MEASUREMENT AND VERIFICATION (M&V) PLAN
FOR
TWIN BIRCH FARM ANAEROBIC DIGESTER GAS (ADG) SYSTEM

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Submitted to:

New York State Energy Research and Development Authority
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Submitted by:

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Introduction

This plan describes the approach used to monitor the performance of the anaerobic digester gas (ADG) system that is currently installed at Twin Birch Farms Inc., Skaneateles, NY to produce biogas and electricity. Biogas will be used to drive seven micro-turbine-generators, four existing turbines, and three new turbines. Turbine seven, one of the new turbines is for reserve use only. The power produced 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 and amount of biogas used by the turbine -generators. The data will serve as the basis for payment of three (3) years of performance incentive payments, which have been applied for under a Standard Performance Contract with NYSERDA. The site will have four existing and two new turbine-generators with Total Contracted Capacities of 100 kW and 50 kW respectively.

ADG System Description

The digester system at the farm was designed by Anaerobics, Inc. and the power plant and gas conditioning system by Niagra Mohawk Energy. The site will operate up to seven 30 kW synchronous micro-turbine-generator units with piping and controls that are installed in a dedicated building near the digester. Once installed unit seven will only run as a back-up. All the electrical loads at the farm have been consolidated into a single 3-phase, 277/480 volt electrical service in order to accommodate the generator system. Each micro-turbine includes controls to synch the generator to the grid as well as a protective relay and controls to automatically isolate the units from the utility grid in the event of a utility power outage.

Capstone Micro-turbines

Biogas Conditioning Skid

Pole Barn and Biogas Flare

Digester

Figure 1. Photos of System Components

Table 1. Biogas Systems at Twin Birch Farms

Digester	Anaerobic digesters plug flow, concrete cover, heated
Feedstock	Dairy Manure, 1170 cows
Engine-Generators	(7) Capstone 330 Micro-turbines 30 kW max. output on biogas 480 VAC, 3 phase
Biogas Conditioning	Cain Industries heat exchangers and condensation tanks for biogas dewatering Compair Hydrovane compressors for gas compression
Engine Backup/startup Fuel	None
Heat Recovery Use	Digester heating
Additional Heat Recovery	None

CB-1 400 A for digester and power generation


Micro-Turbine Control Panel

Figure 2. Photos of Electrical Panels

Sage Mass Flow Meters

E-MonD-Mon Power Meters

Figure 3. Photos of Meters

4 schematically shows the biogas system and micro-turbine-generators. Figure 5 shows the single line electrical diagram for the system. Biogas from the digester is used in the micro-turbines, the auxiliary boiler, or flared. The biogas flare operates using a mechanically-actuated relief valve that vents biogas to maintain the gas input from the digester at 14.5 inches of static pressure. A blower controlled by a VSD which is triggered by a pressure transducer at the digester maintains the internal digester pressure at 0.0-0.02 inches of water column. All digester gas passes through a Roots positive displacement meter. Sage metering devices measure gas flows to the boiler, flare, and micro-turbines. Gas flow to all of the micro-turbines equals Sage 1 reading minus Sage 2 reading. The system does not have separate gas metering to measure gas flow to the new and existing micro-turbines.

Saturated, 95° F gas is cooled by a heat exchanger (HX3) where moisture is condensed out. HX1 reheats the gas to 150° F. The warmer, drier, gas is compressed to 85 to 90 psi. The high pressure gas is cooled by HX4 where more moisture is condensed out. The gas is heated again to 150 °F by HX2 then enters a manifold system to the micro-turbines where it is burned as fuel. Exhaust gases from the micro-turbines pass through the Cain Industries heat exchanger where the exhaust heat is used to heat the digester. The auxiliary boiler will fire on digester gas or oil if necessary and provide additional Btu's to the heating loop for start-up or if there is a need for additional heat to the digester.

