MEASUREMENT AND VERIFICATION (M&V) PLAN

FOR

BOXLER DAIRY FARMS

ANAEROBIC DIGESTER GAS (ADG) SYSTEM

Contract # 116N

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Introduction

Boxler Dairy Farm, located in Varysburg, NY, currently milks 1,700 cows. With the recent addition of a fourth barn, they have capacity for 2,000 cattle. Recently, the farm has installed a mixed plug flow digester and a biogas generation system to help treat the manure produced by the cows and to utilize the waste gas produced by digestion to generate electricity.

This plan describes the approach to monitor the performance of the anaerobic digester gas (ADG) system that is installed at Boxler Farm to produce biogas and electricity. Biogas is used to drive an engine-generator to produce power that is consumed on site and/or exported back to the local utility. A monitoring system is 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 a capacity incentive to help with the capital expenses associated with the procurement of the new generation equipment and three (3) years of performance incentive payments, which the farm has applied for under a Standard Performance Contract with NYSERDA based on a Total Contracted Capacity of 400 kW.

ADG System Description

The digester system at the farm was designed by GHD, Inc. and is approaching substantial completion as of August, 2009. With the addition of the new engine-generator, the site will operate a 400 kW synchronous engine-generator system with piping and controls installed in the engine room of a new pole barn near the digester. Waste heat from the generator will pass through a plate heat exchanger and will be used for space heating in the milk house, digester heating, and solids drying (QHR).

All the electrical loads at the farm (including lighting, HVAC, plugs loads, etc.) have been consolidated into a new 3-phase electrical service in order to accommodate the generator system. The electrical system includes controls to synch the generator to the grid as well as a protective relay and controls to automatically isolate the farm from the utility grid in the event of a utility power outage. The generator is connected through one bi-directional (1) meter to the National Grid distribution system. The facility has a 250 kW backup diesel generator that can be operated during utility outages. The facility energy consumption is approximately 1,130,000 kWh/year (based on October 2006- October 2007 billing data). It is expected that the biogas engine generator will provide 150-200% of the energy required at the farm. Figure 1, located in Appendix A, is a schematic of the electrical system at the farm.

Currently, the farm receives electricity from National Grid via a connection near the road. With the recent building and electricity generation equipment installations, it was decided to move the utility connection to a location proximal to the new facilities. As part of the electrical upgrades completed in preparation for the new generation facilities, National Grid has provided a 500 kW 480/277 transformer connected to a 1,200 amp disconnect/transfer switch. The 1,200 amp main panel serves the 480V engine room panel, the grain facility and barn #4. Outside the building, a high voltage step up transformer, two (2) terminal boxes and a high voltage step down transformer supply electricity to the shop, the sugar house, the home, and barns #1-3. Figure 2, in Appendix A, includes photographs of the digester and the electric generation system.

Figure 3, in Appendix A, schematically shows the biogas system and engines. Approximately 1,700 cows are kept in four (4) barns. Manure from these cows is sent into a reception pit below all four (4) barns. Manure from dry cows is pumped into this pit daily, while heifer manure is collected and trucked in every other day. In addition, silage leachate flows into the reception pit as it accumulates and food waste is also dumped into the pit. From the reception pit, manure is fed to the digester every three (3) hours following a 15-minute period of mixing. A portion of the biogas is directed back to the digester to facilitate mixing. Biogas from the digester is either used in the engine or for mixing. Excess biogas is flared. Direction of the biogas is automatically controlled via a control panel located on the wall to the left of the piping network. Biogas for the engine is de-watered, scrubbed of H_2S and pressurized to one (1) psi via biogas conditioning equipment prior to being sent to the engine-generator. After digestion, the manure is pumped to screw press separators located on the second floor of the generator/solids building. After passing through the separators, the solids are used for bedding and the liquids are sent to a leachate pond. Table 1, below depicts the biogas electric generation system components.

Table 1. Biogas Systems at Boxler Farm

Digester	GHD. Inc. Mixed Plug Flow, heated, hard cover
Feedstock	Dairy Manure, ~1,700 cows
Engine-Generator	Gauscor MGG-950 400 kW contracted output on biogas 480 VAC, 3 phase
Biogas Conditioning	Water trap H_2S removal Pressurization of biogas to 1 psi
Engine Backup/startup Fuel	None
Heat Recovery Use	Digester heating Milk house space heating Solids drying

Monitoring System Equipment, Installation, Operation, and Maintenance

Figure 3 also shows the locations of the three data monitoring points which are used to measure system performance. A gas meter measures biogas input to the flare (**FGF**), and a second meter measures biogas input to the engine (**FGE**). A power meter, located between the engine generator and the Gen-Tec breakers measures the kilowatts generated (**WG**). Information on these data points is shown in Table 2.

