MEASUREMENT AND VERIFICATION (M&V) PLAN
FOR
SUNNY KNOLL DAIRY FARM
ANAEROBIC DIGESTER GAS (ADG) SYSTEM
Contract # 109E

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Submitted to:

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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 Sunny Knoll 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 three (3) years of performance incentive payments, which the farm has applied for under a Standard Performance Contract with NYSERDA.

ADG System Description

The digester system at the farm was designed by RCM Digester International LLC and installed in May 2006. The site operates a 230 kW synchronous engine-generator system with piping and controls installed in a pole barn near the digester and designated 'generator room'. Waste heat from the generator passes through a Mueller heat exchanger (HX) and is used for space heating, and digester heating (QHR).

All the electrical loads at the farm (including lighting, HVAC, plugs loads, etc.) have been consolidated into a 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 (1) meter to the National Grid distribution system. The facility does not have the capability to operate grid-isolated.

Table 1. Biogas Systems at Sunny Knoll Farm

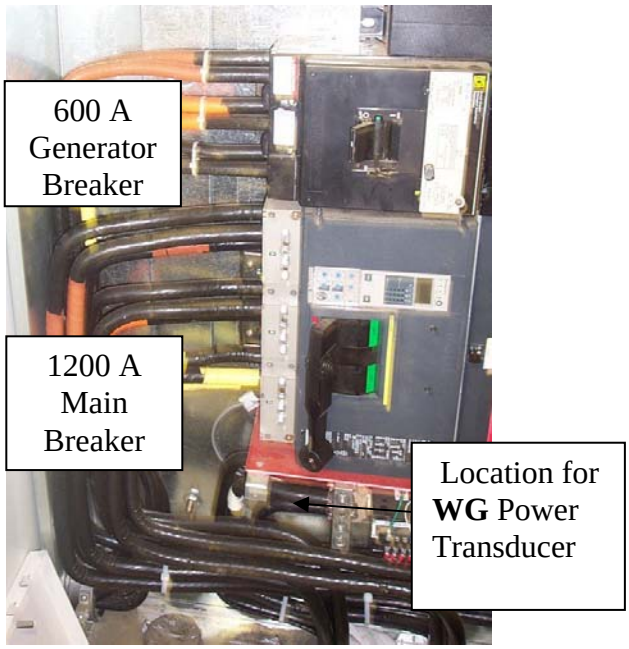
Digester	RCM Digesters Plug Flow, Soft Cover, heated
Feedstock	Dairy Manure, ~1800 cows
Engine-Generator	Caterpillar G379 Stamford HCI636H1L 230 kW output on biogas 480 VAC, 3 phase
Biogas Conditioning	Filtration Systems, Inc Model G84818V Water Separators
Engine Backup/startup Fuel	Natural Gas
Heat Recovery Use	Digester heating Space heating

Partially Installed Engine Skid

Biogas Conditioning Skid

Digester and Biogas Flare

Figure 1. Photos of System Components



Main Electrical Panel

Engine Control Panel

Figure 2. Photos of Electrical Panels

Figure 3, in Appendix A, schematically shows the biogas system and engine. Manure from approximately 1,800 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 the separated solids are removed completely. The digester is then fed with the combination of raw manure and separated liquid from the reception pit. 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 0.8 inches of static pressure.) Biogas for the engine is de-watered and pressurized to 7 inches via equipment located on the biogas conditioning skid, which includes a variable speed drive (VSD) blower to maintain the 7-inch pressure set point.

The hot water leaving the engine jacket runs through an exhaust heat exchanger where it is further heated. The heated jacket water is sent through a plate frame heat exchanger that provides heat to two separate water loops on the load side. The digester heating loop has about 1/3 of the load-side HX surface area. The remaining 2/3 of the load-side HX surface area is used for space heating in the shop. If the jacket water leaving the exhaust HX is too warm, a mechanical, temperature-actuated valve diverts jacket water to the radiator. The radiator fan speed is controlled by a VSD based on temperature. The jacket water loop also includes low temperature mechanical control valve that bypasses the plate frame HX and returns water to the engine block if the water temperature is too low.

Monitoring System Equipment, Installation, Operation, and Maintenance

Figure 3 also shows the locations of the two data monitoring points which are used to measure system performance. A gas meter measures fuel gas input to the engine generator (FGE) and a power meter 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	Veris-H8053-0400 Pulse Output kWh Transducer	kW kWh	0-200 kW (0-50 kWh/15 min)
Pulse	FGE	Engine Biogas Flow	Roots/Dresser Rand Model 5M175 Meter temperature compensated to 60^{o} F pressure = 7 inches	ft^3	0-1,150 ft^3/15 minutes

The electrical output of the engine will be measured with a pulse-output power transducer (**WG**). This power transducer includes an LCD display and will be installed next to the electrical panel for the engine by our electrical contractor. The transducer will be installed according to requirements in the "Veris Industries Power Monitoring Installation Guide Enercept® H8051/H8053 Pulse Output kWh Transducers" (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 Roots gas meter (**FGE**) that provides pulse output proportional to the volume flow that is compensated for temperature to 60^{o} F. The Roots meter will be installed in the vertical biogas pipe feeding the engine in accordance with the provisions of the "Roots Meters Instruments Installation, Operations, and Maintenance Manual" (Appendix B), as part of the gas conditioning equipment that is provided by the digester system vendor, RCM Digester International, LLC. The pipe will have a parallel bypass line with appropriate valves allowing for continuing use of the engine should the meter need to be removed for cleaning or repair. The oil level of the meter will be inspected at least monthly. A log of maintenance activities for the meter will be maintained at the site.

The lower heating value for the biogas is estimated to be 550 Btu/ft^3, based on past measurements of the CO_2 content of the biogas. 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 backup/startup fuel (natural gas) flow will not be continuously metered at this site. Natural gas is rarely utilized in the generator. However, natural gas usage will be manually logged when the generator is utilizing natural gas. This usage will be summarized in a spreadsheet table for the Annual M&V Report in order to account for periods when the backup/startup fuel is used.

CDH Energy has installed a Campbell Scientific C10 data logger to compile and log the data from the two monitoring points listed in Table 2 (see data logger details in Appendix B). 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 is located in the generator room next to the control panel, and is 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.

Sunny Knoll Farm staff will be responsible for the cost to purchase and install the power meter (**WG**) and engine biogas meter (**FGE**).

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) from 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 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. 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 the 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

First Date of the Month	Monthly Periods	Number of Days in Reporting Period	Electricity Production, $kWh_{generator}$	Biogas to Engine CF (cubic ft)	Biogas LHV, BTU/CF	Biogas Energy Content, Q_{biogas} (BTU)	Natural Gas Use, (cubic ft)	Natural Gas Energy Content, $Q_{naturalgas}$ (BTU)	Adjusted Electricity Production, $kWh_{adjusted}$
TOTALS									

Farm personnel will calculate monthly values for lower heating value of the biogas, total energy content of the biogas, total energy content of the natural gas, and adjusted kWh production as indicated on the following page.

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

Monthly Natural Gas Energy Content

Farm personnel will calculate the average monthly Natural Gas Energy Content using the following equation:

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

where,

CF: volume (ft^3) of natural gas in month

Monthly Adjusted Electricity Production

Farm personnel will calculate the monthly adjusted electricity production using the following equation:

$$kWh_{adjusted} = kWh_{generator}\left[\frac{Q_{biogas}}{Q_{biogas} + Q_{naturalgas}}\right]$$

where,

$kWh_{generator}$: actual electricity production

Figure 3. Schematic Biogas System