
Surface Demo & Site Restoration		$	490,800.00
Traffic and Pedestrian Control		$	106,400.00
Erosion Control		$	66,800.00
Subtotal		**$**	**4,895,200.00**
Subtotal Scenario #4 - Digester Located at SRC Swine Facility Construction Cost		**$**	**4,895,200.00**
General Conditions	4.0%	$	195,800.00
Total Scenario #4 - Digester Located at SRC Swine Facility Construction Cost		**$**	**5,091,000.00**

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Summary

South Farms

Anaerobic Digester Feasibility Study

AEI Project No. 12787-00
Estimate Date: 11-22-13 r1

Conceptual Cost Estimate

Description			Sub-Total Costs
Scenario #5 - Digester Located at Beef and Sheep Facility			
Sanitary Piping - Direct Buried		$	4,231,200.00
Surface Demo & Site Restoration		$	490,800.00
Traffic and Pedestrian Control		$	106,400.00
Erosion Control		$	66,800.00
Subtotal		**$**	**4,895,200.00**
Subtotal Scenario #5 - Digester Located at Beef and Sheep Facility Construction Cost		**$**	**4,895,200.00**
General Conditions	4.0%	$	195,800.00
Total Scenario #5 - Digester Located at Beef and Sheep Facility Construction Cost		**$**	**5,091,000.00**

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Affiliated Engineers

University of Illinois - Urbana Champaign

Plumbing - Sanitary

South Farms
Anaerobic Digester Feasibility Study
AEI Project No. 12787-00
Estimate Date: 11-22-13 r1

Conceptual Cost Estimate

Description	Qty	Units	Unit Matl & Labor W/ O & P	Extended Matl & Labor W/ O & P
Scenario #1 - Digester Located at ISRL Swine Facility				
Sanitary Piping - Direct Buried			**Direct Bury Length**	**25,250**
Utility Locating				
Potholing	100	ea	$ 2,500.00	$ 250,000.00
Prefabricated Structures				
Precast Manhole - 10'x10'x6'-6" (inc. Excavation/Bedding/Rigging/Backfill)	4	ea	$ 10,000.00	$ 40,000.00
Sanitary Excavation/Shoring/Backfill				
Excavation	14962.96	cy	$ 20.00	$ 299,260
Dewatering	264	dy	$ 50.00	$ 13,200
Unsuitable Soil (25% of Excav.)	3740.74	cy	$ 15.00	$ 56,110
Stone Base - Bank Run	6312.50	tn	$ 19.65	$ 124,040
Backfill	7481.48	cy	$ 15.00	$ 112,220
Sanitary Piping				
8" SAN - Class 305 PVC	25,250	lf	$ 92.00	$ 2,323,000
Tracer Cable	25,250	lf	$ 0.65	$ 16,413
Warning Tape	25,250	lf	$ 0.11	$ 2,778
Sanitary Fittings and Valves				
8" SAN - Class 305 PVC 90°	5	ea	$ 380.00	$ 1,900
8" SAN - Class 305 PVC Tee	4	ea	$ 560.00	$ 2,240
8" SAN DDC Valve - PVC	10	ea	$ 2,135.00	$ 21,350
Flange/Restraint Connections	1	ls	$ 410,700.00	$ 410,700
Sanitary Pumps				
Dairy Facility - 800 gpm @ 300 ft Hd 75Hp ***(VFD included - Connection by EC)***	1	ea	$ 38,200.00	$ 38,200
SRC Swine Facility - 800 gpm @ 375 ft Hd 100Hp ***(VFD included - Connection by EC)***	1	ea	$ 48,800.00	$ 48,800
Grein Farm - 800 gpm @ 300 ft Hd 75Hp ***(VFD included - Connection by EC)***	1	ea	$ 38,200.00	$ 38,200
Beef and Sheep - 800 gpm @ 500 ft Hd 75Hp ***(VFD included - Connection by EC)***	1	ea	$ 38,200.00	$ 38,200
Poultry Facility - 800 gpm @ 500 ft Hd 75Hp ***(VFD included - Connection by EC)***	1	ea	$ 38,200.00	$ 38,200
Sanitary Pump Power				
75Hp VFD Connection	4	ea	$ 1,830.00	$ 7,320
1 1/2" RGS Conduit	1000	lf	$ 18.24	$ 18,240
3 - #1 THHN Copper Conductor	3300	lf.	$ 3.82	$ 12,606
1 - #6 THHN Copper Gropund	1100	lf	$ 1.65	$ 1,815
#1 Cable Terminations	48	ea	$ 29.32	$ 1,407
#6 Cable Terminations	16	ea	$ 21.65	$ 346
100Hp VFD Connection	1	ea	$ 2,055.00	$ 2,055
2" RGS Conduit	250	lf	$ 22.47	$ 5,618
3 - #2/0 THHN Copper Conductor	825	lf.	$ 5.57	$ 4,595
1 - #6 THHN Copper Gropund	275	lf	$ 1.65	$ 454
#2/0 Cable Terminations	12	ea	$ 40.65	$ 488
#6 Cable Terminations	4	ea	$ 21.65	$ 87
Additional Services/Factors				
Clean & Inspect Sanitary System	1	ls	$ 23,500.00	$ 23,500
Restricted Access Piping 15% of Subtotal	1	ls	$ 277,900.00	$ 277,900
			Subtotal Scenario #1 Sanitary Piping	**$ 4,231,200**
			Cost $/LF	**$ 167.57**
			Total Scenario #1 Sanitary Piping	**$ 4,231,200**

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University of Illinois - Urbana Champaign