Table 2. Monitored Points for ADG System

Point Type	Point Name	Description	Instrument	Engineering Units	Expected Range
Pulse	WG	Engine-Generator Power	IS-NT Data logger	kW kWh	0-500 kW 0-125 kWh/15 minutes
Pulse	FGF	Flared Biogas Flow	Sage Metering Inc. Model SIP-05-06-DC24-D (biogas)	ft^3	0-2,500 ft^3/15 minutes
Pulse	FGE	Biogas Flow to Engine	Sage Metering Inc. Model SIP-05-06-DC24-D (biogas)	ft^3	0-2,500 ft^3/15 minutes

The electrical output of the new engine will be measured with a pulse-output data logger (**WG**). This logger will include an LCD display and will be installed next to the electrical panel for the new engine by the Farm's electrical contractor. The data logger has the capability to measure kWh data and will be utilized instead of a separate power transducer. It will be installed according to requirements in the "InteliGen^{NT}, InteliSys^{NT} Modular Gen-set Controller Operator Guide for SPI, SPtM, MINT, Cox" Software version IGS-NT-2.0, September 2006 (Appendix B). The meter will have its own circuit breaker or inline fuse to provide over-current protection.

The biogas input to the engine will be measured by a Sage Prime industrial gas meter (**FGE**) with pulse output installed near the gas control panel in the engine room. A second gas meter (**FGF**), located near the ceiling, will measure the biogas directed to the flare. The meters will be installed in accordance with the provisions of the "Sage Thermal Gas Mass Flow Meter Operations and Instruction Manual for Industrial Style Models SIP and SRP Document Number 100-0001 Revision 05-SIP/SRP (Sage Prime™)" as part of the engine generation equipment provided by Gen-Tec. Maintenance activities will be performed in accordance with the instructions in the O&M manual. A log of maintenance activities for the meter will be maintained at the site.

The lower heating value for the biogas is conservatively estimated to be 580 Btu/ft^3. Once the system is operational, this value will be verified weekly based on measurements of carbon dioxide using a Fyrite Gas Analyzer Model No. 10-5032 for CO_2 range 0-60%. Farm personnel will perform the CO_2 tests and log the results in the project log.

The Is-NT data logger, supplied by Gen-Tec, will compile and log the data from the following monitoring points:

- SCFM for the flare.
- Total volume to flare
- SCFM for the engine.
- Total volume to engine
- Accumulated kWH.
- Engine run status
- Flare temperature

Additional data points can be added if desired. The data logger will be programmed to average or totalize data for each monitoring point for each 15-minute interval as appropriate. A record of all multipliers and data logger settings will be maintained. The data logger will be located in the generator room next to the control panel, and 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 UPS is capable of powering the data logger for at least one day. The farm will provide a dedicated phone line (or an Ethernet connection with fixed IP address) that will be used to communicate with the data logger. The NYSERDA CHP Website Contractor (CDH Energy Corp.) will communicate with the data logger nightly to extract monitored data from the data logger and transfer the data to the NYSERDA CHP Website. If communications are lost, the data logger is capable of holding at least 15 days of 15-minute interval data.

Boxler Farm staff will be responsible for the cost to purchase and install the data logger/power meter (**WG**) and biogas meters (**FGF and FGE**). The bi-directional power meter on the main utility line ($\mathbf{WT_{in}}$ and $\mathbf{WT_{exp}}$) was installed as part of the net metering interconnection agreement with National Grid.

Management of Monitoring System Data (Farm Responsibilities)

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

Upon installation of the monitoring equipment, the farm equipment manager will work with the installation contractors or equipment vendors to ensure that the monitoring equipment is functioning properly. The farm equipment manager will review the operation manuals for an understanding on how to use and maintain these meters.

The farm equipment manager will then follow the operation & maintenance procedures and will setup a training session to relay these procedures to all other appropriate employees.

On a daily basis, the farm equipment manager (or other specified employee) 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.

On an annual basis, the farm equipment manager will perform a review of the M&V meter installations and performance throughout the year and complete any required recalibration or maintenance as indicated in the operation and maintenance manuals. Should the meters require repair or replacement, the farm equipment manager will contact the meter vendor for direction.

