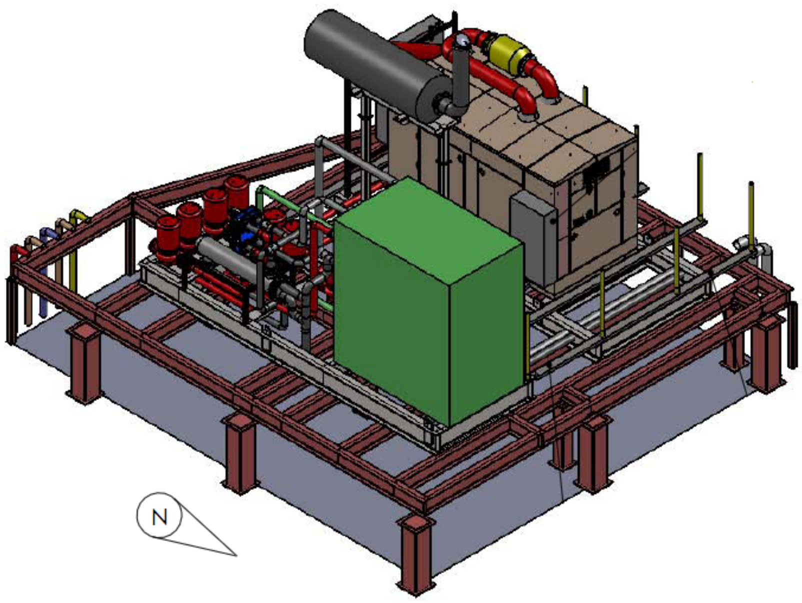
NYSERDA M&V Plan Submission
(Engineering Phase: Tasks #7)

The Cooper Union
for the Advancement of Art and Science



PON 914, Agreement #9180

41 Cooper Square: Combined Heat & Power Plant

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SECTION A. INTRODUCTION

M&V PLAN INTROCUCTION

This Measurement and Verification (M&V) Plan describes the attributes of the 41 Cooper Square automated data collection system designed to monitor the performance of the facility's Combined Heat and Power (CHP) system. The Plan is intended to provide information regarding the monitoring systems as required of demonstration sites that are part of the NYSERDA DG/CHP program.

DG/CHP demonstration sites that receive funding from NYSERDA are required to collect performance data at 15-minute intervals over the first year of operation. The monitored data is intended to quantify facility load profiles, generator power output, fuel consumption, useful thermal outputs, parasitic loads and equipment runtimes. This data shall be used confirm electrical and CHP efficiencies over the year, determine equipment availability, and verify system economics

The following sections of this report present the on-site measurements that are required to meet the goals and monitoring requirements as outlined by the contract between NYSERDA and Cooper Union. The report describes the details of the plant and provides system schematics for technical review and reference purposes.

GENERAL DESCRIPTION

Founded in 1859 by Peter Cooper, industrialist and philanthropist, The Cooper Union offers public programs for the civic, cultural and practicable enrichment of New York City

Through outstanding academic programs in architecture, art and engineering, The Cooper Union for the Advancement of Science and Art prepares talented students to make enlightened contributions to society. The College admits undergraduates solely on merit and awards full scholarships to all enrolled students. The institution provides close contact with a distinguished, creative faculty and fosters rigorous, humanistic learning that is enhanced by the process of design and augmented by the urban setting.

The college's three schools are recognized nationally and internationally for their challenging academic programs and for their exceptional students (most ranked in the top 10 percent of their high school graduating class), who come prepared to undertake a rigorous course of study.[1] With a total annual enrollment of about 1000, The Cooper Union's low faculty-to-student ratio and the small size of classes foster a climate of individual self-discovery while encouraging involvement in a larger community that transcends individual interest. The curricula of the

[1] Their capabilities and motivation are evidenced by high retention rates: 93 percent of the fall 2005 first-year students returned for fall 2006; and 84 percent of first-year students entering in fall 2001 graduated within five years.