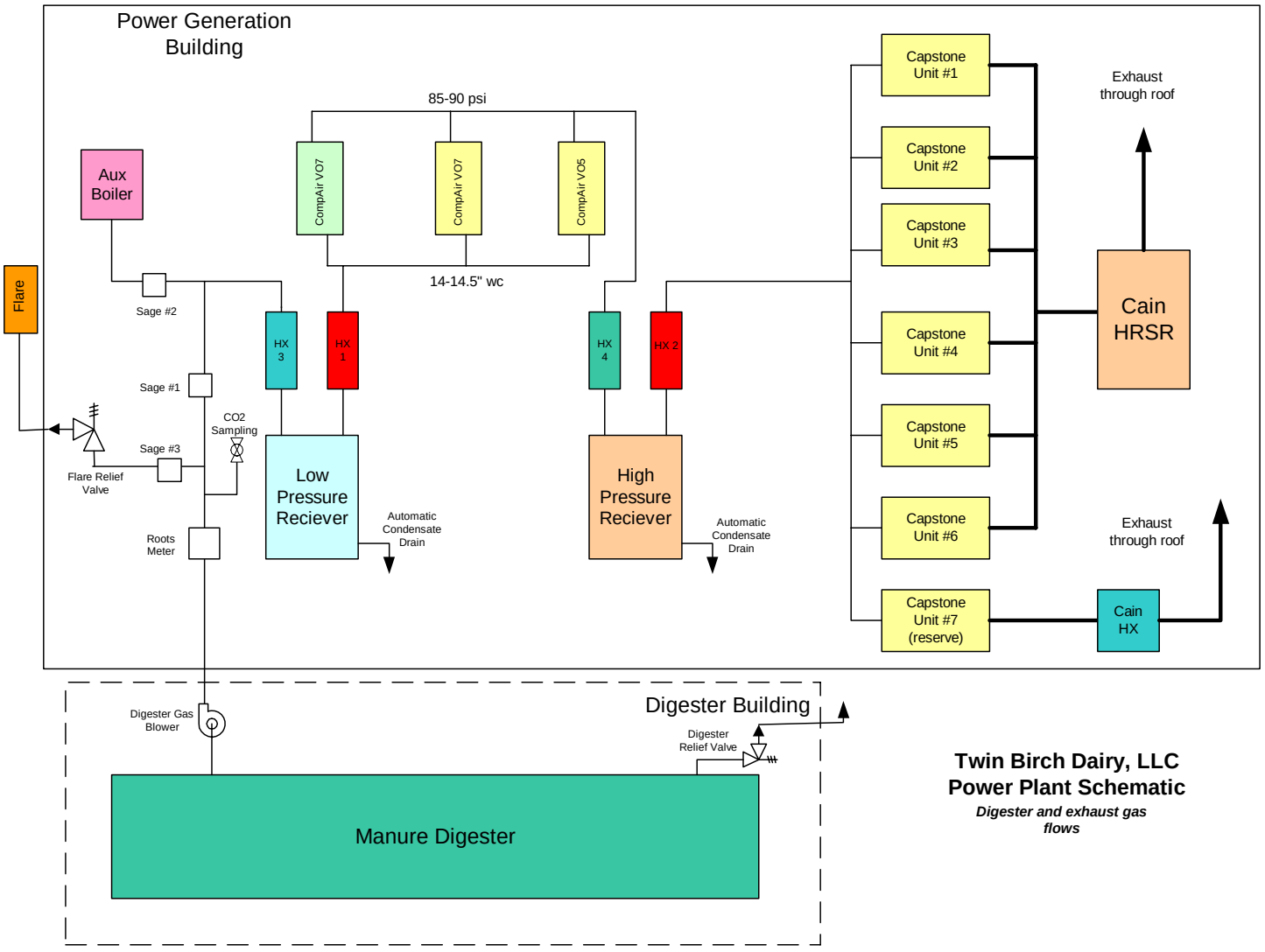

Figure 4. Schematic Biogas System

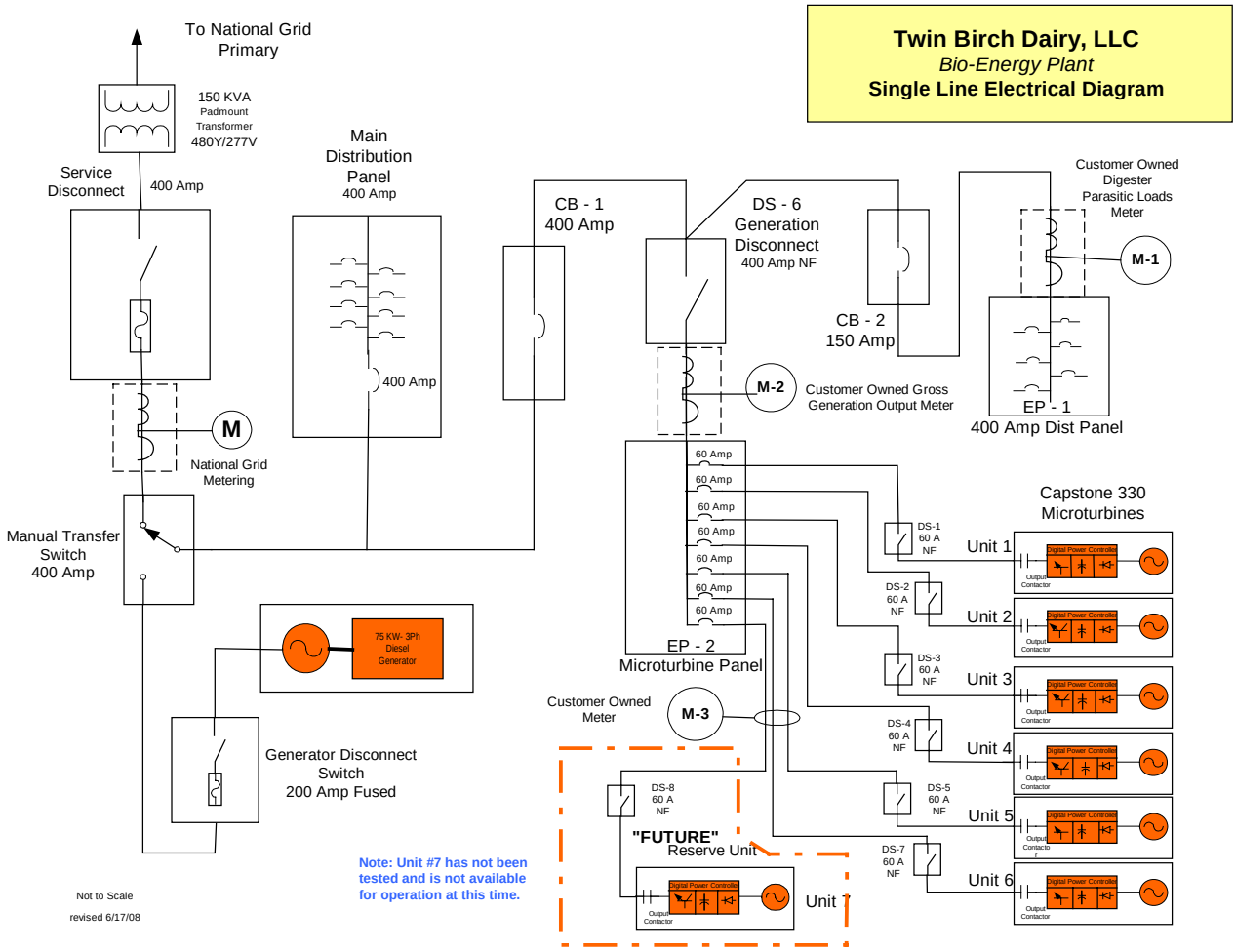

Figure 5. Single Line Electrical Diagram

Monitoring System Equipment, Installation, Operation, and Maintenance

Figure 4 shows the location of the meters used to measure fuel gas input to the micro-turbine-generators (Sage 1 - Sage 2 = input to micro-turbines). Figure 5 shows meters M2 and M3 used to measure the kilowatts generated. Meter M1 measures parasitic loads. Information on these data points is shown in Table 2~~Table 2~~.

Table 2. Monitored Points for ADG System

Point Type	Point Name	Description	Instrument	Engineering Units	Expected Range
Pulse	M2, M3	Engine-Generator Power	E-MonD-Mon Model 480400 KIT w/ (3) CTs, 400 amp with LCD display	kWh/interval	0-230 kW (0-57.5 kWh/int)
Pulse	Sage1, Sage2	Engine Biogas Flow	Sage Metering Inc. Model SIG-05-15 Mass Flow Meter, temperature compensated to 60^{o} F pressure = 7 inches 10 cubic feet per pulse	ft^3/interval	0 – 5700 ft^3/h (0-1500 ft^3/int)

The electrical output of the micro-turbines will be measured with two E-MonD-Mon model 480400 KIT power transducers labeled M2 and M3. These power transducers include an LCD display and are installed above the electrical panel by the electrical contractor. The transducers are installed in accordance to requirements in the "E-MonD-Mon Class 2000 Installation Manual. The meters will be protected by a dedicated circuit breaker. M2 measures output from all of the micro-turbine generators. M3 measures output from new micro-turbines generators, 5 and 6. The power output from existing units 1-4 is calculated by subtracting output reading M3 from output reading M2. M1 measures all parasitic loads.

