Sampling Testing and Evaluation Plan
for
SUNY Morrisville Anaerobic Digester

DRAFT: 11/2/06

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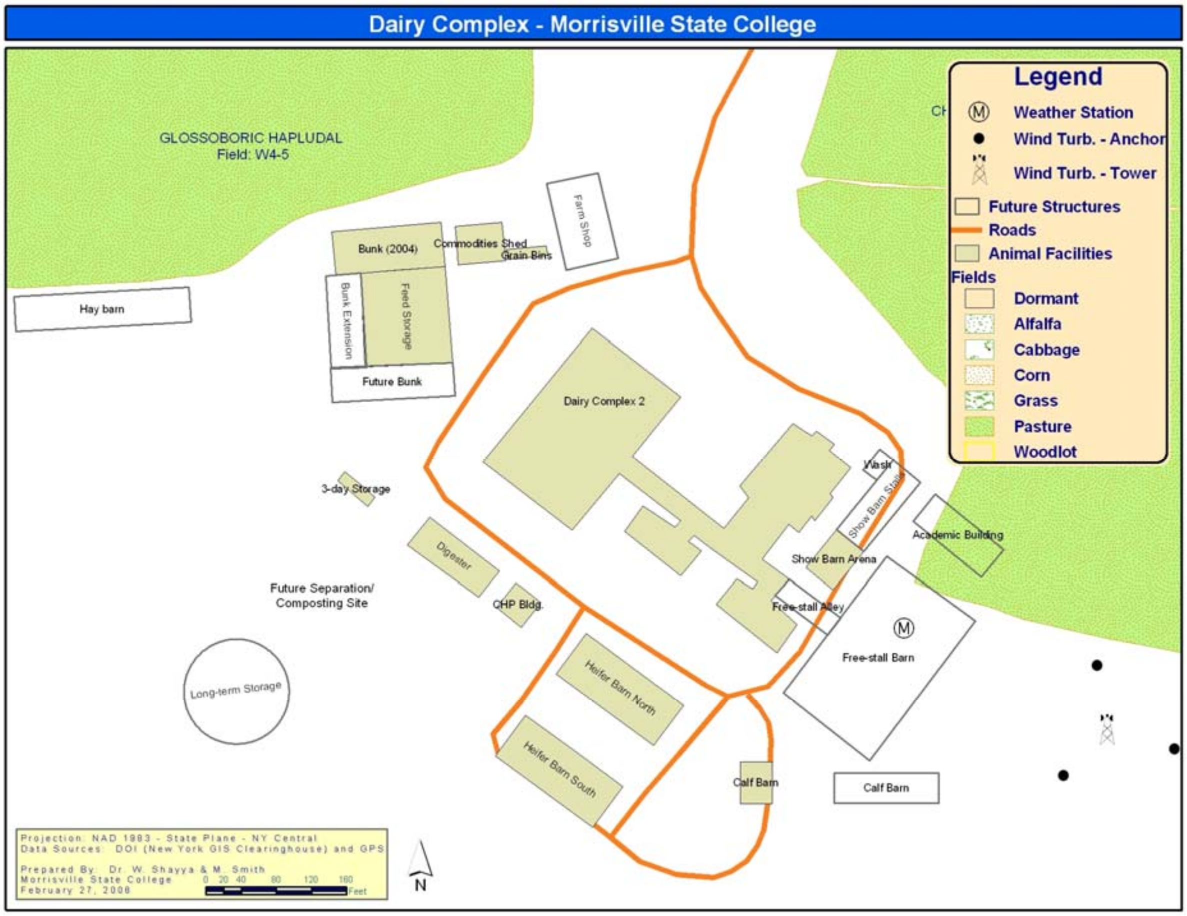
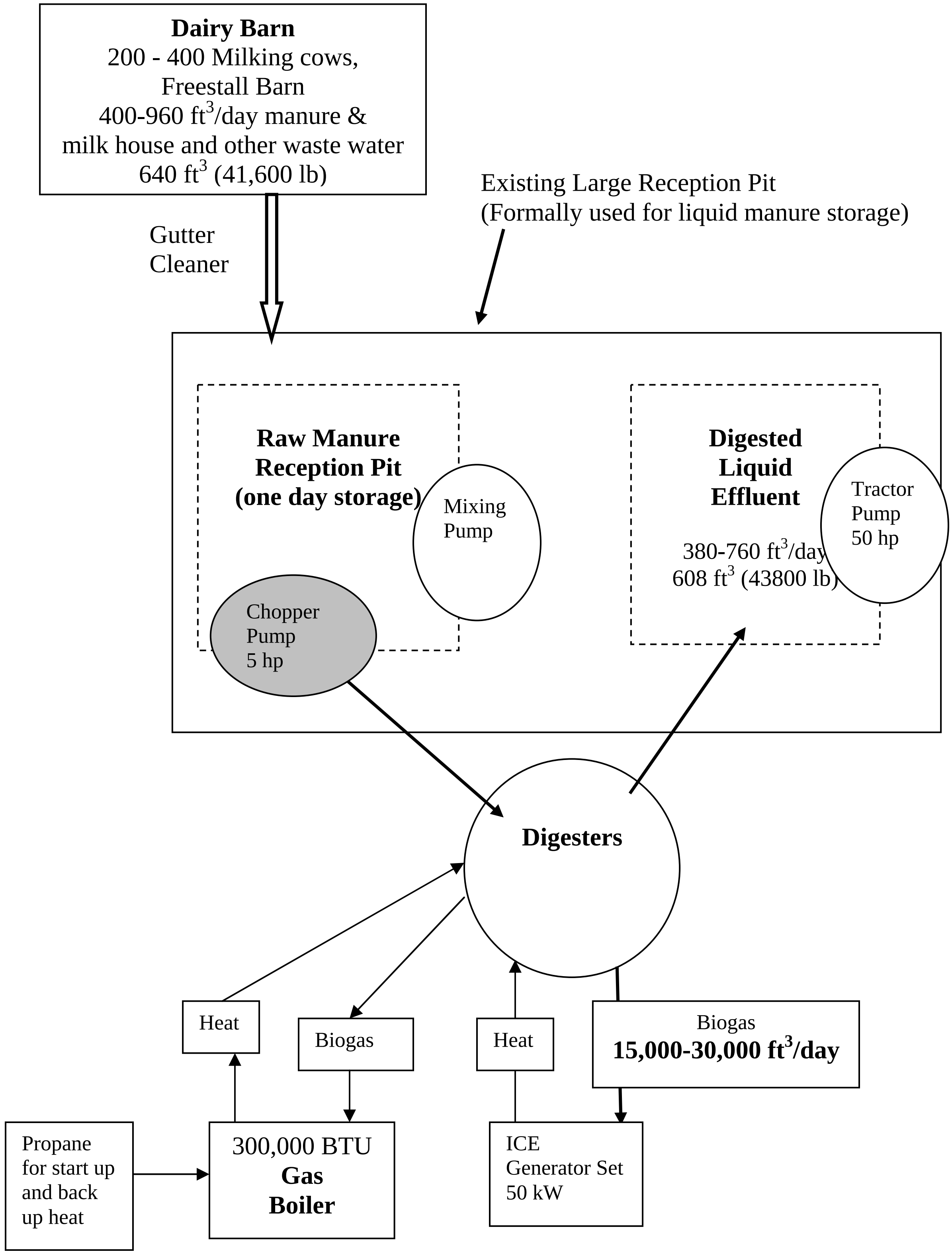
A: PLANS