college's three schools and its division of humanities and social sciences mirror these dual ideals. The programs seek a balance between the mastery of disciplinary fundamentals and the broader

FACILITY DESCRIPTION

To provide its faculty and students with the very best educational facilities and resources, The Cooper Union for the Advancement of Science and Art constructed a new academic building on its campus in Lower Manhattan's East Village. The project site is located at Block 462, Lot 1 on Third Avenue between East 6th and 7th Streets, New York, New York. Before the site was cleared beginning in November 2006, it was the location of the college's Abram S. Hewitt Memorial Building, a two-story structure built in 1910 that provided studio space for the School of Art, but which, by the 1990s, had ceased to serve that school's needs. The project site is owned in fee by the City of New York and leased to The Cooper Union for a term ending January 31, 2106 by lease, dated April 22, 1908, and extended on April 6, 1987.

The nine-story, 175,000 square foot structure will house the Albert Nerken School of Engineering and Faculty of Humanities and Social Sciences, and provide additional studio and gallery space for the School of Art and the Irwin S. Chanin School of Architecture.

In deciding to construct a new academic building, The Cooper Union trustees determined that the current structure housing the Nerken School (built in the fifties and located at 51 Astor Place), despite assiduous maintenance and periodic upgrades, would over the long term be insufficient to meet the academic and research needs of a top-tier engineering school like Cooper Union. In planning a new home for the Nerken School, The Cooper Union took into account the pace of study and learning in the engineering sciences. The college asked Thom Mayne,[2] its chosen architect and 2005 winner of the Pritzker Architecture Prize, to envision a structure that would provide an innovative, adaptable, and environmentally sustainable home, not only for the Nerken School, but also for the other academic, artistic and public purposes the building would serve. Those purposes include an art gallery, auditorium, and media-enhanced classrooms.

Architecturally, the building will embody technical innovations and aesthetic elements such as translucent "sky bridges," a soaring atrium, and a green roof, to name a few. Equally notable, the building is the first LEED (**Leadership in Energy and Environmental Design**) certified "green" academic laboratory facility in New York City, built to Platinum LEED standards—a model for schools across the country that are considering building science and engineering facilities that embody standards and values associated with a sustainable environment.

Like the landmarked Foundation Building, which in its time represented a pioneering step toward technical achievement and architectural elegance, the new academic building will integrate the most advanced mechanical systems with exceptional architecture and materials that maximize energy efficiencies and cost savings, and foster environmental sustainability. According to

[2] Mayne is founder and head of Morphosis, a world-renowned California-based architecture firm, and is internationally recognized for projects like the San Francisco Federal Building that are models of sustainability in the built environment.

Mayne, “In its form and function, the new academic building will be a living ‘classroom’ for environmental leadership.” Ascending the full interior height of the new building will be a central atrium, a design feature that allows for ventilation and natural light to permeate the core space. By way of fulfilling LEED’s standard for connectedness to the outside, a cut-away portion of the building’s sculptured, angular stainless steel exterior screen will reveal the building’s “vertical campus” concept, permitting its occupants to view the street and the Foundation Building across Cooper Square. Conversely, through the screen, pedestrians will be able to see inside as teachers and students move along glass-enclosed stairways that hover in space and cross at intriguing angles through the central atrium.

PROJECT DESCRIPTION

Currently the building infrastructure consists of a main central chilled water plant in the basement of the building and a boiler plant located on the roof. Hot Water and Chilled Water are distributed throughout the building to various services including air handlers, perimeter radiation, ceiling radiant panels. The chiller plant consists of (2) 500 Ton Carrier electric drive centrifugal chillers and a plate and frame heat exchanger to provide free cooling during the winter months. The heating system is a low temperature hot water system fed by Cleaver Brooks Flex-tube (compact fire-tube) boilers operated on an outdoor air reset schedule between 120°F and 180°F.

The building utilities include electric and natural gas fed by Con Edison. The Cogeneration Plant shall operate off of the existing gas service in the building and in parallel with the electric service provided by the utility.