Plumbing - Sanitary

South Farms

Anaerobic Digester Feasibility Study

AEI Project No. 12787-00
Estimate Date: 11-22-13 r1

Conceptual Cost Estimate

Description	Qty	Units	Unit Matl & Labor W/ O & P	Extended Matl & Labor W/ O & P
Scenario #2 - Digester Located at Dairy Facility				
Sanitary Piping - Direct Buried			**Direct Bury Length**	**25,250**
Utility Locating				
Potholing	100	ea	$ 2,500.00	$ 250,000.00
Prefabricated Structures				
Precast Manhole - 10'x10'x6'-6" (inc. Excavation/Bedding/Rigging/Backfill)	4	ea	$ 10,000.00	$ 40,000.00
Sanitary Excavation/Shoring/Backfill				
Excavation	14962.96	cy	$ 20.00	$ 299,260
Dewatering	264	dy	$ 50.00	$ 13,200
Unsuitable Soil (25% of Excav.)	3740.74	cy	$ 15.00	$ 56,110
Stone Base - Bank Run	6312.50	tn	$ 19.65	$ 124,040
Backfill	7481.48	cy	$ 15.00	$ 112,220
Sanitary Piping				
8" SAN - Class 305 PVC	25,250	lf	$ 92.00	$ 2,323,000
Tracer Cable	25,250	lf	$ 0.65	$ 16,413
Warning Tape	25,250	lf	$ 0.11	$ 2,778
Sanitary Fittings and Valves				
8" SAN - Class 305 PVC 90°	5	ea	$ 380.00	$ 1,900
8" SAN - Class 305 PVC Tee	4	ea	$ 560.00	$ 2,240
8" SAN DDC Valve - PVC	10	ea	$ 2,135.00	$ 21,350
Flange/Restraint Connections	1	ls	$ 410,700.00	$ 410,700
Sanitary Pumps				
ISRL Facility - 800 gpm @ 300 ft Hd 75Hp ***(VFD included - Connection by EC)***	1	ea	$ 38,200.00	$ 38,200
SRC Swine Facility - 800 gpm @ 300 ft Hd 75Hp ***(VFD included - Connection by EC)***	1	ea	$ 38,200.00	$ 38,200
Grein Farm - 800 gpm @ 300 ft Hd 75Hp ***(VFD included - Connection by EC)***	1	ea	$ 38,200.00	$ 38,200
Beef and Sheep - 800 gpm @ 400 ft Hd 100Hp ***(VFD included - Connection by EC)***	1	ea	$ 48,800.00	$ 48,800
Poultry Facility - 800 gpm @ 400 ft Hd 100Hp ***(VFD included - Connection by EC)***	1	ea	$ 48,800.00	$ 48,800
Sanitary Pump Power				
75Hp VFD Connection	3	ea	$ 1,830.00	$ 5,490
1 1/2" RGS Conduit	750	lf	$ 18.24	$ 13,680
3 - #1 THHN Copper Conductor	2475	lf.	$ 3.82	$ 9,455
1 - #6 THHN Copper Gropund	825	lf	$ 1.65	$ 1,361
#1 Cable Terminations	36	ea	$ 29.32	$ 1,056
#6 Cable Terminations	12	ea	$ 21.65	$ 260
100Hp VFD Connection	2	ea	$ 2,055.00	$ 4,110
2" RGS Conduit	500	lf	$ 22.47	$ 11,237
3 - #2/0 THHN Copper Conductor	1650	lf.	$ 5.57	$ 9,191
1 - #6 THHN Copper Gropund	550	lf	$ 1.65	$ 908
#2/0 Cable Terminations	24	ea	$ 40.65	$ 976
#6 Cable Terminations	8	ea	$ 21.65	$ 173
Additional Services/Factors				
Clean & Inspect Sanitary System	1	ls	$ 23,500.00	$ 23,500
Restricted Access Piping 15% of Subtotal	1	ls	$ 277,900.00	$ 277,900
			Subtotal Scenario #2 Sanitary Piping	**$ 4,244,700**
			Cost $/LF	**$ 168.11**
			Total Scenario #2 Sanitary Piping	**$ 4,244,700**

University of Illinois - Urbana Champaign

Plumbing - Sanitary

South Farms
Anaerobic Digester Feasibility Study
AEI Project No. 12787-00
Estimate Date: 11-22-13 r1

Conceptual Cost Estimate

Scenario #3 - Digester Located at Grein Farm
Sanitary Piping - Direct Buried

Description	Qty	Units		Unit Matl & Labor W/ O & P		Extended Matl & Labor W/ O & P
				Direct Bury Length		**25,250**
Utility Locating						
Potholing	100	ea	$	2,500.00	$	250,000.00
Prefabricated Structures						
Precast Manhole - 10'x10'x6'-6" (inc. Excavation/Bedding/Rigging/Backfill)	4	ea	$	10,000.00	$	40,000.00
Sanitary Excavation/Shoring/Backfill						
Excavation	14962.96	cy	$	20.00	$	299,260
Dewatering	264	dy	$	50.00	$	13,200
Unsuitable Soil (25% of Excav.)	3740.74	cy	$	15.00	$	56,110
Stone Base - Bank Run	6312.50	tn	$	19.65	$	124,040
Backfill	7481.48	cy	$	15.00	$	112,220
Sanitary Piping						
8" SAN - Class 305 PVC	25,250	lf	$	92.00	$	2,323,000
Tracer Cable	25,250	lf	$	0.65	$	16,413
Warning Tape	25,250	lf	$	0.11	$	2,778
Sanitary Fittings and Valves						
8" SAN - Class 305 PVC 90°	5	ea	$	380.00	$	1,900
8" SAN - Class 305 PVC Tee	4	ea	$	560.00	$	2,240
8" SAN DDC Valve - PVC	10	ea	$	2,135.00	$	21,350
Flange/Restraint Connections	1	ls	$	410,700.00	$	410,700
Sanitary Pumps						
ISRL Facility - 800 gpm @ 300 ft Hd 75Hp ***(VFD included - Connection by EC)***	1	ea	$	38,200.00	$	38,200
Dairy Facility - 800 gpm @ 300 ft Hd 75Hp ***(VFD included - Connection by EC)***	1	ea	$	38,200.00	$	38,200
SRC Swine Facility - 800 gpm @ 300 ft Hd 75Hp ***(VFD included - Connection by EC)***	1	ea	$	38,200.00	$	38,200
Beef and Sheep - 800 gpm @ 300 ft Hd 75Hp ***(VFD included - Connection by EC)***	1	ea	$	38,200.00	$	38,200
Poultry Facility - 800 gpm @ 300 ft Hd 75Hp ***(VFD included - Connection by EC)***	1	ea	$	38,200.00	$	38,200
Sanitary Pump Power						
75Hp VFD Connection	5	ea	$	1,830.00	$	9,150
1 1/2" RGS Conduit	1250	lf	$	18.24	$	22,800
3 - #1 THHN Copper Conductor	4125	lf.	$	3.82	$	15,758
1 - #6 THHN Copper Gropund	1375	lf	$	1.65	$	2,269
#1 Cable Terminations	60	ea	$	29.32	$	1,759
#6 Cable Terminations	20	ea	$	21.65	$	433
Additional Services/Factors						
Clean & Inspect Sanitary System	1	ls	$	23,500.00	$	23,500
Restricted Access Piping 15% of Subtotal	1	ls	$	277,900.00	$	277,900
				Subtotal Scenario #3 Sanitary Piping	**$**	**4,217,800**
				Cost $/LF	**$**	**167.04**
				Total Scenario #3 Sanitary Piping	**$**	**4,217,800**

ILLINOIS
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Affiliated Engineers

