MEASUREMENT AND VERIFICATION (M&V) PLAN

FOR

LAMB FARM'S

Agreement # - ADG 121N

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Submitted to:

New York State Energy Research and Development Authority
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Introduction

This plan describes the approach to monitor the performance of the anaerobic digester gas (ADG) system installed at Lamb Farms, Inc. (ADG Contractor) to produce electricity from biogas. Biogas will be used to drive an engine-generator to produce power that will be consumed on site and/or exported back to the local utility. A monitoring system will be installed to measure and collect the data necessary to quantify the electric power produced by the engine-generator. The data will serve as the basis for payment of three (3) years of performance incentive payments, which Lamb Farms has applied for under a Standard Performance Contract with NYSERDA. The system has a Total Contracted Capacity of 400 kW.

ADG System Description

The digester system at the farm was designed by GHD, Inc. The site will operate a synchronous engine-generator system, provided by Martin Machinery, with piping and controls installed in the barn in front of the digester. The farm has a single 3-phase electrical service, which the engine is installed on, that is capable of accommodating the generator system. The system is tied to the grid and is able to run grid isolated, in the event of a utility outage.

Table 1. Biogas Systems at Site

Digester	GDH Anaerobic Digesters Plug Flow with Mixing, Hard Cover, Heated
Feedstock	Dairy Manure from approximately 1,100 cows and food waste
Engine-Generator	Guascor MGG-712 416 kW output on Biogas 480 VAC, 3-phase
Biogas Conditioning	Chilled water, Plate Frame Heat Exchanger (HX) for cooling and de-watering
Engine Backup/startup Fuel	No backup fuel. Propane tank used only for water loop / digester heating
Heat Recovery Use	Digester heating and in-floor heating in the separator barn, utility room, and parlor
Additional Heat Recovery	None