A1) Site Plan

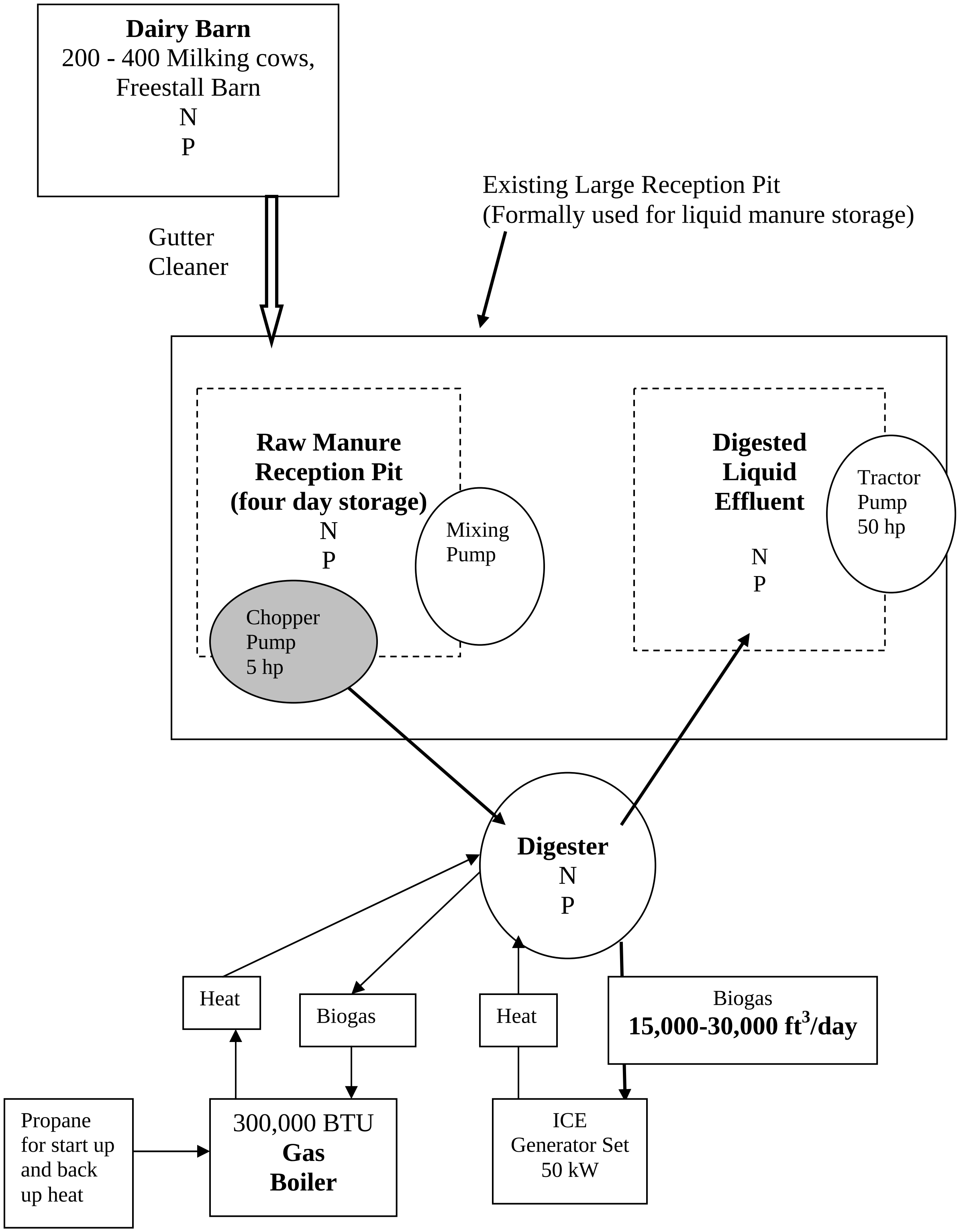


A2) Flow diagrams

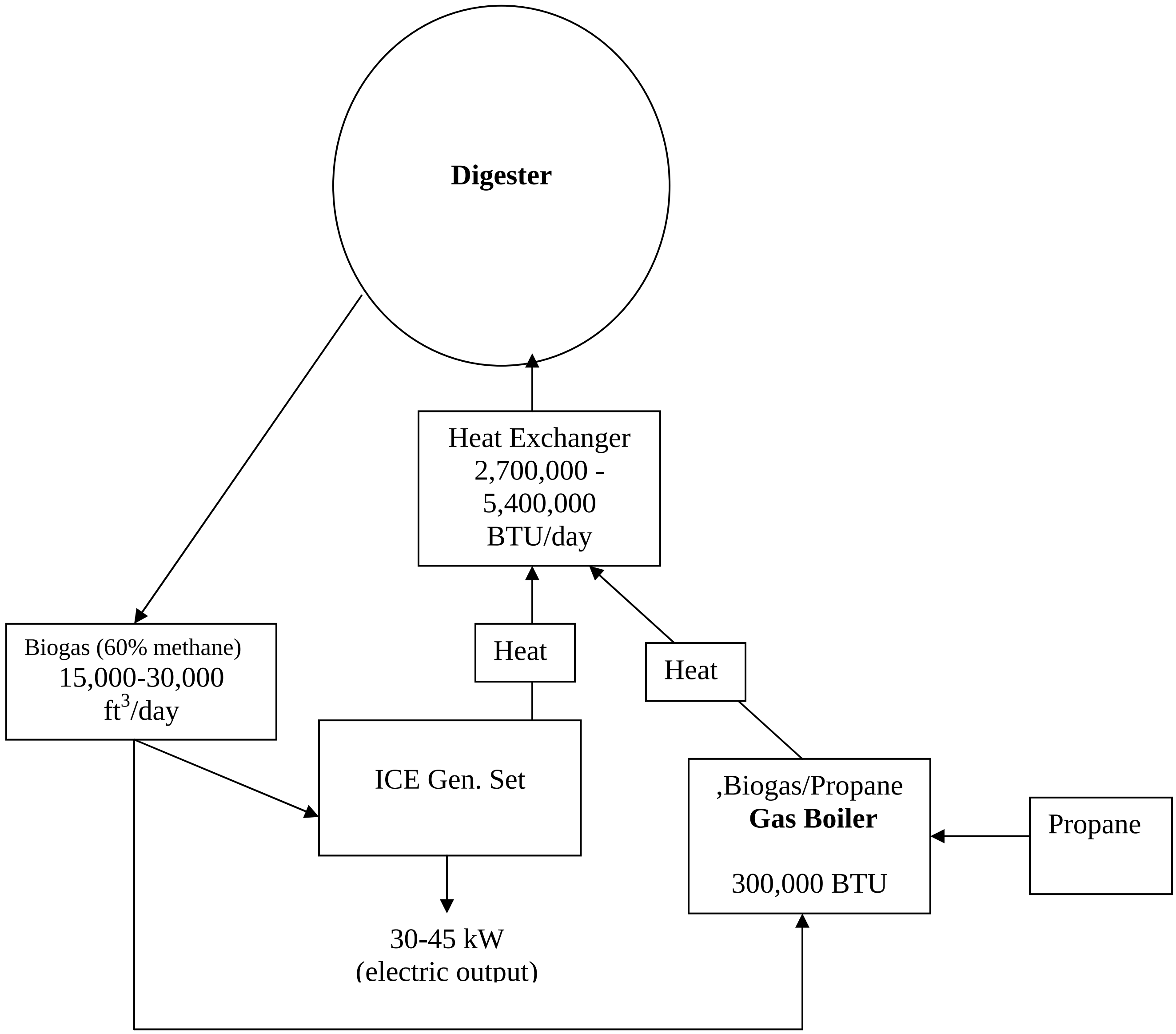
Mass Flow Diagram



Nutrient Flow Diagram



Heat Flow diagram



A3) Material Flow volumes, weights, products and effluents

Item description	Flow rate (gal/day)	Volume	Weight	Effluent
Manure from barn into reception pit / day	3600-7200 gal/day	480-960 ft^3	31,200-62,400 lb	
Milk house waste and other water waste into reception pit	4800 gal/day	640 ft^3	40,000 lb	
Effluent from digester	8000-11,400 gal/day	1065-1600 ft^3	69,000-102,000 lb	Biogas / heat / Digested manure
Biogas from digester		15,000-30,000 ft^3		CO_2, H_2O, H_2S

A4) Significant pieces of equipment (still rough estimates)

Item	Description	Cost
Pumps	Manure transfer pumps to digester Company: Sirumi Size: 5 hp	$3,000
Pipe rack heat exchanger	Heat exchanger to heat manure digester from waste heat. Company: Martin Machinery (Gen Tec)	$25,000
Boiler	Propane for start-up and breakdown, and run on methane produced otherwise Company: Performance Engineering Size: 300,000 BTU	$5,000
Engine	Company: MANN Size: 50kW, estimated 45 kW on biogas	$10,000
Generator	Assembly provided by Martin Machinery	$20,000
Insulated Tank (Digester)	Concrete tank with urethane insulation. Will act as anaerobic digester. Equipped with gas and water tight lids and pressure release valves to maintain 12-15” H_2O pressure head.	$400,000

A5) Operation and maintenance plan, Safety procedures.

See documents from Martin Machinery and Cow Power (to be provided at startup)?