University of Illinois - Urbana Champaign

Plumbing - Sanitary

South Farms

Anaerobic Digester Feasibility Study

AEI Project No. 12787-00
Estimate Date: 11-22-13 r1

Conceptual Cost Estimate

Description	Qty	Units	Unit Matl & Labor W/ O & P	Extended Matl & Labor W/ O & P
Scenario #4 - Digester Located at SRC Swine Facility				
Sanitary Piping - Direct Buried			**Direct Bury Length**	**25,250**
Utility Locating				
Potholing	100	ea	$ 2,500.00	$ 250,000.00
Prefabricated Structures				
Precast Manhole - 10'x10'x6'-6" (inc. Excavation/Bedding/Rigging/Backfill)	4	ea	$ 10,000.00	$ 40,000.00
Sanitary Excavation/Shoring/Backfill				
Excavation	14962.96	cy	$ 20.00	$ 299,260
Dewatering	264	dy	$ 50.00	$ 13,200
Unsuitable Soil (25% of Excav.)	3740.74	cy	$ 15.00	$ 56,110
Stone Base - Bank Run	6312.50	tn	$ 19.65	$ 124,040
Backfill	7481.48	cy	$ 15.00	$ 112,220
Sanitary Piping				
8" SAN - Class 305 PVC	25,250	lf	$ 92.00	$ 2,323,000
Tracer Cable	25,250	lf	$ 0.65	$ 16,413
Warning Tape	25,250	lf	$ 0.11	$ 2,778
Sanitary Fittings and Valves				
8" SAN - Class 305 PVC 90°	5	ea	$ 380.00	$ 1,900
8" SAN - Class 305 PVC Tee	4	ea	$ 560.00	$ 2,240
8" SAN DDC Valve - PVC	10	ea	$ 2,135.00	$ 21,350
Flange/Restraint Connections	1	ls	$ 410,700.00	$ 410,700
Sanitary Pumps				
ISRL Facility - 800 gpm @ 375 ft Hd 100Hp ***(VFD included - Connection by EC)***	1	ea	$ 48,800.00	$ 48,800
Dairy Facility - 800 gpm @ 300 ft Hd 75Hp ***(VFD included - Connection by EC)***	1	ea	$ 38,200.00	$ 38,200
Grein Farm - 800 gpm @ 300 ft Hd 75Hp ***(VFD included - Connection by EC)***	1	ea	$ 38,200.00	$ 38,200
Beef and Sheep - 800 gpm @ 300 ft Hd 75Hp ***(VFD included - Connection by EC)***	1	ea	$ 38,200.00	$ 38,200
Poultry Facility - 800 gpm @ 300 ft Hd 75Hp ***(VFD included - Connection by EC)***	1	ea	$ 38,200.00	$ 38,200
Sanitary Pump Power				
75Hp VFD Connection	4	ea	$ 1,830.00	$ 7,320
1 1/2" RGS Conduit	1000	lf	$ 18.24	$ 18,240
3 - #1 THHN Copper Conductor	3300	lf.	$ 3.82	$ 12,606
1 - #6 THHN Copper Gropund	1100	lf	$ 1.65	$ 1,815
#1 Cable Terminations	48	ea	$ 29.32	$ 1,407
#6 Cable Terminations	16	ea	$ 21.65	$ 346
100Hp VFD Connection	1	ea	$ 2,055.00	$ 2,055
2" RGS Conduit	250	lf	$ 22.47	$ 5,618
3 - #2/0 THHN Copper Conductor	825	lf.	$ 5.57	$ 4,595
1 - #6 THHN Copper Gropund	275	lf	$ 1.65	$ 454
#2/0 Cable Terminations	12	ea	$ 40.65	$ 488
#6 Cable Terminations	4	ea	$ 21.65	$ 87
Additional Services/Factors				
Clean & Inspect Sanitary System	1	ls	$ 23,500.00	$ 23,500
Restricted Access Piping 15% of Subtotal	1	ls	$ 277,900.00	$ 277,900
			Subtotal Scenario #4 Sanitary Piping	**$ 4,231,200**
			Cost $/LF	**$ 167.57**
			Total Scenario #4 Sanitary Piping	**$ 4,231,200**

University of Illinois - Urbana Champaign | **Plumbing - Sanitary**

South Farms

Anaerobic Digester Feasibility Study

AEI Project No. 12787-00

Estimate Date: 11-22-13 r1

Conceptual Cost Estimate

Description	Qty	Units	Unit Matl & Labor W/ O & P	Extended Matl & Labor W/ O & P
Scenario #5 - Digester Located at Beef and Sheep Facility				
Sanitary Piping - Direct Buried			**Direct Bury Length**	**25,250**
Utility Locating				
Potholing	100	ea	$ 2,500.00	$ 250,000.00
Prefabricated Structures				
Precast Manhole - 10'x10'x6'-6" (inc. Excavation/Bedding/Rigging/Backfill)	4	ea	$ 10,000.00	$ 40,000.00
Sanitary Excavation/Shoring/Backfill				
Excavation	14962.96	cy	$ 20.00	$ 299,260
Dewatering	264	dy	$ 50.00	$ 13,200
Unsuitable Soil (25% of Excav.)	3740.74	cy	$ 15.00	$ 56,110
Stone Base - Bank Run	6312.50	tn	$ 19.65	$ 124,040
Backfill	7481.48	cy	$ 15.00	$ 112,220
Sanitary Piping				
8" SAN - Class 305 PVC	25,250	lf	$ 92.00	$ 2,323,000
Tracer Cable	25,250	lf	$ 0.65	$ 16,413
Warning Tape	25,250	lf	$ 0.11	$ 2,778
Sanitary Fittings and Valves				
8" SAN - Class 305 PVC 90°	5	ea	$ 380.00	$ 1,900
8" SAN - Class 305 PVC Tee	4	ea	$ 560.00	$ 2,240
8" SAN DDC Valve - PVC	10	ea	$ 2,135.00	$ 21,350
Flange/Restraint Connections	1	ls	$ 410,700.00	$ 410,700
Sanitary Pumps				
ISRL Facility - 800 gpm @ 500 ft Hd 75Hp ***(VFD included - Connection by EC)***	1	ea	$ 38,200.00	$ 38,200
Dairy Facility - 800 gpm @ 400 ft Hd 100Hp ***(VFD included - Connection by EC)***	1	ea	$ 48,800.00	$ 48,800
Grein Farm - 800 gpm @ 300 ft Hd 75Hp ***(VFD included - Connection by EC)***	1	ea	$ 38,200.00	$ 38,200
SRC Swine Facility - 800 gpm @ 300 ft Hd 75Hp ***(VFD included - Connection by EC)***	1	ea	$ 38,200.00	$ 38,200
Poultry Facility - 800 gpm @ 300 ft Hd 75Hp ***(VFD included - Connection by EC)***	1	ea	$ 38,200.00	$ 38,200
Sanitary Pump Power				
75Hp VFD Connection	4	ea	$ 1,830.00	$ 7,320
1 1/2" RGS Conduit	1000	lf	$ 18.24	$ 18,240
3 - #1 THHN Copper Conductor	3300	lf.	$ 3.82	$ 12,606
1 - #6 THHN Copper Gropund	1100	lf	$ 1.65	$ 1,815
#1 Cable Terminations	48	ea	$ 29.32	$ 1,407
#6 Cable Terminations	16	ea	$ 21.65	$ 346
100Hp VFD Connection	1	ea	$ 2,055.00	$ 2,055
2" RGS Conduit	250	lf	$ 22.47	$ 5,618
3 - #2/0 THHN Copper Conductor	825	lf.	$ 5.57	$ 4,595
1 - #6 THHN Copper Gropund	275	lf	$ 1.65	$ 454
#2/0 Cable Terminations	12	ea	$ 40.65	$ 488
#6 Cable Terminations	4	ea	$ 21.65	$ 87
Additional Services/Factors				
Clean & Inspect Sanitary System	1	ls	$ 23,500.00	$ 23,500
Restricted Access Piping 15% of Subtotal	1	ls	$ 277,900.00	$ 277,900
			Subtotal Scenario #5 Sanitary Piping	**$ 4,231,200**
			Cost $/LF	**$ 167.57**
			Total Scenario #5 Sanitary Piping	**$ 4,231,200**