Guascor Engine and GenTec Engine Control Panel

Generator Nameplate: 416 kW

Biogas de-watering heat exchanger; 5 HP blower, and biogas piping to engine

Hot water storage tank and piping

Digester heat piping

Engine exhaust and biogas flare

Figure 1. Photos of System Components

Electric Panel

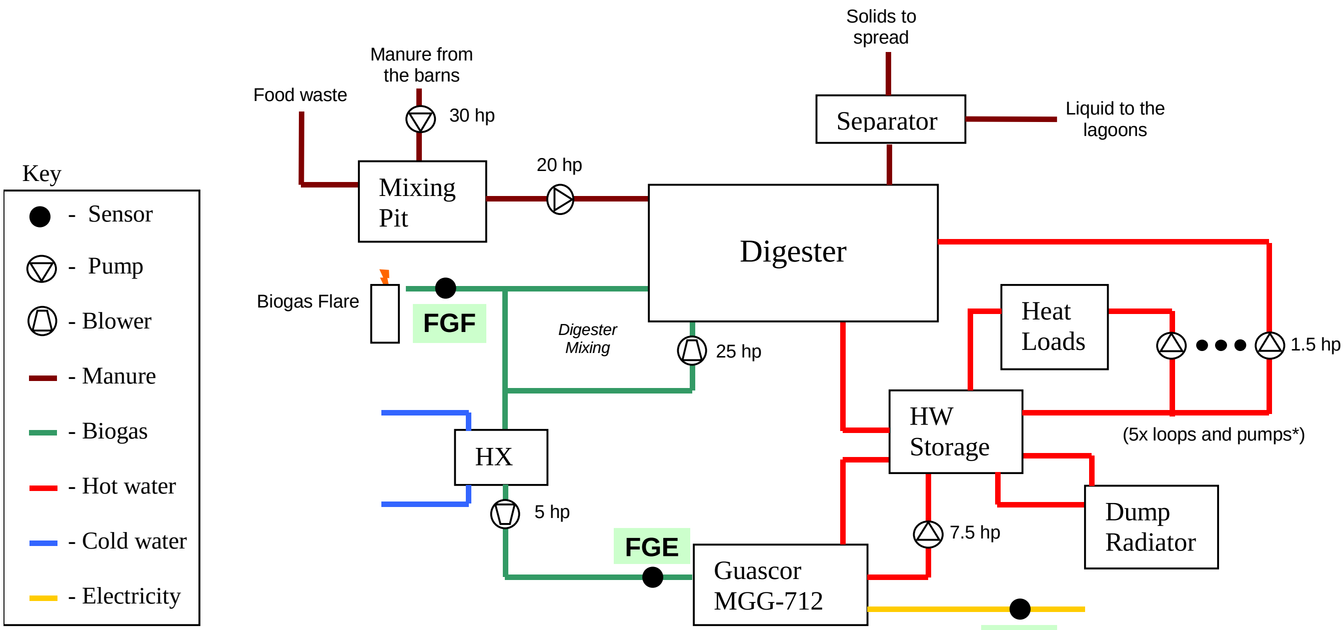
Digester Temperature Control Panel

Figure 2. Photos of Electrical Panels

Effluent Separators (4x, raised)

Figure 3. Manure Separator Units

Figure 4 schematically shows the biogas system, engine and instrumentation. Biogas from the digester is either used in the engine or flared. A 25 HP blower re-circulates biogas back thru the digester to provide mixing. Biogas supplied to the engine is cooled and dewatered by a chilled water loop and plate frame heat exchanger. The engine does not use any backup fuel, but propane could be used in a boiler to provide additional heat to the water loop / digester. A log of propane use will be kept by the farm.



* Three digester heating loops, one to separator barn & milk house, and one to food waste storage tanks.

Figure 4: Schematic of ADG System

Manure from the approximately 1,100 dairy cows and food waste is to be pumped directly into a mixing pit, before being pumped into the digester. Upon leaving the digester, effluent is pumped to one of the four separators. The solids are removed from the liquids and then spread over the fields for fertilizer, while the liquid waste is pumped to the storage lagoon. The digester is a plug flow design that uses biogas recirculation to provide some mixing. The biogas bubbles cause a corkscrew flow pattern as manure travels along the U-shaped digester (see plan view). The digester is heated with recovered heat from the engine. Heat transfer is enhanced by biogas bubbles driving manure flow across the hot water pipes which are mounted on the inside wall of the digester. The biogas recirculation helps provide some mixing to keep sediment from accumulating at the bottom of the digester while retaining the performance benefits of a plug flow arrangement. Figure 5 schematically shows a basic layout of the digester.