The biogas input to the micro-turbines will be measured by two Sage mass flow meters, Sage1 measuring total biogas flow to the micro-turbines and the auxiliary boiler and Sage 2 measuring biogas flow to the boiler only. The gas flow input to all of the micro-turbines is equal to Sage meter 2 reading subtracted from Sage meter 1 reading. A third Sage meter, Sage 3 measures gas flow to the flare. The meters are installed according to the "Sage Thermal Gas Flow Meter Operations and Instruction Manual for Models SIG/SRG". A log of maintenance activities for the meters 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 confirmed or adjusted based on weekly measurements of carbon dioxide using a Fyrite Gas Analyzer Model No. 10-5032 for CO_2 range 0-60%. Our farm owner, Dirk Young or other qualified staff, will perform the CO_2 tests and log the results in the project log. This test is performed by taking a gas sample from the low pressure gas supply before it enters the skid. The sampling point is marked in Figure 4 as "CO2 Sampling"

There is no backup/startup fuel for the micro-turbines in this system. The auxiliary boiler runs on digester gas or #2 oil. The Aux Boiler is run on the fuel oil during digester start up until such time as there is enough gas production to switch over to biogas fuel.

The CHP website consultant will install an Obvius AcquiLite datalogger to compile and log the data from the four monitoring points listed in Table 2 (see datalogger details in Appendix). The datalogger will be programmed to record the totalized data for each monitoring point for each 15-minute interval. A record of all multipliers and datalogger settings will be maintained. The datalogger will be located on the same wall as the Sage meters in the pole barn and will be connected to an uninteruptable power supply (UPS) to ensure the datalogger retains its settings and data in the event of a power outage. We

will provide a phone line that will be used to communicate with the datalogger. We have confirmed that the NYSERDA CHP Website Contractor will call the datalogger nightly, via a phone modem link, to extract monitoring data from our ADG system and transfer the data to the NYSERDA CHP Website. If communications are lost, the Obvius datalogger is capable of holding at least 15 days of 15 minute interval data.

Management of Monitoring System Data

We will perform the following quality assurance and quality control measures to ensure the data produced from our system accurately describes system performance.

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

On a weekly basis, the 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. We will also maintain a weekly log of the cumulative power generation (kWh) from meters M3 and M2 and gas flow (cf or ft^3) recorded by the three Sage meters and the Roots Meter in the event that data transfer to the NYSERDA CHP Website fails or other anomalies occur.

On a weekly basis, our staff will review the data stored in the NYSERDA CHP Website (chp.nyserda.org) to ensure it is consistent with our observed performance of the ADG system and logged readings. We will review the data using the *Monitored Data – Plots and Graphs* and *RPS: Customer-Sited Tier Anaerobic Digester Gas-to-Electricity Program NYSERDA Incentive Program Reports*, which can both be accessed through the NYSERDA CHP Website.

We understand that the CHP Website Contractor will take the data called from the datalogger and evaluate the quality of the data for each hour of the day using range and relational checks. The expected ranges for both sensors, which will be used for the range checks, are listed in Table 2 under the "Expected Range" header. We understand that 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., a meter has failed). We understand that only hourly data that passes these quality checks are used in the *RPS: Customer-Sited Tier Anaerobic Digester Gas-to-Electricity Program NYSERDA Incentive Program Reports*; however, all hourly data, those that pass the range and relational checks and those that do not, can be downloaded from the NYSERDA CHP Website using the "Download (CSV file)" reporting option.

We will sign up for automated emails at the NYSERDA CHP Website in order to receive: 1) a periodic report summarizing system performance and the estimated incentive, 2) an email report sent out if data are not received at the web site or do not pass the quality checks. In the event of a communications or meter failure, we will work to resolve the issue in a few days.

We will communicate any significant discrepancies we find to the CHP Website Contractor, the Project Technical Consultant and the NYSERDA Project Manager. If discrepancies in the data are found, the farm understands that we have the responsibility to clearly explain the discrepancy if we intend to invoice NYSERDA based on the electricity generation associated with the data in question.

If unanticipated loss of data occurs when the engine-generator continues to produce electricity, we intend to follow the procedures outlined in Exhibit D, i.e. use data from similar periods - just before or after the outage, to replace the lost data. We understand that we can use this approach for up to two 36 hour periods within each 12-month performance period. If more than two such data outages occur for time periods during which production incentives will be requested, we will provide information from other acceptable data sources to definitively demonstrate the amount of power that was being produced from ADG fuel during the period in question.