University of Illinois - Urbana Champaign

South Farms

Anaerobic Digester Feasibility Study

AEI Project No. 12787-00

Estimate Date: 11-22-13 r1

Surface Demolition & Site Restoration

Common to All Scenarios

Conceptual Cost Estimate

Description	Qty	Units	Unit Matl & Labor W/ O & P	Extended Matl & Labor W/ O & P
Surface Demolition & Protection				
Sawcut Concrete Pavement	2,500	lf	$ 3.17	$ 7,930.00
Sawcut Asphaltic Pavement	7,500	lf	$ 2.73	$ 20,480.00
Demo Concrete Pavement	5,000	sf	$ 1.85	$ 9,250.00
Demo Asphaltic Pavement	15,100	sf	$ 1.15	$ 17,370.00
Demo Curb & Gutter	150	lf	$ 6.50	$ 980.00
Demo/Trim Trees ***(by UIUC if Required)***	***0***	***ea***	***$ -***	***$ -***
Demo Sod & Soil	80,800	sf	$ 0.92	$ 74,340.00
Remove Fence ***(Assumption)***	500	lf	$ 3.24	$ 1,620.00
Protect Trees ***(Assumption)***	24	ea	$ 500.00	$ 12,000.00
Hauling of Demo'd Material (12 cy Truck, 5 mile Round Trip, 1 Load/Hour)	1,371	cy	$ 14.50	$ 19,890.00
Subtotal Surface Demolition & Protection				**$ 163,900**
Hardscape				
Concrete Pavement (inc. Base)	5,000	sf	$ 5.75	$ 28,750.00
Asphaltic Pavement (inc. Base)	15,100	sf	$ 3.47	$ 52,400.00
Slipform Curb & Gutter (inc. Base)	150	lf	$ 18.05	$ 2,710.00
Reinstall Fence	500	lf	$ 16.76	$ 8,380.00
Pavement Marking - 4" Epoxy	210	lf	$ 1.74	$ 370.00
Subtotal Hardscape				**$ 92,600**
Landscaping				
Sod Restoration	80800	sf	$ 1.90	$ 153,520
Subtotal Landscaping				**$ 153,500**
Grading				
Finish Grading - to Work Area Limit	101,000	sf	$ 0.80	$ 80,800.00
Subtotal Grading				**$ 80,800**
Total Surface Demolition & Site Restoration				**$ 490,800.00**

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University of Illinois - Urbana Champaign

South Farms

Anaerobic Digester Feasibility Study

AEI Project No. 12787-00
Estimate Date: 11-22-13 r1

Traffic and Pedestrian Control

Common to All Scenarios

Conceptual Cost Estimate

Description	Qty	Units	Unit Matl & Labor W/ O & P	Extended Matl & Labor W/ O & P
Vehicle Traffic & Pedestrian Control				
All Areas - All Phases				
Parking/Metering Allowance	1	ls	$ 25,000.00	$ 25,000.00
Type III Barricade	24	ea	$ 154.00	$ 3,700.00
Construction Fencing - 6'	10,000	lf	$ 9.20	$ 92,000.00
Traffic/Pedestrian Signage	36	ea	$ 295.00	$ 10,620.00
Total Traffic and Pedestrian Control				**$ 131,400**
Total Traffic and Pedestrian Control				**$ 131,400.00**

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University of Illinois - Urbana Champaign
South Farms
Anaerobic Digester Feasibility Study
AEI Project No. 12787-00
Estimate Date: 11-22-13 r1

Erosion Control
Common to All Scenarios

Conceptual Cost Estimate

Description	Qty	Units	Unit Matl & Labor W/ O & P	Extended Matl & Labor W/ O & P
Erosion Control				
Silt Fence	50500	lf	$ 1.21	$ 61,110.00
Curb Inlet Protection	60	ea	$ 95.00	$ 5,700.00
Subtotal Erosion Control				**$ 66,800**
Total Erosion Control				**$ 66,800.00**