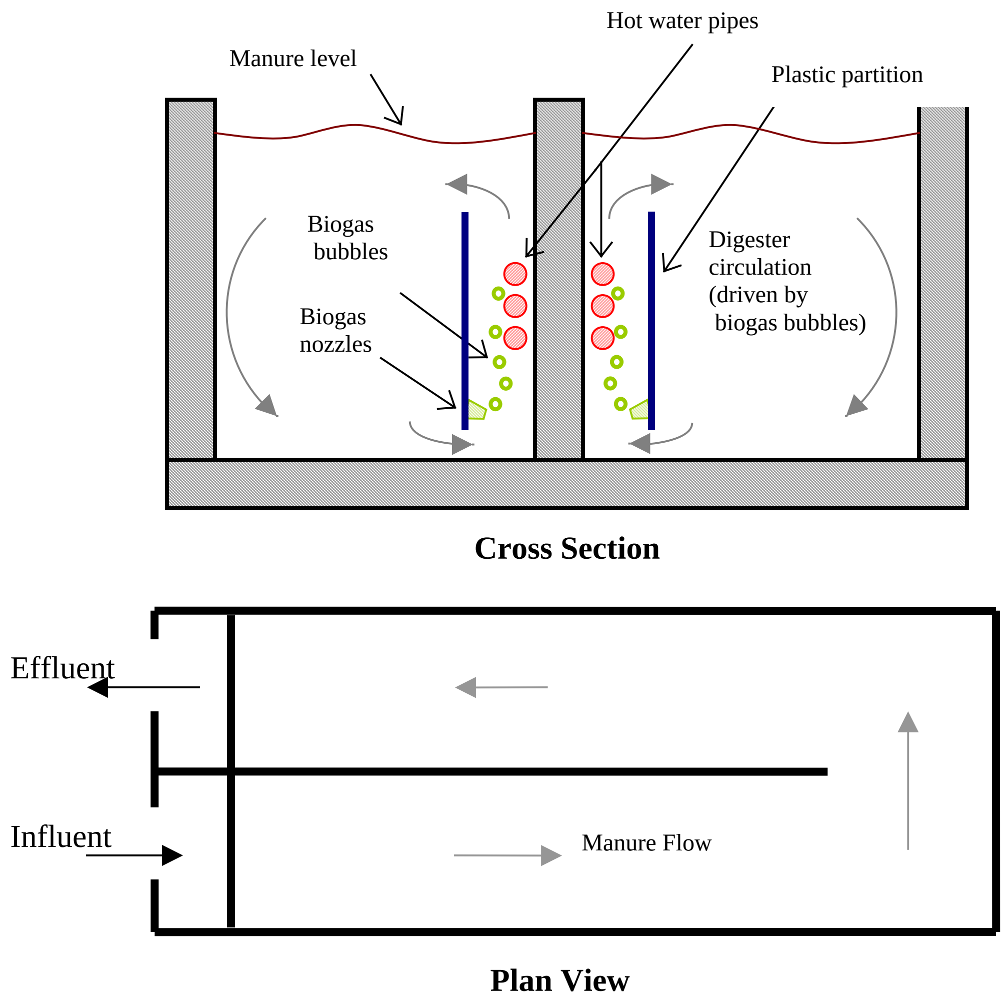


Figure 5. Digester Schematic

Monitoring System Equipment, Installation, Operation, and Maintenance

Figure 4 also shows the locations of the three data monitoring points where system performance will be measured: 1) a meter to measure fuel gas input to the engine generator (**FGE**), 2) a meter to measure fuel gas being flared **(FGF)**, and 3) a meter to measure the kilowatts generated by the engine (**WG**). Information on these data points is shown in Table 2.

Table 2. Monitored Points for ADG System

Point Type	Point Name	Description	Instrument	Expected Range
Pulse	WG	Engine-Generator Power	Intelisys NT Engine Controller	0 – 550 kWh
Pulse	FGE	Engine Biogas Flow	Sage Instruments Industrial Mass Flow Meter (Model: SIP 05-06), Material: 316 SS, with Modbus Output Calibrated for 6 inch pipe.	0 – 14,000 SCF / hour
Pulse	FGF	Flare Biogas Flow	Sage Instruments Industrial Mass Flow Meter (Model: SIP 05-06), Material: 316 SS, with Modbus Output Calibrated for 6 inch pipe.	0 – 14,000 SCF / hour

Note: ranges will be applied per interval as appropriate

The electrical output of the engine-generator will be measured with a Gen-Tec power transducer, connected to the Intelisys NT engine controller. The controller will be installed in a stand alone cabinet next to the engine. It has an external graphical display, which shows real time and total kWh. The power transducer will be installed according to Gen-Tec requirements.

The biogas input to the engine-generator will be measured by a Sage Prime mass flow meter installed in-line just above the engine-generator. A second Sage Prime mass flow meter, installed on the flare piping, measures biogas flow to the flare. The meters will be installed and maintained according to the "Sage Thermal Gas Mass Flow Meter Operations and Instruction Manual for Models SIP/SRP, Document 100-0001 Revision 05-SIP/SRG" as part of the engine generation equipment provided by Gen-Tec. A log of maintenance activities for the meters will be maintained at the site.