Supporting infrastructure was designed and built during the main phase of building construction, and was in place at the time the project was started. This included: a rooftop dunnage platform; chilled water, condenser water and hot water taps adjacent to the dunnage; gas service, in the adjacent boiler plant, with a tap provided for the Cogeneration Plant service; and an electrical service panel. The project goal was to connect to the existing building systems and operate in parallel with the other equipment.

The plant itself consists of a single 250 kW Elite Energy combined heat and power (CHP) module, a nominal 80 ton Thermax hot water source absorption chiller and associated pumps, heat exchangers, valves and controls. The plant was constructed in a factory, skidded, test, and then broken down for shipping purposes. Once it reached the site it was rigged to the 9th Floor Roof and installed on the existing dunnage platform installed during the base building project.

SECTION B. SYSTEM OVERVIEW

OPERATING DESCRIPTION

Time of Operation

The cogeneration plant is designed for continuous operation. The planned operation is for nearly 24/7 except for maintenance periods. The system will operate on a time clock synchronized through the internet. The time clock may be necessary to reduce load during nights and/or weekends.

Starting

Once the timer initiates the plant operation, the start sequence for the induction generator is performed. The generator will start and maintain near synchronous speed of 1800 RPM. The control will close the unit breaker when the generator is running slightly faster than synchronous speed.

The prime mover will be at operating temperature before attaining full load. Once the breaker is closed, the generator will maintain a fixed load (approximately 1/3 of rating) for a warm-up period. At the end of the warm-up period, the generators will be ramped (2 kW/sec) up to rated load.

Shutdown

At the end of the generating cycle, the system will initiate a power down cycle. The engines will be ramped down (2 kW/sec) until they are at 10 kW or below. The breaker will be commanded open and a cool down cycle will start. At the end of the cool down, the engine operation will be deactivated.

Electrical Shutdown

The utility relay at the PCC (Point of Common Coupling) will monitor elements 27, 59, 81, and 32. A trip on any of these elements will communicate to the generator to immediately disconnect. The breaker (52G) will be commanded open. The engines will cool down and deactivate.

The generators require user intervention to restart after an electrical event like a trip from the relay. After the relay trip occurs, a user must manually restart the system. If utility power has not returned to normal operation, the relay will inhibit the operation of the generator. When the utility power returns to normal, the relay clears the trip. The generator initiates a protective hold for 5 minutes; barring restart. Once the protective hold has expired the user can restart the system. No auto-restarts are possible after an electrical or mechanical shutdown.

Redundant Electrical Shutdowns

Even though the PCC is equipped with a Beckwith relay, the generator also has electrical and mechanical shutdown elements. The generator is programmed for over/under voltage, over/under frequency, over current, overpower and reverse (anti-motoring) power shutdowns. Standard over temperature and low pressure sensors provide additional named shutdowns.

Mechanical Operation

The cogeneration plant will issue all commands for the generator and plant operation. Chiller and building heat will be enable after a signal from the building is received. These signals will be conveyed via dry contacts to the cogeneration control.

When the generator is called to start, the controls will activate the circulator pump on the skid. The System will monitor the loop temperature until the outgoing temperature reaches 180°F. If the ambient temperature is greater than 50°F, the chiller will be operated. If the ambient temperature is less than 45°F then the chiller will be stopped and the heating loop will be fully served. The heating loop will be used as a heat sink for excess heat after the chiller cycle and before the main dump system. The control system will modulate the dump valve to ensure the return temperature to the cogeneration unit does not exceed the nominal set point of 165°F.

The condenser water pumps operate to provide cooling water to the chiller and as an excess heat dump for the generator. The condenser pump will be operated as necessary to provide for the generator and/or the chiller.

The DHW loop, cogen loop, and condenser loop pumps are controlled on the skid. The redundant pumps will alternate operation when called to run. The VFDs on the building hot water circuit will be set at the highest flow.