Annual M&V Reports

Twin Birch Dairy will prepare Annual M&V Reports including data needed for the existing four micro-turbines covered in Agreement 113-E and separate data for the new micro-turbines covered by Agreementt 113-N. The reports will include a table (example provided below) showing the monthly kWh production, biogas use by the micro-turbines, other data listed in Table 3, and if used, any propane or other fuel used for the subject micro-turbines. We may use data summarized in the *RPS: Customer-Sited Tier Anaerobic Digester Gas-to-Electricity Program NYSERDA Incentive Program Reports* to populate this table; however, if we disagree with the *Reports* we will provide our own summary of the data (e.g., hourly CSV data downloaded from the Website using the "Download (CSV file)" reporting option), along with a narrative justifying why we feel our calculations are more appropriate. Our methods for calculating these values are provided below.

Table 3. Summary of Monthly Data for Annual M&V Reports

Start Date of Reporting Period (e.g. March 1,, 2009)	Number of Days in Reporting Period	Electricty Production from All Micro-turbines (kWh)	Electricity Production from 2 New Micro-turbines (kWh)	Electricity Production from 4 Existing Micro-turbines (kWh)	Biogas Use by All Micro-Turbines CF (cubic feet)	Biogas LHV, BTU (cubic feet)	Biogas Energy Content, Q_{biogas} (BTU)
TOTALS							

We will calculate monthly values for lower heating value of the biogas, total energy content of the biogas used, and any adjusted kWh production as follows.

Monthly Biogas Lower Heating Value

We 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:

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

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

We 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

Appendices

Cut sheets and Manuals for:

Sage Metering Inc. Model SIG-05-15 Mass Flow
http://sagemetering.com/description_files/SRG_specs_insertion.pdf

AquiLite Data Acquisition Server – A7801-1
http://www.obvius.com/documentation/Obvius/A7801Cutsheet.pdf
http://www.obvius.com/documentation/Obvius/A7801Manual.pdf

E-MonD-Mon Model 480400 KIT
http://www.emon.com/products_class2000.htm

Roots Meter Series B3: 8C175
http://www.rootsmeters.com/internet/businessunits/flowcontrol/subunits/rootsmeters/MetersTechInfo.cfm?numPageID=1102
http://www.rootsmeters.com/internet/businessunits/flowcontrol/subunits/rootsmeters/iom.cfm?numPageID=5872

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

Twin Birch Addendum

Site Events

Date	Event
11/14/2009	Automatic data export set up but only first file received. Manually downloaded all back data. Goes back as far as 10/21/09
11/25/2009	Data export still not working. Datalogger plug came lose – no power – lost approx 11 days worth of data. Logger turned back on and continues logging.
12/31/2009	Swapped out AcquiLite for AcquiSuite, data upload to CDH website began working.

Data Logger Setup

Logger Chan	Chan Type	Data Point	Wire	Logger Mult	Notes
001-In1	Pulse	M2	Red/Blk	0.125 kWh/p	
001-In2	Pulse	M3	Grn/Wht	0.125 kWh/p	
001-In3	Pulse	Sage 1	Grn/Wht	10 cf/p	
001-In4	Pulse	Sage 2	Red/Blk	10 cf/p	

Notes: 001 = AcquiLite

Database Setup

```
Chan Name  Device    column
WGT_ACC,   mb-001,   0
WGB_ACC,   mb-001,   5
FT_ACC,    mb-001,   14
FB_ACC,    mb-001,   19
WGB_ACC,   mb-250,   5    (12/31/2009)
FT_ACC,    mb-250,   10   (12/31/2009)
FB_ACC,    mb-250,   15   (12/31/2009)
```

Sensor Verification

Power Meters

Power Meters: E Mon D Mon			
	Obvius (kW)	Turbine Display (kW)	% Difference
M2	79.5	80.5	1.24%
M3	40	40.6	1.48%

Flow Meters

Flow Meters: Sage			
	Obvius (scf/h)	Sage (scf/h)	% Difference
Sage #1	5000	5280	5.30%
Sage #2	1956	2052	4.68%

	Sage #1 Display (scf/int)	Sage #1 (scf/h)	Sage #2 Display (scf/int)	Sage #2 (scf/h)
2:00 PM	21119907		604545	
2:20 PM	21121471	4692	605160	1845
2:30 PM	21122301	4788	605514	1938

Photos

Digester House – Turbines (left), power meters (center), hot water loop equipment (right)

Capstone 30kW natural gas micro-turbines

Obvius Datalogger Panel

E-Mon D-Mon interior and pulser.

FT & FB – Sage flow meter readouts

E-Mon D-Mon Power Meters