MEASUREMENT AND VERIFICATION (M&V) PLAN

FOR

SHELAND FARMS DIGESTER GAS (ADG) SYSTEM

CONTRACT # ADG 120N

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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 that is installed at Sheland Farms (ADG Contractor) to produce biogas and electricity. Biogas is 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 has been installed to measure and collect the data necessary to quantify the electric power produced by the engine-generator. The data serves as the basis for payment of three (3) years of performance incentive payments, which Sheland Farms has applied for under a Standard Performance Contract with NYSERDA. The system has a total contracted capacity of 100 kW.

ADG System Description

The digester system was designed by Siemens and Stearns & Wheeler. The synchronous engine-generator system, with piping and controls, are installed in the building adjacent to the digester. All the electrical loads at the farm have been consolidated into one 3-phase electrical service in order to accommodate the generator systems. Electricity is produced in parallel with the utility, so power can be exported to the grid. The electrical system includes controls to synch the generator to the grid as well as protective relays and controls to automatically isolate the farm from the utility grid in the event of a utility power outage. The system does not have the capability to run grid isolated, so in the event of a power outage the biogas engine will go down.

Table 1. Biogas System

Digester	Siemens Building Technologies, Inc. Vertical Complete Mixed, Covered, Heated
Feedstock	Dairy Manure, approximately 800 mature cow equivalents
Engine-Generator	CAT : Wagner Power Systems
Biogas Conditioning	De-watering (via shell and tube heat exchanger with air cooled chiller)
Engine Backup/startup Fuel	None (propane used for boiler)
Heat Recovery Use	Digester heating, unit heaters, manure preheating, recovered solids drying
Additional Heat Recovery	Space Heating

Caterpillar engine and generator

Biogas flare

Biogas Conditioning - Chiller

Biogas Conditioning – shell and tube heat exchanger

Figure 1a. System Components

Sage Gas Flow Meter - #1 (total gas flow)

Sage Gas Flow Meter - #2 (flow to engine)

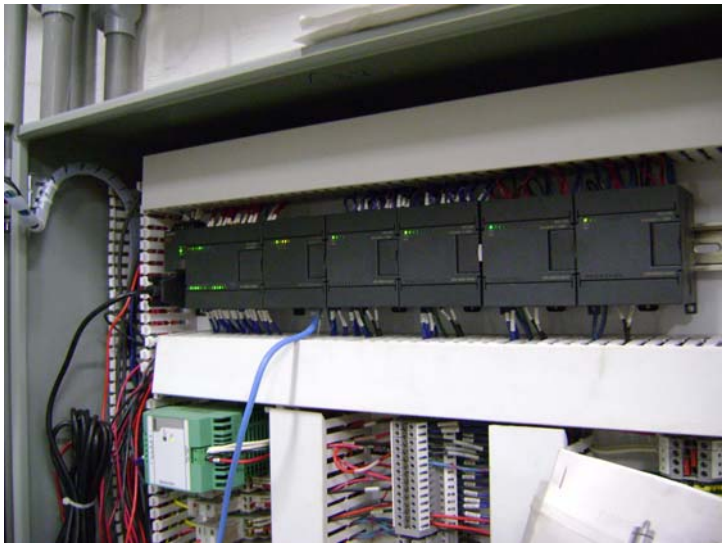
Sage Meter #1 Display

Sage Flow Meter #2 Readout Display

Figure 2b. System Components

Electric control panel, Siemens PLC, and Touch Screen

Siemens Touch Screen (back of door)



Siemens PLC and Electric Box Interior

Veris Power Meters (measuring power use in back dairy barn, EP-2 on the Display; EP-4 at Breaker)

Figure 2. Meters and Electrical Panels

Figure 3 schematically shows the biogas system and engines. Manure from approximately 800 cows is pumped into the reception pit. From there the manure is fed through a separator with the separated liquids and overflow manure returning to the reception pit, while solids separated are removed completely. The digester is then fed with the combination of raw manure and separated liquid from the reception pit. Slurry from the digester is pumped thru a heat exchanger so that heat recovered from the engine can be used to heat the digester. In the event that the engine heat recovery system is not providing enough heat to the water loop, a propane boiler provides additional heat. Digester slurry is pulled through the Rotamix system, which consists of piping, a horizontal end suction chopper pump, and three nozzles in the digester. The system runs for 2 hours at a time on 4 hour cycles and is responsible for keeping the digester well mixed and preventing a crust layer from building up on the top layer of the digester.