Once the chiller is activated, the chiller control will start the chilled water pump and the chemical cycle. After verifying condenser water and chilled water flow, the chiller will modulate the hot water valve to start the chemical process and produce chilled water. The building will maintain condenser water input temperature at a nominal 85°F. The chiller is expected to take 15 minutes from start to produce adequate chilled water temperatures.

The chilled water circuit on the chiller is fed from redundant pumps. The chiller will request pump operation when it initiates cooling and after run for the de-crystallization cycle as necessary. The lead pump will be selectable at a control panel. The lag pump will operate in the event the first pump is electrically incapable of running. The lead pump control should be switched monthly with the generator service routine.

Data and External Inputs

The control requires an internet connection with a static IP address for monitoring and maintenance operations.

An additional shutdown input has been reserved in the event that the building would like to locate a remote stop switch.

SYSTEM SCHEMATIC

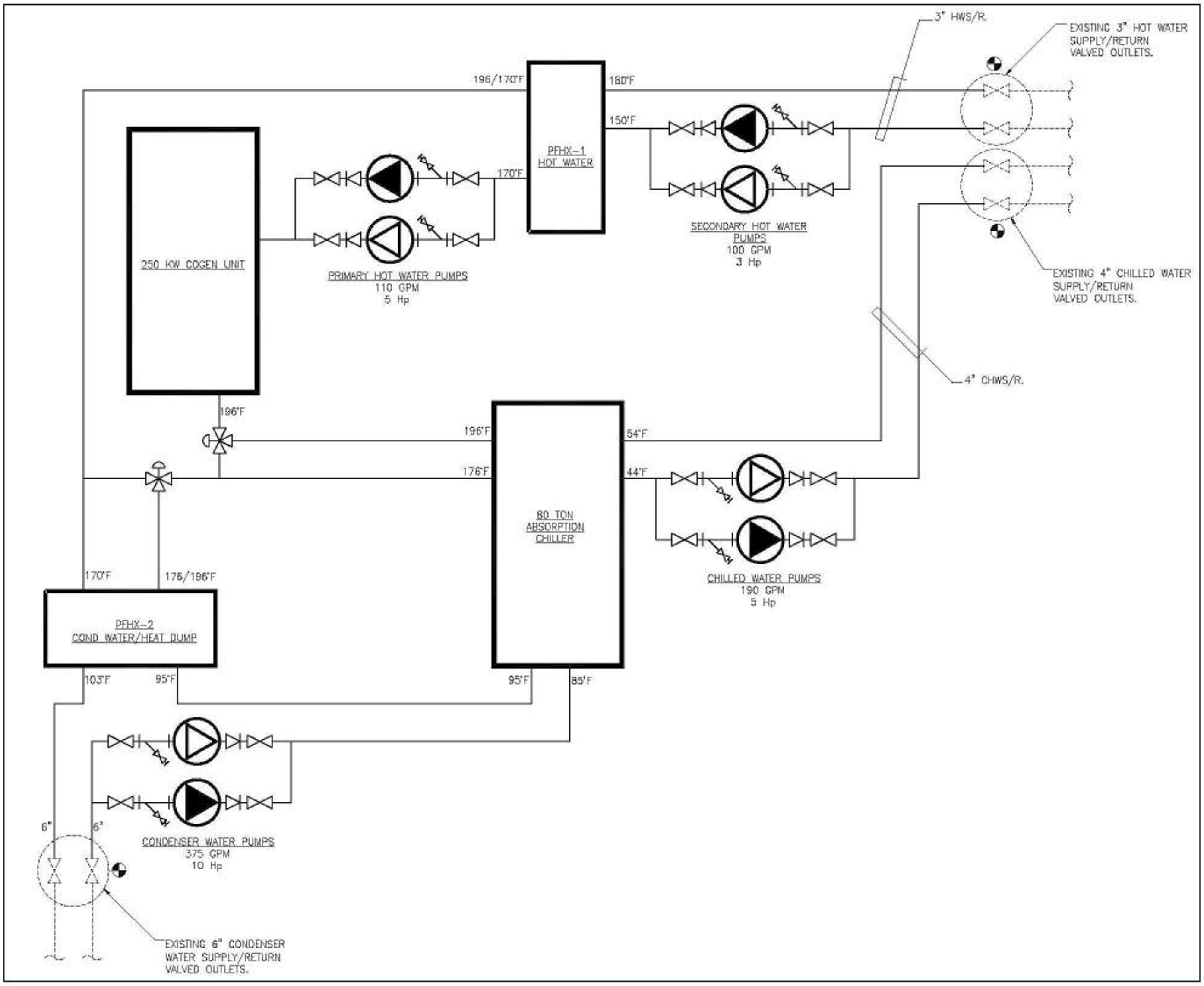

Diagram B.1 – System Schematic:
The above diagram shows the general plant equipment flow diagram. In addition the main CHP package connects in parallel with Con Edison and produces 250kW of electrical power.

MONITORING POINTS LIST

Point ID	Controller	Parameter	Unit	Multiplier	Expected Values
CHP-M.V-1	Plant	Total Instant kW Production	kW	1	0-1000
CHP-M.V-2	Plant	Total Instant power factor	pf	100	-100-100
CHP-M.V-3	Plant	Total Instant Thermal	TH/hr	1	-10-60
CHP-M.V-4	Plant	Con Ed feeder kW	kW	1	0-3000
CHP-M.V-5	Plant	Con Ed Power factor	pf	100	-100-100