Appendix D

Appendix D – LCCA Detail – LCCA Min

Equipment	Minimum Life	Replacement Cost	10 Year Cost	20 Year Cost	30 Year Cost	40 Year Cost	50 Year Cost	Replacements in 50 Years
Pasteurizer/Grinder	10	$150,000.00	$150,000.00	$258,363.19	$338,995.58	$398,993.65	$443,637.85	4
Feedstock Transport (6 trucks)	5	$350,000.00	$643,119.49	$1,114,075.37	$1,464,510.77	$1,725,267.62	$1,919,295.20	9
Receiving and Preprocessing	15	$200,000.00	$200,000.00	$324,633.39	$324,633.39	$404,630.82	$455,978.12	3
Flare	15	$30,000.00	$30,000.00	$48,695.01	$48,695.01	$60,694.62	$68,396.72	3
Influent/Effluent Storage Tanks	25	$125,000.00	$125,000.00	$125,000.00	$182,961.84	$182,961.84	$182,961.84	1
Coarse Fiber Separation/ Storage	15	$150,000.00	$150,000.00	$243,475.04	$243,475.04	$303,473.11	$341,983.59	3
Drying Drum for Soil Amendment	15	$125,000.00	$125,000.00	$202,895.87	$202,895.87	$252,894.26	$284,986.33	3
ICE	25	$1,600,000.00	$1,600,000.00	$1,600,000.00	$2,341,911.56	$2,341,911.56	$2,341,911.56	1
Micro turbine	15	$3,250,000.00	$3,250,000.00	$5,275,292.55	$5,275,292.55	$6,575,250.77	$7,409,644.49	3
Turbine	15	$4,400,000.00	$4,400,000.00	$7,141,934.53	$7,141,934.53	$8,901,877.97	$10,031,518.69	3
Fuel Cell	10	$6,000,000.00	$6,000,000.00	$10,334,527.66	$13,559,823.32	$15,959,746.19	$17,745,514.19	4
Condenser	30	$150,000.00	$150,000.00	$150,000.00	$150,000.00	$209,998.07	$209,998.07	1
H2S Upgrade	30	$145,000.00	$145,000.00	$145,000.00	$145,000.00	$202,998.14	$202,998.14	1
CO2 Upgrade	30	$400,000.00	$400,000.00	$400,000.00	$400,000.00	$559,994.86	$559,994.86	1
CNG Facility	30	$800,000.00	$800,000.00	$800,000.00	$800,000.00	$1,119,989.72	$1,119,989.72	1
Storage Tanks	30	$400,000.00	$400,000.00	$400,000.00	$400,000.00	$559,994.86	$559,994.86	1
LNG Facility	25	$1,300,000.00	$1,300,000.00	$1,300,000.00	$1,902,803.15	$1,902,803.15	$1,902,803.15	1
Grid	30	$111,111.00	$111,111.00	$111,111.00	$111,111.00	$155,553.97	$155,553.97	1
COW Line	40	$5,000,000.00	$5,000,000.00	$5,000,000.00	$5,000,000.00	$5,000,000.00	$6,488,140.00	1
Digester Tanks	30	$1,500,000.00	$1,500,000.00	$1,500,000.00	$1,500,000.00	$2,099,980.72	$2,099,980.72	1
Digester Machinery (once built)	15	$500,000.00	$500,000.00	$811,583.47	$811,583.47	$1,011,577.04	$1,139,945.31	3
Tire Wash – per location	5	$15,000.00	$27,562.26	$47,746.09	$62,764.75	$73,940.04	$82,255.51	
Truck Wash – per location	10	$45,000.00	$45,000.00	$77,508.96	$101,698.67	$119,698.10	$133,091.36	
	Interest Rate	3%						
Assumes that replacement occurs in year right after useful life ends. For example with a useful life of 10 years, replacement would occur at the start of the 11th year.								

Appendix D – LCCA Detail - LCCA Typical

Equipment	Minimum Life	Replacement Cost	10 Year Cost	20 Year Cost	30 Year Cost	40 Year Cost	50 Year Cost	Replacements in 50 Years
Pasteurizer/Grinder	15	$150,000.00	$150,000.00	$243,475.04	$243,475.04	$303,473.11	$341,983.59	3
Feedstock Transport (6 trucks)	10	$350,000.00	$350,000.00	$602,847.45	$790,989.69	$930,985.19	$1,035,154.99	4
Receiving and Preprocessing	25	$200,000.00	$200,000.00	$200,000.00	$292,738.95	$292,738.95	$292,738.95	1
Flare	25	$30,000.00	$30,000.00	$30,000.00	$43,910.84	$43,910.84	$43,910.84	1
Influent/Effluent Storage Tanks	25	$125,000.00	$125,000.00	$125,000.00	$182,961.84	$182,961.84	$182,961.84	1
Coarse Fiber Separation/ Storage	25	$150,000.00	$150,000.00	$150,000.00	$219,554.21	$219,554.21	$219,554.21	1
Drying Drum for Soil Amendment	25	$125,000.00	$125,000.00	$125,000.00	$182,961.84	$182,961.84	$182,961.84	1
ICE	30	$1,600,000.00	$1,600,000.00	$1,600,000.00	$1,600,000.00	$2,239,979.43	$2,239,979.43	1
Micro turbine	20	$3,250,000.00	$3,250,000.00	$3,250,000.00	$4,997,035.15	$4,997,035.15	$5,964,326.15	2
Turbine	20	$4,400,000.00	$4,400,000.00	$4,400,000.00	$6,765,216.81	$6,765,216.81	$8,074,780.02	2
Fuel Cell	15	$6,000,000.00	$6,000,000.00	$9,739,001.64	$9,739,001.64	$12,138,924.51	$13,679,343.67	3
Condenser	40	$150,000.00	$150,000.00	$150,000.00	$150,000.00	$150,000.00	$194,644.20	1
H2S Upgrade	40	$145,000.00	$145,000.00	$145,000.00	$145,000.00	$145,000.00	$188,156.06	1
CO2 Upgrade	40	$400,000.00	$400,000.00	$400,000.00	$400,000.00	$400,000.00	$519,051.20	1
CNG Facility	40	$800,000.00	$800,000.00	$800,000.00	$800,000.00	$800,000.00	$1,038,102.40	1
Storage Tanks	40	$400,000.00	$400,000.00	$400,000.00	$400,000.00	$400,000.00	$519,051.20	1
LNG Facility	30	$1,300,000.00	$1,300,000.00	$1,300,000.00	$1,300,000.00	$1,819,983.29	$1,819,983.29	1
Grid	40	$111,111.00	$111,111.00	$111,111.00	$111,111.00	$111,111.00	$144,180.74	1
COW Line	50	$5,000,000.00	$5,000,000.00	$5,000,000.00	$5,000,000.00	$5,000,000.00	$5,000,000.00	0
Digester Tanks	45	$1,500,000.00	$1,500,000.00	$1,500,000.00	$1,500,000.00	$1,500,000.00	$1,885,104.79	1
Digester Machinery (once built)	20	$500,000.00	$500,000.00	$500,000.00	$768,774.64	$768,774.64	$917,588.64	2
Tire Wash – per location	10	$15,000.00	$15,000.00	$25,836.32	$33,899.56	$39,899.37	$44,363.79	
Truck Wash – per location	15	$45,000.00	$45,000.00	$73,042.51	$73,042.51	$91,041.93	$102,595.08	
	Interest Rate	3%						
Assumes that replacement occurs in year right after useful life ends. For example with a useful life of 10 years, replacement would occur at the start of the 11th year.								