Biogas from the digester is either used in the engine or flared. The biogas flare operates using a mechanically actuated valve that vents biogas to maintain the digester at the desired static pressure of 8.3" of water column. Biogas for the engines is treated by a mechanically cooled de-watering system in the room adjacent to the engine generator.

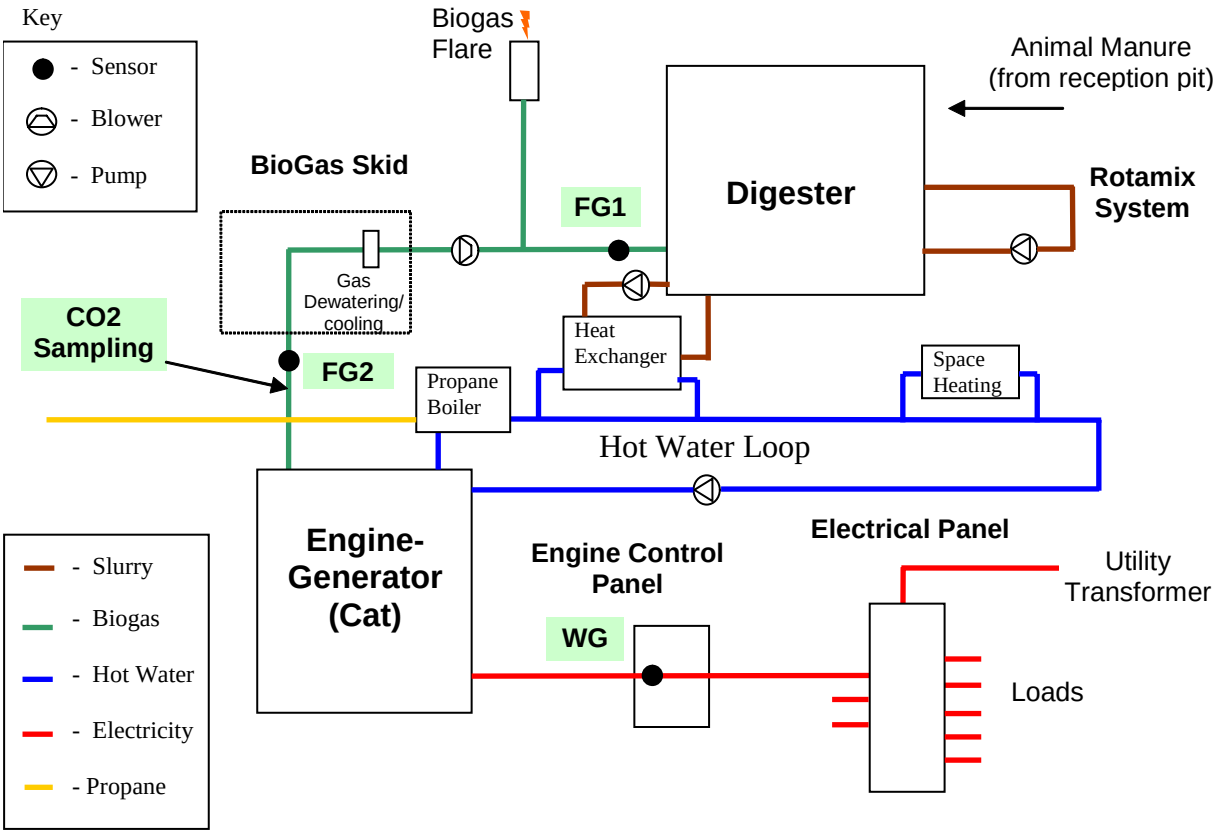


Figure 3. Schematic of Biogas System with Meters and Sensors Shown

Monitoring System Equipment, Installation, Operation, and Maintenance

Figure 3 also schematically shows the locations of the monitoring points that are used to measure system performance. Two gas meters measure the total amount of biogas from the digester (**FG1**) and the amount of biogas used by to the engine generator (FG2). A separate power meter was installed to measure the kilowatts generated by the engine generator (WG).