CHP-M.V-6	Plant	Gas Consumption			
CHP-M.V-7	Plant	Instant Chilled Water Output *	Ton-hr	1	-300-400
CHP-M.V-8	Plant	Thermal Dumped	TH/hr	1	-10-60
CHP-M.V-9	Plant	Instant Hot Water Delivered	TH/hr	1	-10-60
CHP-M.V-10	Plant	Plant Water Output temperature	°F	1	25-215
CHP-M.V-11	Plant	Condenser Water Temp	°F	1	25-215
CHP-M.V-12	Plant	Chilled Water Supply Temp	°F	1	25-215
CHP-M.V-13	Unit	Chilled Water Return Temp	°F	1	25-215
CHP-M.V-14	Unit	Cogen Output Temp	°F	1	25-215
CHP-M.V-15	Unit	Engine Jacket Temp	°F	1	25-215
CHP-M.V-16	Unit	Engine Oil temp	°F	1	25-215
CHP-M.V-17	Unit	Engine Oil Pressure	PSI	1	0-100
CHP-M.V-18	Plant	Breaker Position	Seconds	1	-1000-1000
CHP-M.V-19	Plant	General Alarm	Seconds	1	-1000-1000
CHP-M.V-20	Plant	Plant Water Return Temp	°F	1	25-215
CHP-M.V-21	Plant	Dump Valve Position	%	100	0-100
CHP-M.V-22	Unit	Thermal Transfer Valve Position	%	100	0-100
CHP-M.V-23	Unit	Engine RPM	RPM	1	0-2000
CHP-M.V-24	Unit	Con Ed Frequency	Hz	100	0-6500
CHP-M.V-25	Unit	Ambient Temp	°F	1	25-215
CHP-M.V-26	Unit	Gallons Reserve Oil	Gal	10	0-500
CHP-M.V-27	Unit	Generator Amps A	Amp	1	0-600
CHP-M.V-28	Unit	Generator Amps B	Amp	1	0-600
CHP-M.V-29	Unit	Generator Amps C	Amp	1	0-600
CHP-M.V-30	Unit	Generator Voltage A	Volt	1	0-600
CHP-M.V-31	Unit	Generator Voltage B	Volt	1	0-600
CHP-M.V-32	Unit	Generator Voltage C	Volt	1	0-600
CHP-M.V-33	Unit	Generator kVA	kVA	1	0-300
CHP-M.V-34	Unit	Generator VARs	kVar	1	-300 - 0
CHP-M.V-35	Unit	Pre-Cat Exhaust Temp	°F	1	0-1300
CHP-M.V-36	Unit	Post-Cat Exhaust Temp	°F	1	0-1300
CHP-M.V-37	Unit	Control Temp	°F	1	25-215
CHP-M.V-38	Unit	Manifold Pressure	PSI	10	0-15
CHP-M.V-39	Plant	Cogen Pump on/off	Seconds	1	-1000-1000
CHP-M.V-40	Plant	Chiller on/off	Seconds	1	-1000-1000
CHP-M.V-41	Plant	Hot Water Pump on/off	Seconds	1	-1000-1000