Appendix D – LCCA Detail – LCCA Max

Equipment	Minimum Life	Replacement Cost	10 Year Cost	20 Year Cost	30 Year Cost	40 Year Cost	50 Year Cost	Replacements in 50 Years
Pasteurizer/Grinder	25	$150,000.00	$150,000.00	$150,000.00	$219,554.21	$219,554.21	$219,554.21	1
Feedstock Transport	15	$350,000.00	$350,000.00	$568,108.43	$568,108.43	$708,103.93	$797,961.71	3
Receiving and Preprocessing	30	$200,000.00	$200,000.00	$200,000.00	$200,000.00	$279,997.43	$279,997.43	1
Flare	60	$30,000.00	$30,000.00	$30,000.00	$30,000.00	$30,000.00	$30,000.00	0
Influent/Effluent Storage Tanks	50	$125,000.00	$125,000.00	$125,000.00	$125,000.00	$125,000.00	$125,000.00	0
Coarse Fiber Separation/ Storage	30	$150,000.00	$150,000.00	$150,000.00	$150,000.00	$209,998.07	$209,998.07	1
Drying Drum for Soil Amendment	30	$125,000.00	$125,000.00	$125,000.00	$125,000.00	$174,998.39	$174,998.39	1
ICE	60	$1,600,000.00	$1,600,000.00	$1,600,000.00	$1,600,000.00	$1,600,000.00	$1,600,000.00	0
Micro turbine	30	$3,250,000.00	$3,250,000.00	$3,250,000.00	$3,250,000.00	$4,549,958.22	$4,549,958.22	1
Turbine	30	$4,400,000.00	$4,400,000.00	$4,400,000.00	$4,400,000.00	$6,159,943.44	$6,159,943.44	1
Fuel Cell	25	$6,000,000.00	$6,000,000.00	$6,000,000.00	$8,782,168.36	$8,782,168.36	$8,782,168.36	1
Condenser	50	$150,000.00	$150,000.00	$150,000.00	$150,000.00	$150,000.00	$150,000.00	0
H2S Upgrade	50	$145,000.00	$145,000.00	$145,000.00	$145,000.00	$145,000.00	$145,000.00	0
CO2 Upgrade	50	$400,000.00	$400,000.00	$400,000.00	$400,000.00	$400,000.00	$400,000.00	0
CNG Facility	60	$800,000.00	$800,000.00	$800,000.00	$800,000.00	$800,000.00	$800,000.00	0
Storage Tanks	60	$400,000.00	$400,000.00	$400,000.00	$400,000.00	$400,000.00	$400,000.00	0
LNG Facility	50	$1,300,000.00	$1,300,000.00	$1,300,000.00	$1,300,000.00	$1,300,000.00	$1,300,000.00	0
Grid	50	$111,111.00	$111,111.00	$111,111.00	$111,111.00	$111,111.00	$111,111.00	0
Pipeline	80	$5,000,000.00	$5,000,000.00	$5,000,000.00	$5,000,000.00	$5,000,000.00	$5,000,000.00	0
COW Line	60	$1,500,000.00	$1,500,000.00	$1,500,000.00	$1,500,000.00	$1,500,000.00	$1,500,000.00	0
Digester Machinery (once built)	25	$500,000.00	$500,000.00	$500,000.00	$731,847.36	$731,847.36	$731,847.36	1
Tire Wash – per location	15	$15,000.00	$15,000.00	$24,347.50	$24,347.50	$30,347.31	$34,198.36	3
Truck Wash – per location	20	$45,000.00	$45,000.00	$45,000.00	$69,189.72	$69,189.72	$82,582.98	2
	Interest Rate	3%						
Assumes that replacement occurs in year right after useful life ends. For example with a useful life of 10 years, replacement would occur at the start of the 11th year.								

Appendix E

University of Illinois BMP Trials

Submitted to:

SeaHold, LLC

Date Assay Conducted: March 1st, 2013 to April 26th, 2013

Biogas Assay Type: nine different samples were submitted for analysis.

Draft Report Submitted: May 13th, 2013

UWP Principal Investigator: Tim Zauche (zauchet@uwplatt.edu 608-342-1678)

Lab Technicians: Rebecca Stangl
Elliot Mills
Aaron Bednarski

Goal

This assay determined the anaerobic biodegradability and biogas recovery potential of samples from a variety of sources around the Univ of Illinois Farm and campus.

Certificate of Analysis

The procedure followed for biochemical methane potential assays was presented by (Gunaseelan 1997)1993, "Biochemical Methane Potential of Biomass and Waste Feedstocks." Biomass & Bioenergy 5(1): 95-111. COD analysis was performed using the Hach DRB 200 heating block with Hach COD reagent vials for 0-1500mg/L, mercury free. Sulfide test was determined using the Sulfide titrimetric test in the “Standard Methods for the Examination of Water and Wastewater”. Methane gas production was monitored using the AMPTS II model unit.
Respectfully,

Tim Zauche, Lab Director
May 13th, 2013

Table 1. Initial characterization of waste samples

Lab#	Sample	Type	*DM* %	*Total N* % of DM	*Total P* % of DM	*Total K* % of DM	*NH_4-N* % of DM	*C:N* Ratio
3187	**13001**	Horse	32.8	2.1	0.42	1.59	0.5	25:1
3176	**13003**	Dairy Solid	40.5	1.3	0.24	0.70	0.5	12:1
3177	**13005**	Imp Swine	0.9	17.6	2.80	10.39	14.2	3:1
3178	**13006**	Imp Swine	1.1	15.2	6.00	15.41	12.0	3:1
3179	**13007**	Farrowing	0.6	30.5	1.45	19.95	29.1	2:1
3180	**13008**	Nursery	14.1	7.1	2.84	2.21	3.7	7:1
3181	**13009**	Finishing	2.9	10.5	5.90	2.59	7.3	4:1
3182	**13010**	Man hole	1.7	10.3	4.20	5.91	6.0	5:1
3183	**13011**	Beef/sheep	23.3	3.5	0.28	0.33	0.2	16:1
3184	**13012**	Poultry	30.8	5.7	1.54	2.06	2.2	6:1
3185	**13013**	Beef	0.4	18.2	1.40	6.29	16.6	3:1
3188	**13014**	yard waste	36.0	0.9	0.14	0.32	0.1	58:1
3186	**13015**	Dairy Flush	0.7	12.9	1.25	10.10	12.7	3:1
	Post BMP							
3216	**13005**	Imp Swine	5.4				3.8	
3217	**13009**	Finishing	5.3				4.0	
3218	**13012**	Poultry	7.3				4.6	

Observations: Samples 13001-14 were delivered on March 1, 2013
Sample 13015 arrived on March 29, 2013
Samples 13005, 6, 7, 8, 9, 10, 13, 15 were liquids, with 8 containing more solids than the others

For optimal digestion, a carbon to nitrogen ratio of greater than at least 12:1 is preferred.

These tests were performed by the *UW-System Soil and Forage Analysis Lab*.
NPK is provided for the fertilizer value determination. These amounts do not change appreciably during the digestion process as it is mainly the carbon that is being broken down by the bacteria.

Table 2. Biochemical Methane Potential Analysis of the samples using digested dairy manure bacteria seed; average of 3 trials

Assay	Sample	ml CH_4	ml CO_2	Total gas	% CH_4	% CO_2	ppm H_2S	Diff from control
DVO-seed	Control 1-3	1290	372	1661	77.6%	22.4%	2189	
13001	Horse Manure	1922	738	2661	72.3%	27.7%	4192	2003
13003	Dairy-solid	2018	852	2870	70.3%	29.7%	2089	-99
13005	Imported Swine	885	303	1188	74.5%	25.5%	2917	728
13009	Hog - Finishing	1138	506	1644	69.2%	30.8%	4051	1863
13010	Hog Manure-manhole	2052	403	2455	83.6%	16.4%	2718	529
13011	Beef and Sheep-flush	1101	1652	2753	40.0%	60.0%	12436	10247
13012	Poultry waste	932	1497	2429	38.4%	61.6%	21497	19309
13015	Dairy-flush	1629	847	2476	65.8%	34.2%	1713	-476
Representative Mix	Representative Mix	2070	376	2446	84.6%	15.4%	8302	6114

All volumes of gases are listed in the units of milliliters. The hydrogen sulfide (H_2S) is provided in parts per million. CH_4 is methane and is the energy producing gas making up about 98% of "natural gas".