Table 2. Monitored Points for ADG System

Point Type	Point Name	Description	Instrument	Expected Range
Analog	FG1	Biogas produced	Sage inline flow meter SRG-05-15	0 – 3600 SCF / hr
Analog	FG2	Biogas to engine	Sage inline flow meter SRG-05-15	0 – 3000 SCF / hr
Analog	WG	Power produced by generator	Veris power meter H8044-0300, 4-20 ma out	0 – 120 kWh / hr

The electrical output of the engine is measured with a Veris analog-output power transducer (**WG**). The Veris meter was installed in the Disconnect near the Woodward Panel consistent with Veris' typical installation standards (copy in Appendix). The meter has its own inline fuse to provide over-current protection. Veris power meters are also measuring the power usage of the back dairy barn, the total parasitic load of the biogas system, and the total farm power.

The total biogas produced and the biogas input to the engine is measured by two Sage SRP-300 in-line, hot-wire mass flow meters, (**FG1)** and (**FG2**) respectively, which were both recalibrated and reinstalled February 19, 2009. The meters provide signals proportional to the volumetric flow rate (SCF – standard cubic feet), which are compensated for temperature up to 60^{o} F. The Sage meter **FG1 is** installed in the biogas conditioning room and meter **FG2** is installed in the horizontal biogas pipe leading to the engine; both can be seen in Figure 1. A log of maintenance activities for both meters will be maintained at the farm.

The lower heating value for the biogas is calculated from measurements of the CO_2 content of the biogas. This value will be adjusted based on weekly measurements of carbon dioxide using a Fyrite Gas Analyzer Model No. 10-5032 for CO_2 range 0-60%. The farm staff will perform the CO_2 tests and log the results on the biogas log sheet.

There is a propane line running to the pump room to supply the burner for supplementing the engine heat recovery. Since propane is not used by the engine its use will not be measured.

Data is collected by the Siemens programmable logic controller (PLC), which is installed in the pump room (see Figure 2). The data is sampled for each 15-minute interval. Recorded values include engine output (kW), biogas flow from the digester (SCF/h), and biogas flow to the

engine (SCF/h). The PLC is "bridged" to a PC in the farmhouse[1] via secure wireless Ethernet. All the monitored data is stored on the PC using the software package XLReporter (an Excel addin). The PC has a scheduled task to upload logged data to the NYSERDA CHP Website on a daily basis. If communications are lost the PC is capable of storing several months of data.

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) from and gas flow (cf or ft^3) to the engine 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 is not received at the web site or does not pass the quality checks

Stored data will be uploaded to the CHP website on regular intervals. The website will 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 is available from the NYSERDA CHP Website using the "Download (CSV file)" reporting option.

[1] The PC will eventually be moved into the new farm office.

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 in 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 Annual M&V Report will include a table showing the monthly kWh production and biogas production. The farm may use the standardized Annual M&V report (see Table 3). 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 table will also include monthly values for the calculated lower heating value of the biogas and total energy content of the biogas. The methods for calculating these values are provided below.

Table 3. Summary of Data for Annual M&V Report

Monthly Periods	No of Days in Each Period	Electricity Production $kWh_{generator}$	Biogas to Engine meter **FG2** (SCF/h)	LHV_{biogas} (BTU/cf)	Biogas Energy Content Q_{biogas} (Btu)

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 (from FG2)

Since the engine does not use a backup fuel, there are no adjustments to $kWh_{generator}$.