A separate cabinet, supplied by Gen-Tec, ie, the "Carbon Catcher System" houses the Red Lion HMI data logger. This unit monitors and records biogas flow and power output data from the three monitoring points described in Table 2 into csv files. The following data will be logged and compiled by the data logger:

1. Flare SCFM
2. Total CF to the flare
3. Engine SCFM
4. total CF to the engine
5. Accumulated kWh
6. Flare temperature

A graphical display on the Carbon Catcher shows kWh production and biogas flow information. The data logger will be programmed to record data for each monitoring point for each 15-minute interval. CDH will come on site to confirm all multipliers and data logger settings. The data logger will be connected to an uninterruptible power supply (UPS) to ensure the data logger retains its settings and data in the event of a power outage. The farm will provide a static IP address that will be used by the NYSERDA CHP Website Contractor to communicate with the data logger. The NYSERDA CHP Website Contractor will connect to the data logger nightly to extract data from the "Carbon Catcher" and transfer the data to the NYSERDA CHP Website. If communications are lost, the Red Lion data logger is capable of holding up to 2 years of 15 minute interval data.

The lower heating value of the biogas will be determined weekly from the measurements of carbon dioxide using a Fyrite Gas Analyzer, Model No. 10-5032 for CO_2 range 0-60%. Lamb Farms's staff, will perform the CO_2 tests and record the results in the project log.

Management of Monitoring System Data (Farm Responsibilities)

The farm will perform the following quality assurance and quality control measures to ensure the data produced from the monitoring system accurately describes system performance.

On a daily basis, the farm equipment manager will perform inspections of the digester and engine-generator equipment and record findings into the project log.

On a weekly basis, the farm equipment manager will perform inspections of the M&V meter installations and complete the routine maintenance on the meters, noting any abnormalities or unexpected readings. The farm will also maintain a weekly log of the cumulative power generation (kWh) and gas flow (cf or ft^3) from both the engine and flare in the event that data transfer to the NYSERDA CHP Website fails or other anomalies occur.

On a weekly basis, the farm staff agrees to review the data available on the NYSERDA CHP Website (chp.nyserda.org) to ensure it is consistent with their observed performance of the ADG system and logged readings. The farm will review the data using the reporting features at the web site, including:

- Monitored Data – Plots and Graphs
- RPS: Customer-Sited Tier Anaerobic Digester Gas-to-Electricity Program NYSERDA Incentive Program Reports

In addition, the farm staff will also setup and use the email reports that are available to help the track system performance, including:

- a periodic email report summarizing system performance and the estimated incentive,
- an email report sent out if data are not received at web site or do not pass the quality checks

The website will automatically take the data collected from the datalogger and evaluate the quality of the data for each interval using range and relational checks. The expected ranges for the sensors (see Table 2) will be used for the range checks. The relational check will compare the kWh production data and gas production data for each interval to ensure both meters always provide non-zero readings at the same time (e.g., to detect if a meter has failed). Only data that pass the range and relational quality checks are used in the incentive reports listed above. However, all hourly data are available from the NYSERDA CHP Website using the "Download (CSV file)" reporting option.

In the event of a communications or meter failure, the farm will work with CDH to resolve the issue in a few days.

If unanticipated loss of data occurs when the engine-generator continues to produce electricity, the farm will follow the procedures outlined in Exhibit D of their contract, i.e. using data from similar periods – either just before or after the outage – to replace the lost data. The farm understands that they can use this approach for up to two 36 hour periods within each 12-month performance reporting period. If more than two such data outages occur, the farm will provide information from other acceptable data sources (e.g., weekly recorded logs) to definitively determine the amount of power that was produced from biogas during the period in question.

Annual M&V Reports

The farm will prepare the Annual M&V Report, which will include a table showing the monthly kWh production biogas sent to the engine, and other data listed in Table 3. The farm may use the NYSERDA Incentive Program Reports found on the CHP website. Alternatively, they may provide their own summary of the data (using hourly CSV data downloaded from the Website) along with a narrative justifying why their data and calculations are more appropriate. The methods for calculating these values are provided below.