Table B.1 Monitoring Points List:

Above is a list of the points that shall be monitored and exported to NYSERDA

SECTION C. DATA COLLECTION & MONITORING PLAN

INTRODUCTION

This section of the Measurement and Verification plan shall identify the specific technical and logistical concerns around the Cooper Union Cogeneration Plant. The follow shall identify:

- Which points will be monitored
- The frequency the data is collected
- The standard reports that will be generated
- The communication protocols with NYSERDA
- The frequency of data export
- Standard reports

MONITORING REPORTS AND INTERVALS

Daily reports

Data shall be gathered on a 15-minute interval basis on all items listed on table B.1 in the previous section. This information shall be consolidated into a single report and uploaded to NYSERDA once daily.

Weekly Reports

On Friday of each week, a report shall be generated using the previous 7 days worth of daily reports. The data shall be aggregated and used for calculation purposes. This information shall be used for operational purposes and trending of system performance. The main input data shall be the following:

- Total Operated Hours
- Engine Starts
- Electric Production (kWh)
- Gas Consumption (BTU)
- Thermal Heat Recovery (BTU)
- Thermal Heat Dump (BTU)

Based upon the data gather above, the following shall be information shall be calculated and reported to Cooper operational staff:

- System Availability (%) = Total Operated Hours / 168 (7days x 24 hours)
- Run vs. Start Ratio = Total Operated Hours / # of Engine Starts

- Electrical Efficiency (%) = Electric Production (kWh) x 3412 / Gas Consumption
- System Efficiency (%) = Electric Production (kWh) x 3412 + Thermal Heat Recovery / Gas Consumption
- Total Potential System Efficiency (%)(%) = Electric Production (kWh) x 3412 + Thermal Heat Recovery + Thermal Heat Dump/ Gas Consumption
- Lost System Efficiency (%) = Total Potential System Efficiency – System Efficiency

The operational staff shall use this information to maximize system efficiency, and determine if and when there are issues. Also, the operations team shall target maximizing the Run vs. Start ratio. This will limit the wear and tear on the system due to frequent short cycling.

Quarterly & Annual Reports

Once per quarter, the Operational Staff shall generate a report trending the information in the weekly reports, and the efforts to maximize efficiencies and minimize down time. In addition, the cost savings of the plant shall be calculated and reported to internal Cooper management staff to ensure that the system is meeting the savings and payback targets. In the event that targets are not being met, the operations staff shall make recommendations and take the appropriate actions necessary to meet the desired goals of energy cost savings.

The annual report shall be a collection of all weekly and quarterly reports. The Director of the operations team shall create an executive summary that reports the plant performance during the period along with maintenance, and energy cost. The savings shall be measured against projections. Any deficiencies or process improvements shall be identified.

SECTION D. COMMUNICATION & REPORTING PROCEDURE

INTRODUCTION

COMMUNICATION PROTOCOL

SUMMARY OF DATA REQUIREMENTS FOR CHP WEB-BASED DATA SYSTEM

The Data Integrator project team (CDH Energy) is working with NYSERDA to collect and integrate detailed data from their portfolio of DG/CHP projects. The types of data they are looking for include:

1. ***Detailed system performance data*** automatically collected at regular intervals (e.g., 15-minutesor hourly) by a data logger or control system. The required data includes generator power output, fuel input, facility power use, and heat recovery rates. This data should be supplied to us in an electronic format (ASCII, XLS, etc) and can be transferred to use automatically (automated emails, FTP, etc) or manually (by email or disk). We can automatically receive data as often as once a day.
2. ***Operational Reliability data*** that is entered by your system operators once a month. This data includes information on any scheduled or unscheduled equipment outages at your site, including the time and date of the outage, its cause, and the resolution. You will be assigned an account for entering this data into an easy-to-use web page. We will remind you each month when it is time to enter new outage information. This data will be entered into an on-line database that will allow users to track, evaluate and compare the performance of all NYSERDA-funded DG/CHP sites.