Appendices

Cut sheets and Manuals for:

Sage Flow Meter
http://www.sagemetering.com/docs/product_brochure500.pdf

Veris Power Meter
http://www.powermeterstore.com/crm_uploads/h8040_d.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

Sheland Farms Addendum

Site Events

Date	Event
11/9/2007	Data collection begins
3/1/2009	Had flow meters recalibrated
8/5/2009	Verified recalibrated Sage meters

Hardware

Device	Serial #	Output	Siemens Tag	CDH Tag
Sage SRG-05-15-SVA05	28890-29584	CFM	FT-1 Gas Flow	FG1
Sage SRG-05-15-SVA05	28889-29587	CFM	FT-2 Gas Flow	FG2
Veris Power Meter H8044-0300		kW	Cogen Output Power	WG

Database Setup

Chan Name	Device	column
FT-1 Gas Flow,	CDH_REPORT,	0
FT-2 Gas Flow,	CDH_REPORT,	1
Cogen Output Power,	CDH_REPORT,	3
Parasitic Load Power,	CDH_REPORT,	4
Farm Load Power,	CDH_REPORT,	5
Engine Heat Exchanger Input Temp,	CDH_REPORT,	11
Engine Heat Exchanger Output Temp,	CDH_REPORT,	12

Sensor Verification

Power Readings (kW) for each Meter

	10 to 11 am				noon
Woodward Power Transducer (screen)	68	87	74-89	72-88	85-88
Veris 8804-300 (on PLC screen)	67	85	73-85.5	72-85.5	84.5-85
Fluke 39 (handheld)	-	-	70-87	70-87	-

Note: Values recorded in the raw data file for the Veris meter (COGEN) for 10-11 am period ranged from 71.5 to 85 kW with average of 80 kW

Generally the CDH Energy's hand held Fluke meter was halfway between the Woodward and Veris meters. The Veris reading was lower than the Fluke meter by 2-2.5 kW.

The biogas readings for the two meters were taken when the flare was off (so the two meters should be equal). The two readings were typically off by 10% indicating the uncertainty of the Sage meters (or the impact of the biogas chilling system).

Biogas Readings (scfm) for each Meter

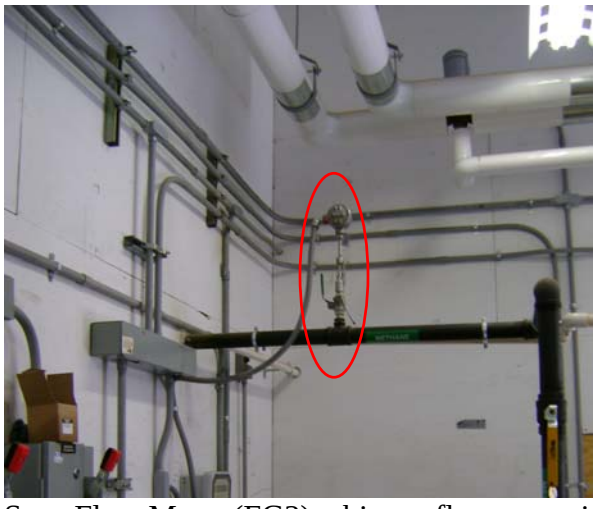
	10 am	10:30 am	noon
Engine Biogas (FG2)	29-31	24	31.3
Total Biogas (FG1)	32-34	26	33.7

We also verified that the EP-2 power transducer (actually Breaker EP-4) was high by a factor of 3, indicating that the multiplier for this 100 amp transducer was incorrect (300 amp multiplier may have been used instead).

Siemens control panel with Veris Power Transducer's output displayed on far left.

Woodward Power Transducer's display screen

Sage Flow Meter (FG1) – total biogas flow



Sage Flow Meter (FG2) – biogas flow to engine

Sage Display (FG1) – total biogas flow

Sage Display (FG2) – Biogas flow to engine