A6) Drawings and Specifications of design approved by Mike Tiry, PE, and Dave Palmer

A7) Design Criteria for Mesophilic Digester

Parameter (For Steady State)	**Mesophilic**
Volume and Methane content of gas	75ft^3/cow/day 60% methane
BTU's produced	600 BTU/ft^3 biogas
Boiler efficiency	82%
BTU partition	30% to digester
Total Volatile Solids (Output vs input)	50% reduction
Total Solids (Output vs input)	30% reduction??
N, P, K, Output vs input	same with 14% more ammonia expected
Fecal Coliform counts	2 log reduction
Retention time	30-15 days
Temperature	98-100^{0}F

B: Economics

B1) Projected Economics

Capital Cost Items	**ICE**	**Life**	**Justification**
Manure Treatment Facility	763,000	10	Site work, Equipment Building, Tank
Manure Facility Equipment		5	Engine-Gen Set
Total Annual fixed costs		Includes: depreciation, interest, and taxes.	
Operating Costs			
Repairs/maintenance			10% of total cost?
Utilities			Natural gas backup?
Management labor @ $20/hr			240 hrs @ $20/hr skilled labor
Tractor Fuel			1.31 gal/hr, 180 hr, $1.40 per gallon for spreading manure
Insurance			Cost of insurance
Total annual operating costs			
Total Annual Costs			
Annual per cow cost			Assuming 400 cows

C: Schedule

D: Data Collection Procedures

D1) <u>Tracking Cost and revenues as listed in Task B above</u>

Objectives

To track the cost of the system to see if it is an economically-feasible alternative for small dairies to treat manure in this manner for odor control, power generation, and nutrient management.

Methods

Information on capital costs are recorded upon purchase, running costs will be recorded as the system is used over time.

D2) <u>Tracking material flows through the system by weight and volume.</u>

Objectives

To make a record of system performance while running under steady state conditions. This can be used to test system boundaries and optimize the performance of the system.

Methods

Manure Liquids

The weight of the liquids will be measured with a 5 gallon pail. The pail will have a known weight and volume and will be weighed with a hand held spring scale. The volume of liquids can be determined when all flows are confined to their respected storages. A measurement of the concrete tanks will be taken before liquids are added. After a known time, the tanks will be measured again. The change in height with the known dimension of the tanks will give the volume over the known time.

This will be done at least on one occasion (4 times in one day) to get an idea of the variance in the material. The value can then be compared to the pump run time and characteristics curve to establish a relationship between pump run-time and volume. After the relationship is established, manure volume flow can be determined automatically by recording pump run times.

Water

A water meter will be installed for the entire facility.

Material in Grit Chamber

An access port is already in place in each chamber of the digester. The port is 4" in size and goes all the way past the main heat exchanger which sits on a rack about three feet above the bottom. Before the startup of the digester, the distance to the bottom of the each chamber will be measured with a line having a heavy object secured to the end that will be lowered into the chamber. Subsequent measurements will be made once the digester is filled (probably on weekly basis) to monitor the buildup of deposits at the bottom of the chamber. After the digester has been operated for a period of 3-4 months, a determination will be made as to the frequency at which measurements to monitor material in each grit chamber ought to be made.

D3) Measuring product quality and quantity

Objective

To optimize system output based on the quality and quantity of methane.

Methods

Biogas

The gas produced is used in the biogas boiler at startup. After startup, the biogas will be used in the ICE to generate electricity and heat. A CO_2 meter will be used to determine the quality of the methane gas. The biogas through the system will be recorded daily. Measurements will be made using two gas meters that will be installed on the lines from each side of the digester as well as the flare (a gas meter will have to be added since only two meters were included in the existing contract with Yaman Construction). All biogas production reporting should be production under standard conditions (0°C, 1 atm) to allow direct comparisons of production among different systems. Measurements can be adjusted using the universal gas law:

$$V_2 = V_1 * (T_2/T_1) * (P_1/P_2)$$

Where: V_1 = gas volume (m^3) at temperature T_1 (°K) and pressure P_1 (mm Hg)
V_2 = gas volume (m^3) at temperature T_2 (°K) and pressure P_2 (mm Hg)

Heat

There are two BTU meters on the heat loop. The BTU meters will be used to keep track of the heat being used to maintain the digester's temperature. The heat lost from the heat dump radiator will be calculated by subtraction.