The ratio of methane to carbon dioxide is in the range typical of dairy farm digesters. The hydrogen sulfide appears a little high except for the samples containing manure from the poultry and the beef/sheep flush system. This was anticipated for the poultry system, but was not for the beef/sheep manure. We would suggest focusing more on the difference in hydrogen sulfide production compared to the seed stock or control sample. The seed solution makes up 90% of the total solution and is thus responsible for the higher than normal sulfide production in the BMP samples.

The hog manure from the "manhole" did exceptionally well both in total gas production as well as methane concentration.

The representative mix did well combining low and high producing waste streams into a sample that produced a high level of methane.

To provide a representative mix for the BMP test, the following recipe was followed to mimic various amounts of the different types of possible waste material. Although, the yard waste was not added, it has been used by others as a way to reach the optimal C:N ratio for digestion.

Table 3. Waste Mixture for BMP sample

Sample #	Recipe Mixture	Amount (g)	Percentage
Proxy	Food Prep Waste	34.982	17.3%
13001	Horse	14.0015	6.9%
13003	Dairy Solid	29.8034	14.8%
13005	Imported Swine	16.5484	8.2%
13009	Swine Finishing	18.78	9.3%
13011	Beef/Sheep	16.9431	8.4%
13012	Chicken	13.976	6.9%
13013	Beef	16.7645	8.3%
13015	Dairy Liquid	40.1852	19.9%
	Total	201.9841	100%

Food Prep Waste: this was food trimmings or waste food from a local industrial kitchen. This included fruit peels, greens, spoiled donuts, flour, vegetables, etc.

Figures 1 and 2 are from the continuous monitoring of the methane gas production using an **AMPTS II** unit.

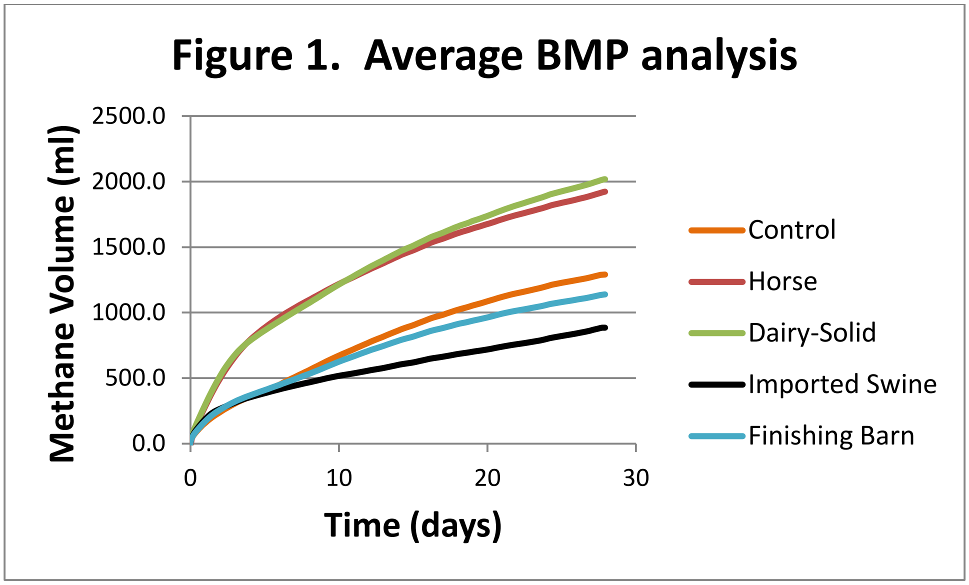


Figure 1: Each sample was run in triplicate and the averages are shown

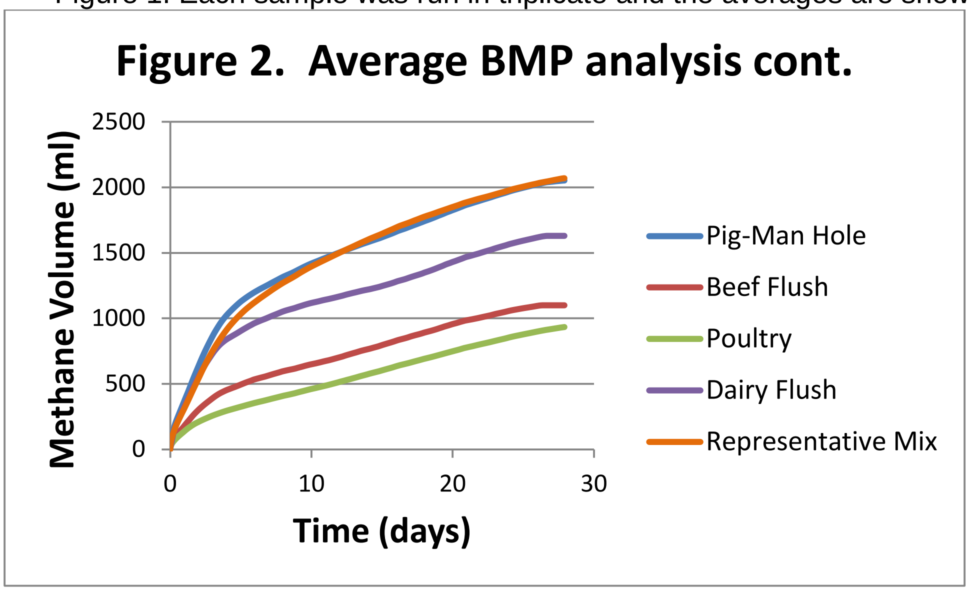
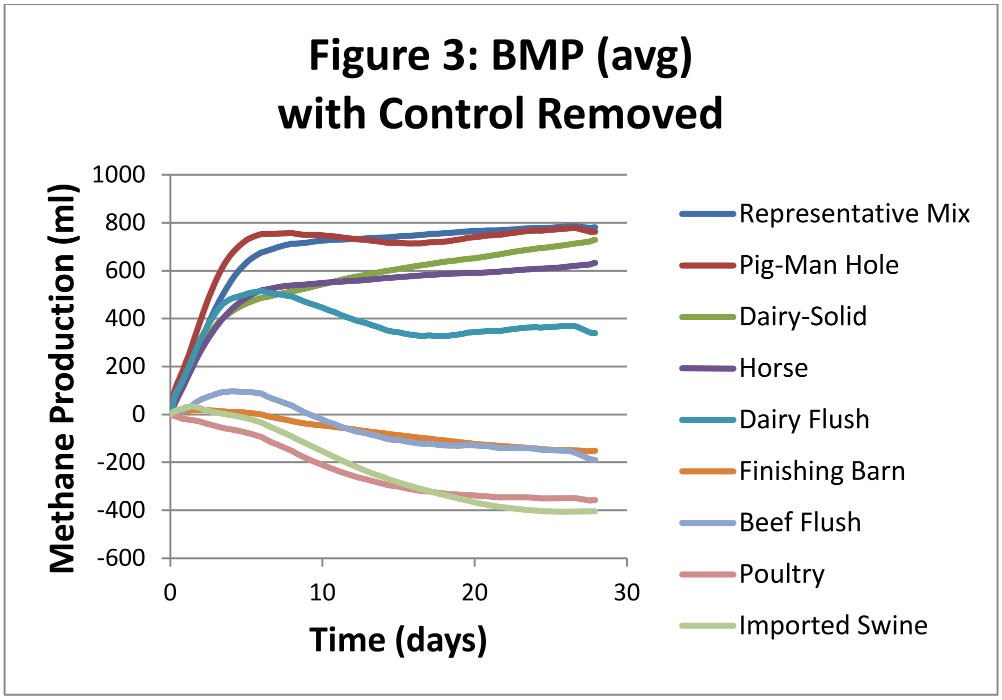