Detailed System Performance Data and Supporting Information

- Data can be supplied to us in any *consistent* electronic file format. Suggested formats include CSV, txt, ASCII, etc. The files should include time-and-date stamped records that are consistently delimited or in a fixed format. Each file should be provided with a unique filename that corresponds to the site name and the data it contains (e.g., Smith_uint2_May05.dat).
- A list of the measured values or data points that are included in each data file. The list should include the corresponding column/row in the file, the data point name, a description, the engineering units of the measurement (e.g., kWh per interval, avg kW, etc), and the sensor/instrument used to take the reading. The list should indicate if the reading an average or sum over the interval or a sample.
- A simple schematic of the DG/CHP system that shows the location of each data point in the system. A more detailed description of the monitoring requirements are given in the a separate document (www.cdhenergy.com/data_int/Monitoring_Data_Collection_Std.pdf).

Operational Reliability (OR) and Other Data

The OR data needs to be entered periodically to document the availability of the system. The OR section of the web site includes step-by-step instructions on how to enter the time, date, and reason of each outage event. We would also collect and one-time emissions readings that may have been collected on your system. We will provide detailed guidance and support to help you enter this information into the database each month.

DATA SUBMISSION TO THE DATA INTEGRATOR

The following summarizes the steps for a monitoring contractor to submit data to the CDH Energy for the DG/CHP Integrated Database.

Programs

The data server uses the Secure FTP (SFTP) file transfer protocol for the uploading of files. SFTP is different from FTP and requires different programs. We recommend using WinSCP for a graphical user interface program that is similar to using Explorer for regular FTP. The project page for this program is located at

http://winscp.net/eng/index.php.

For automated uploading of files, psftp can be used as a replacement for the command line ftp routine in Windows. It is part of the PuTTY package and located at

http://www.nbcs.rutgers.edu/newdocs/psftp/psftp.php3.

Steps for Submitting Data

These are the steps for submitting data to the data integrator.

1. Call CDH to ask for a username and password. We will also discuss the format of the data being uploaded and the available channels at this time.
2. After initiation of automated uploading, please contact CDH to verify the data was received.
3. After two weeks of data uploading, CDH will prepare an Initial Data Summary. This summary will include interpretations of the available data and identify any issues we see with the data. Data may be included in the system at this time.
4. The Initial Data Summary will be sent to the monitoring contractor for review. The monitoring contractor must respond to all questions in the summary section of the document. When there are no further issues, the data will be loaded into the system.
5. Periodically, CDH will review the data provided and will notify the monitoring contractor of any issues.

Data Format

The data shall be submitted in comma-separated variable (CSV) format. Column descriptors should go in a header row. Each row should begin with a timestamp. Here is an example of the preferred format:

"Standard Date","Total Utility Import Power","Elect Service A Import Pwr"
12/25/07 00:00:00,31.65,20.73
12/25/07 00:15:00,31.76,21.61

Automated Uploading

Uploading shall occur once per day. To ensure the Integrated Data System will show a full set of data for the previous day for your site, data should be submitted at least once between 2 and 4am.

Files will be prefixed with the site name and include a timestamp for the time of their creation.

Data can be uploaded in an automated fashion using psftp. Here is an example psftp script:

- open cdhenrgy.user.openhosting.com
- mput cooperunion*.csv
- quit

This can be called from the command line using a batch file. Here is an example Batch File:

psftp -l username -pw password -b upload.psftp