The farm will also maintain a weekly log of the cumulative power generation (kWh) and gas flow (cf or ft^3) to the new engine in the event that data transfer to the NYSERDA CHP Website fails or other anomalies occur.

On a weekly basis, the farm staff will review the data stored on the NYSERDA CHP Website (chp.nyserda.org) to ensure it is consistent with their observed performance of the ADG system and logged readings. If data abnormalities are identified, farm personnel will take corrective action. The farm will review the data using the reporting features at the website, including:

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

The website will automatically take the data collected from the data logger 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 15-minute 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.

To help track system performance, the farm staff will sign up for automated emails at the NYSERDA CHP Website in order to receive:

- A periodic email report summarizing system performance and the estimated incentive
- An email report sent out if data is not received at web site or does not pass the quality checks

In the event of a communications or meter failure, farm personnel 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. Farm personnel understand that they can use this approach for up to two (2) 36-hour periods within each 12-month performance reporting period. If more than two such data outages occur, farm personnel 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

Measurement and verification (M&V) reports are designed to quantify the variation of the ADG system's gas consumption, power output and efficiency over an extended period of time as well as demonstrate the benefits of heat recovery for other uses at the facility. As part of NYSERDA's ADG program, the M&V Report must be completed annually for a period of three (3) years. Farm personnel 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.

Farm personnel 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 Monthly Data for Annual M&V Report

Start Date of Reporting Period	Monthly Periods	Number of Days in Reporting Period	Electricity Production, $kWh_{generator}$	Biogas Production, CF (cubic feet)	Biogas to Flare, CF	Biogas to Engine, CF	Biogas LHV, BTU/CF	Biogas Energy Content, Q_{biogas} BTU
TOTALS								

Farm personnel will calculate monthly values for lower heating value of the biogas and total energy content of the biogas, as indicated on the following page. The engine generator runs only on biogas. There is no backup fuel or start-up fuel. Generator outputs are turned down when biogas availability decreases. Therefore, no additional calculations are required to determine adjusted electricity production.

Monthly Biogas to Engine

Farm personnel will use the readings from the biogas production and biogas flared meters to determine the monthly Biogas to Engine using the following equation:

$$Biogas_{engine} = Biogas_{produced} - Biogas_{flared}$$

Monthly Biogas Lower Heating Value

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

$$LHV_{biogas} = LHV_{methane} \cdot (1 - F_{CO_2})$$

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

Farm personnel will 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 on Boxler Dairy Farm.

Figure 2: **Photos of Digester Gas Generation System Components**

Engine Room

Biogas Engine Generator

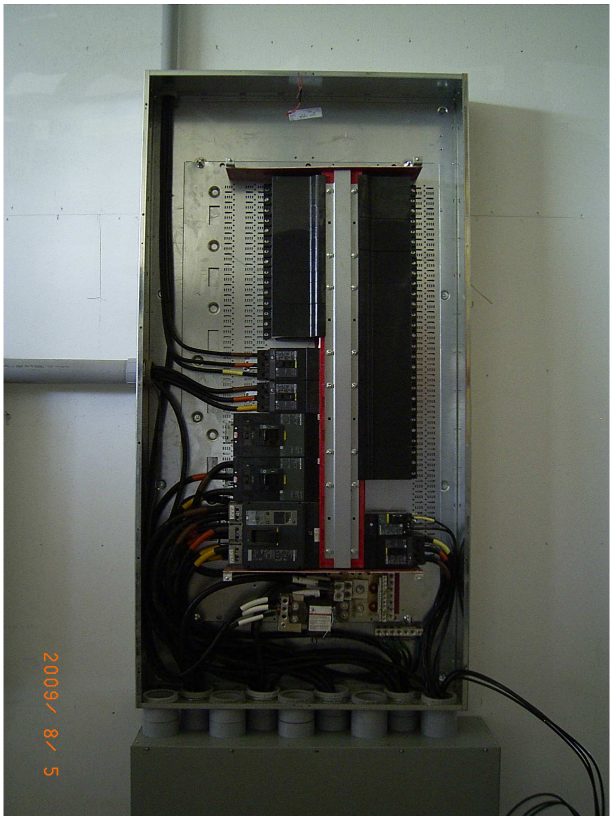
Red and blue heat exchange piping, water tank

Sludge Separators

Foreground: Top of Digester, Background: Engine Room and Solids Building

Digester

Breaker/Transfer Switch Gear Box



480V Panel

1,200 amp Breaker Box for Gen-Tec

Figure 3: Biogas System Schematic