Table 3. Summary of Data for Annual M&V Report (provided for each engine)

Monthly Periods	No. of Days in Each Period	Biogas Used by Engine (cubic feet)	LHV_{biogas} (BTU/cf)	Biogas Energy Content Q_{biogas}	Electricity Production $kWh_{generation}$

The farm will calculate monthly values for lower heating value of the biogas (LHV_{biogas}) and total energy content of the biogas (Q_{biogas}) as defined below.

Monthly Biogas Lower Heating Value

The readings of CO_2 concentration in the biogas will be gathered weekly to estimate the average monthly Biogas Lower Heating Value using the following equation:

$$LHV_{biogas} = LHV_{methane} \cdot (1 - F_{CO2})$$

where:

$LHV_{methane}$ - lower heating value of methane (911 Btu/ft^3 at standard conditions, 60 °F and 1 atm)

F_{CO2} - fraction of biogas that is CO_2 (average of readings for each month)

Monthly Biogas Energy Content

Calculate the average monthly Biogas Energy Content using the following equation:

$$Q_{biogas} = CF \cdot LHV_{biogas}$$

where:

CF - volume (ft^3) of biogas in month

Reasonable Electrical Efficiency

The M&V Report will also provide a comparison of power output and fuel input for the engine to confirm their reasonableness. For instance the electrical efficiency – measured as power output ($kWh_{generator}$) divided by the energy content of the fuel input (Q_{biogas}) in similar units and based on lower heating value – should be in the 25%-35% range over any interval for the engine generator at Lamb Farm.

Appendices

Cut sheets and Manuals for:

Sage Metering Inc. Model SIP-05-06-STCF05-DC24-DIG-GAS Mass Flow Meter
http://www.sagemetering.com/specs/2ndgen/SIP-insertion-spec.pdf

Carbon Catcher
http://cdhnrgy1.user.openhosting.com/Documentation/Carbon Catcher Generic Info Sheet v2-1.pdf

Red Lion Controls G306A000 Data Logger with Graphic Interface
http://www.redlion.net/products/groups/operatorinterface/g306/docs/07037.pdf

Fyrite Gas Analyzer
http://www.bacharach-inc.com/PDF/Brochures/fyrite_gas_analyzers.pdf
http://www.bacharach-inc.com/PDF/Instructions/11-9026.pdf

Lamb Farms Addendum

Site Events

Date	Event
1/25/2010	Data first up to site. Engine only running at 75 kW (rated for 400 kW).

Hardware

Device	Serial #	Outut	Carbon Catcher Data Point
Intelisys NT Engine Controller		kWh (acc)	KWH_Output
Sage SIP-05-06		CF & CFM	SCF_Total_Engine1
Sage SIP-05-06		CF & CFM	SCF_Total_Flare

Database Setup

```
Chan Name               Device        column
KWH_Output,             GasUsage,       2
SCF_Total_flare,        GasUsage,       3
Flare1_Temp,            GasUsage,       4
SCF_Total_Engine1,      GasUsage,       5
SCFM_Flare,             FlowRate,       2
SCFM_Engine,            FlowRate,       3
```

Sensor Verification

Power Meters

		WG (kW)
CC Log	2/23/2010 1:45	76
GenTec Meter	2/23/2010 1:50	74.5
Manual	2/23/2010 2:15	68.8

Flow Meters

	Date & Time	FGE (acc)	FGE (scfm)	FGF(acc)	FGF (scfm)
CC Log	2/23/2010 1:45	795157	65	2295306	76
Meter	2/23/2010 1:50	795750	63	2196088	77
% Diff		0.1%	3.1%	4.3%	1.3%

Photos

Gentec engine control panel.


Digester control panel.