Figure 2: Each sample was run in triplicate and the averages are shown

To gain a better picture of the methane produced from the samples being tested, the following graph was made where the control's methane production has been subtracted.



For these samples, the majority of the methane production occurred within the first 10 days. Usually this initial rate of methane production occurs within the first 17 days. This indicates the possibility of a shorter hydraulic retention time than the industry standard of approximately 28 days. Any of the gas produced after ~8 days is most likely due to the residual solids from the seed stock; such as alfalfa stems and other cellulosic materials. This hypothesis is supported by observing the two more solid samples continued to produce gas above the control after the initial 10 day (Dairy-solid and Horse manure) as they have more of this type of material.
We are unsure the exact reason why there were negative productions in methane from four samples other than that those samples were really dilute or that the bacteria population may not be used to this waste stream. This is supported by the low *total solids* as well as low *COD* values in the samples. The low performance of some of the samples could also be due to the low C:N ratios as was observed in **Table 1**.

Table 4. Potential Total Gas production from the waste streams

Assay	Sample	Total gas	Diff in Gas production	Grams added	ml Gas/ gram added	ft^3 gas/ton sample	ft^3 CH_4/ton sample
DVO-seed	Blank 1-3	1661.202		270	6	197	153
13001	Horse Manure	2660.663	999.4615	30.13533	33	1063	768
13003	Dairy-solid	2869.801	1208.599	30.81767	39	1256	884
13005	Imported Swine	1187.976	-473.226	30	-16	NA	NA
13009	Hog -Finishing	1644.427	-16.7746	30	-1	NA	NA
13010	Hog Manure-manhole	2454.546	793.3446	30	26	847	708
13011	Beef and Sheep-flush	2752.72	1091.518	30.894	35	1132	453
13012	Poultry waste	2429.225	768.0235	30.51833	25	806	309
13015	Dairy-flush	2475.689	814.4876	30	27	870	572
Representative Mix	Representative Mix	2446.498	785.2965	33.37	24	754	638

All volumes are in milliliters unless otherwise noted.
It is typical that once a bacteria population becomes optimized for a given waste stream that the gas yields would increase. This would be extremely important to keep in mind when comparing waste streams as the seed stock came from a diary digester and thus the higher yields were typically from the dairy manure streams.

Table 5. Chemical Oxygen Demand (COD) Destruction from BMP Test

Sample Type	Sample #	Initial COD*	Pre BMP	Post BMP	% COD destroyed
Horse	13001	62,700	41000	21,000	49%
Dairy Solid	13003	28,200	38000	20,000	47%
Imp Swine	13005	15,200	36000	24,000	33%
Farrowing	13007	6,170			
Nursery	13008	38,500			
Finishing	13009	46,100	35000	11,000	69%
Man hole	13010	27,500	39000	9,500	76%
Beef/sheep	13011	47,600	39000	21,000	46%
Poultry	13012	39,800	38000	23,000	39%
Beef	13013	3,570			
Dairy Flush	13015	7,200	40000	11,000	73%
Representative Mix	Mix	50,000**	39000	16,000	59%
Seed	Control	34,867	38000	13,000	66%

*All COD results are in mg/Kg of sample or solution.
** The representative mix was approximated to have an initial COD of 50,000. This included the kitchen food scraps which have a large variation of COD between 90,000 and 130,000 mg/Kg COD. Due to this high variability and difficulty in capturing a 1.0 gram representative sample for COD determination, the value of 50,000 was approximated.

Table 6. Total Solids, Volatile Solids, and Conductivity

		Pre BMP analysis				Post BMP analysis			
Sample #	Type	Conductivity (mS/cm)	pH	Total Solids	Volatile Solids	Conductivity (mS/cm)	pH	Total Solids	Volatile Solids
13001	Horse	9.72	8.2	36.6	88.0	19.14	7.73	7.75	79.31
13003	Dairy Solid	9.90	8.0	39.1	29.2	19.39	7.73	8.41	70.73
13005	Imp Swine	11.89	7.2	0.8	61.5	18.25	7.73	5.09	73.42
13007	Farrowing	13.52	8.6	0.4	48.7				
13008	Nursery	19.90	6.8	12.9	82.2				
13009	Finishing	13.98	7.5	3.1	66.0	18.29	7.70	5.22	73.47
13010	Man hole	8.82	6.8	1.6	76.4	18.32	7.67	4.71	72.87
13011	Beef/sheep	3.18	5.9	20.2	93.9	18.25	7.73	6.28	77.92
13012	Poultry	20.50	7.8	19.9	65.6	24.30	7.90	6.35	68.81
13013	Beef	5.52	7.9	0.3	64.8				
13015	Dairy Flush	NA	8.00	0.6	63.2	17.91	7.60	4.45	72.88
	Representative Mix	NA	NA	14.9	61.5	18.74	7.60	5.12	71.67
DVO Seed	Seed	17.64	7.7	5.5	76.2	17.59	7.67	6.05	74.20

Conductivity is in the units of millisiemens/cm of liquid (cross section). This is a measure of the amount of salts in the sample. To obtain this value for the solids, 50 ml of reverse osmosis water was added to 50 grams of the solid sample.
Total Solids are listed as percentage of the total mass
Volatile Solids are listed as percentage of the Total Solids combusted at 550 °C.
BMP tests were not carried out on a few of the samples. This was at the request of SeaHold who had determined that the volumes of these waste streams were minimal or would not vary substantially from other streams already being tested.

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