Stored Manure (to be constructed after the startup of the digester)

Twice a year, the storage will be sampled at three depths (top, middle, and bottom). These samples will be tested for the nutrients and pathogens listed in the chart below. Samples will be taken from four locations of the proposed long-term circular storage tank at each depth. The four samples will form a composite sample at each depth.

Nutrients

NH_4, TKN, Ortho P, P and other nutrients will be ascertained using Standard Methods at Cornell's bioenergy lab. Grab samples will be taken from the raw manure reception pit and the digester effluent pipe. These samples will immediately be placed in an ice-filled cooler and will be delivered to Cornell by the end of the working day (within 5 hours).

Composite samples

Composite samples will be needed of both the raw manure and the digester effluent. At least 6 grab samples of at least 1L will be taken over at least 1 hour. The total composite same will be at least 20L. The sample taken from this composite will be at least 1L, will be iced or refrigerated immediately, and delivered to the lab for testing within 24 hours.

Raw Manure from the Reception pit

Standard operating procedure is to run the recirculating pump while the alley scrapper is running to mix the incoming solids with the existing material in the pit. It will then be sampled with the procedure listed above for composite samples.

Digester Effluent

The effluent will be taken from the effluent chamber of the digester. The mixed composite sample will be poured into a 1L container to be delivered to the lab. If the sampling cannot be done from the effluent chamber of the digester, a sample will be taken from the tank that will hold the anaerobicly-digested liquids (tank to be constructed by splitting the existing 3-day storage tank).

Temperature

The temperature is logged on a data sheet daily by the system operator on site. These readings are taken using thermocouples. The ambient temperature will be extracted from the records of the on-site automatic weather station.

Electricity Generated

The amount of generated electricity will be tracked by the system. Records will be kept of the amounts of electricity generated, sold, and used on the farm. Parasitic power of the digester will be recorded by noting the times that digester motors and pumps are run daily and the energy used will be calculated from the run times.

Greenhouse Gas Emissions Reductions

Estimates of reductions in methane emissions should not be based on methane production. Rather, they should be based on estimated emissions from the previous conventional manure storage tank. Estimates of carbon dioxide emissions avoided by reducing the demand for electricity generated from fossil fuels should be based on the value for coal of 2,249 lbs of carbon dioxide per megawatt-hour (MWh)

D4) Monitoring Engine and Digester

Objective

Determine the effectiveness of the IC engine and ensure safe operation.

Methods

Engine

Meters will be in place to automatically monitor engine shut-down, oil pressure, coolant temperatures, phase voltages, and amperes. The data will be recorded automatically by the system. The following parameters will be reported:

*On-line efficiency, % = (engine-generator set hr per unit time/hr per unit time) * 100*

Average generator set output, kW = (kWh per unit time)/(engine-gen set hr per unit time)

Thermal conversion efficiency

*Thermal conversion efficiency, % = [(kWh generated/unit time * 3,412) / (biogas combusted, ft^3/unit time * methane content, decimal * lower heating value of methane, Btu/ft^3)] * 100*

The LHV of methane under standard conditions (0 °C, 1 atm) is 960 BTU per ft^3. However, the LHV of methane varies with temperature and pressure in accordance with the universal gas law and the LHV used should be for the temperature and pressure at which the biogas produced is being measured.

Tank Pressure

The pressure inside the digester tank, which is equivalent to the pressure in the gas line, will be monitored automatically and made available, both in real-time and historically at the system panel.

Maintenance

A log of time and materials used for engine maintenance will be recorded in a maintenance manual maintained on site in the CHP building.

D5) Cost and Frequency of Samples

The table below shows the cost for the samples, the area of sampling and the amount of money budgeted to sample.

In order to determine a baseline sample the digester will be sampled 6 times consecutively based on its retention time. If it has a 20 day retention time, every 20 days the samples will be taken until 6 sets are complete. After the initial baseline testing a sample will be pulled once a month for 6 months.

Start-up sampling: Each retention time

Sampling / monitoring Parameter	Raw Manure	Digested Effluent	Gas	Cost Each	Total samples	Cost Total
Total Solids	6	6		8	12	96
Total Volatile Solids	6	6		8	12	96
pH	6	6		3	12	36
Flow/ Volume/ CO_2/Weight/Temperature	X	X	X			
Total					36	$228

Continual sampling: Monthly

Sampling / monitoring Parameter	Raw Manure	Digested Effluent	Gas	Cost Each	Total samples	Cost Total
Total Solids	6	6		8	12	96
Total Volatile Solids	6	6		8	12	96
Total P	6	6		15	12	180
Ortho P	6	6		12	12	144
Total Kjeldahl Nitrogen	6	6		20	12	240
Ammonia	6	6		12	12	144
pH	6	6		3	12	36
Chemical Oxygen Demand	6	6		18	12	216
Flow/Volume/ Weight/Temperature	X	X	X			
CO_2			X			
H_2S			X			
Total					96	$1152

Short-Term Sampling:

Sampling/ monitoring Parameter	Raw Manure	Digested Effluent	Cost Each	Total samples	Cost Total
Fecal Coliform	3	3	20	6	120
MAPS	3	3	20	6	120
Total				12	$240

D6) Testing Methods

Sampling / monitoring Parameter	Test Method	Where
Gases: Methane/carbon dioxide Hydrogen sulfide Ammonia	 ASTM Method D 1945 ASTM Method D 5504-94 EPA Method 350.1	Cornell
Total Solids	Standard 2540 B from Standard Methods APHA AWWA WEF	Morrisville
Total Volatile Solids	Standard 2540 E from Standard Methods APHA AWWA WEF	Morrisville
Fecal Coliform	SM 18 9221C	CES
Total Phosphorous	HACH Method 10127	Cornell
Ortho Phosphorous		Cornell
Total Kjeldahl Nitrogen	HACH Method 8075 Nessler Method	Cornell
Ammonia	HACH Method 10031	Cornell
Total Organic Carbon	HACH Method 10128	Cornell
pH		On-Site
Chemical Oxygen Demand	HACH Reactor Digestion Method 8000 (EPA approved)	Cornell
Flow	Meter or other	On-site

Volume	Measurement per time	On-site
Weight	Spring Scale	On-site
Temperature	Thermocouple	On-site
Gases: Methane/carbon dioxide Hydrogen sulfide Ammonia	 ASTM Method D 1945 ASTM Method D 5504-94 EPA Method 350.1	Cornell
CO_2	CO_2 meter	On-Site

D7) Analysis

When the data is collected we will use statistical methods to determine that all the assumptions are met in order to determine the mean, standard deviation, variance and the 95% confidence interval of the mean. A comparison will be made with project expectations and design criteria and measured results. We also may run a regression to determine if there is a relationship between any of the measured parameters and gas production, heat production, hydraulic retention time or other outputs from the digester.

D8) Sampling reasons

Sampling/ monitoring parameter	**Reason for monitoring**	**Expected Results**
Total solids	This will allow us to get a more accurate flow model of the system	Reduction of 3% from system
Total volatile solids	This is a measure of how well the system is running and may help show odor reduction	Reduction of 30% from system
Fecal Coliform	Pathogen kill is important in the NYC watershed	2-3 log reduction
Total phosphorus	Reduction of phosphorus is a goal of this system	Possible reduction through separated solids
Ortho phosphorus	Nutrient flow is important for fertilizer value and CAFO plan	Possible exportation through selling composted solids
Total Kjeldahl nitrogen	Nutrient flow monitoring	Possible reduction
Ammonia	Nutrient flow monitoring	Possible reduction
pH	This is a system parameter to show how well the system is operating	At steady state unchanging
Chemical oxygen demand	This is a measure of potential gas production, also a measure of how potent the end material may be	Possible reduction, with hopes of good gas quality
Flow	Without measuring the flow of the system we have no way of monitoring total production of nutrients and mass	Steady state flow at a given retention time

Volume	Same as flow	
Weight	A reduction in the weight of the solids will allow for spreading further	Expected reduction in weight of material as solids
Temperature	This is a system parameter that needs to be monitored for the system to run correctly	Steady state temperature around 98^{o}F
Odor	Odor is the main cause of complaint from neighbors	Odor reduction.

Portions taken from: Association of State Energy Research and Technology Transfer Institutions (ASERTTI) Protocol for Quantifying and Reporting the Performance of Anaerobic Digestion Systems for Livestock Manures by John H. Martin, 2006