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Test and Quality Assurance Plan

Climate Energy freewatt™ Micro-Combined Heat and Power System

Prepared by:

Greenhouse Gas Technology Center

Operated by
Southern Research Institute

Under a Cooperative Agreement With
U.S. Environmental Protection Agency

and

Under Agreement With
New York State Energy Research and Development Authority

EPA REVIEW NOTICE

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Greenhouse Gas Technology Center

A U.S. EPA Sponsored Environmental Technology Verification (ETV) Organization

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Climate Energy freewatt™
Micro-Combined Heat and Power System

This Test and Quality Assurance Plan has been reviewed and approved by the Greenhouse Gas Technology Center Project Manager and Center Director, the U.S. EPA APPCD Project Officer, and the U.S. EPA APPCD Quality Assurance Manager.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

AFUE	annual fuel utilization efficiency
APPCD	Air Pollution Prevention and Control Division
AWG	American Wire Gauge
BoP	balance of plant
Btu/h	British thermal units per hour
Btu/scf	British thermal units per standard cubic foot
C_3H_8	propane (reference for FID)
CH_3	methane (reference for FID)
CHP	combined heat and power
c_i	mean concentration of constituent i
c_{corr}	Mean concentration corrected to 15% O_2
CLD	chemiluminiscent detector
CO_2	carbon dioxide
CO_2	carbon monoxide
CT	current transformer
DG	distributed generation
DG / CHP	distributed generation / combined heat and power
DHW	domestic hot water
DQO	data quality objective
DVM	digital volt meter
EP	electric power
EPA	U.S. Environmental Protection Agency
EP_B	electric power flow to the boiler & controls
EP_{MCHP}	electric power flow to/from the generator unit under test
ETV	Environmental Technology Verification
ºF	degrees Fahrenheit
F_{Gn}	gas flow (nth, volumetric)
FID	flame ionization detector
F_{Vn}	volumetric flow (nth unit)
GHG	greenhouse gas
gpm	U.S. gallons per minute
H_2O	water
"H_2O	inches water column
HHI	hybrid hydronic integration unit
HI	hybrid integration unit
HR_{LHV}	heat rate for power generation on a LHV basis (Btu/kWh)
Hz	Hertz (cycles per second)
IC	internal combustion
kBtu/h	thousand BTU/h
kW	kiloWatt
LHV	lower heating value (fuel gas)
MMBtu/h	million BTU/h
MQO	measurement quality objective
NDIR	non-dispersive infrared
NDUV	non-dispersive ultraviolet
NIST	National Institutes of Standards and Technology
NMHC	non-methane hydrocarbon
NO_x	nitrogen oxides
NYSERDA	New York State Energy Research and Development Authority
O_2	oxygen
PEMS	portable emissions measurement system
ph	phase
ppmv	volumetric parts per million
PVC	polyvinyl chloride
QA	quality assurance
QA/QC	quality assurance / quality control
RTD	resistance temperature device
scfh	standard cubic feet per hour
THC	total hydrocarbons
THD	total harmonic distortion
T_{Rn}	return fluid temperature (nth unit)
T_{Sn}	supply fluid temperature (nth unit)
UL	Underwriters Laboratory
V	Volt (electric potential)
η	efficiency (%)
$\eta_{e,LHV}$	fuel:electric power efficiency (LHV)
$\eta_{th,LHV}$	fuel:heat efficiency (LHV)
η_{tot}	fuel:total output energy (LHV)

DISTRIBUTION LIST

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1.0 INTRODUCTION

The intent of this Test and Quality Assurance Plan (test plan) is to guide the planning, execution, data analysis, and reporting for performance verification of a Climate Energy freewatt Micro-Combined Heat and Power System. The system is a reciprocating internal combustion (IC) engine distributed electrical generation and combined heat and power (DG / CHP) installation designed and commissioned by Climate Energy. Heat is captured from the generator engine and passed to domestic heat loads via a closed heat transfer loop.

Climate Energy has installed a hydronic version of the freewatt system at a private residence in Lake Ronkonkoma, Long Island, New York. Appendix B provides the freewatt module specifications.

The CHP system provides domestic hot water via an indirectly-heated hot water heater and comfort heat to the residence via a hydronic heating system. Included in the package is a high efficiency boiler that provides backup/peak heating and a “hybrid” hydronic system controller that manages the hot water temperatures delivered to the hydronic system from the boiler/CHP system. The system is connected in parallel to the electric utility grid, which provides standby and peak power as required.

The system operates on a thermal-load-following mode, in which power is generated only when heat is called for from the system. The system is configured to enable export of excess power generation to the grid.

Manufacturer specifications indicate that the recovered energy will supply up to 12 thousand British thermal units per hour (kBtu/h) to the local heating loads while producing 1.2 kilo Watt (kW) of electric power. The supplementary boiler can provide up to an additional 190 kBtu/h.

On-site loads include:

- year-round domestic hot water (DHW)
- hydronic space heating during cold weather

The test campaign will determine the emissions performance, electrical performance, thermal recovery and electrical efficiency of the CHP module during a “controlled test period”. An additional “extended monitoring period” will report thermal recovery, electrical efficiency and will develop an estimate of energy savings over a period of not less than three months during the heating season.

1.1. PURPOSE

The New York State Energy Research and Development Authority (NYSERDA) and the U.S. Environmental Protection Agency (EPA) Environmental Technology Verification (ETV) program have commissioned this test campaign. Test results also are of interest to the ETV program because previous CHP verifications have not included this technology.

1.2. PARTICIPANTS, ROLES, AND RESPONSIBILITIES

Southern Research Institute’s (Southern’s) Greenhouse Gas (GHG) Technology Center will manage the test campaign. Responsibilities include:

- test strategy development and documentation
- coordination and execution of all field testing, including:
- installation, operation, and removal of emissions testing equipment
- providing electrical power monitoring, CHP heat production, and data logging equipment
- subcontract management for installation and removal of electrical power monitors
- inspection of calibrations, performance of crosschecks, and other activities
- data validation, quality assurance and quality control (QA / QC), and reporting

The residence located in Lake Ronkonkoma, NY will serve as the host facility. The freewatt™ system was installed by Climate Energy, LLC. Southern will work closely with Climate Energy personnel to ensure reasonable access to the host home and minimal effects on the residents.

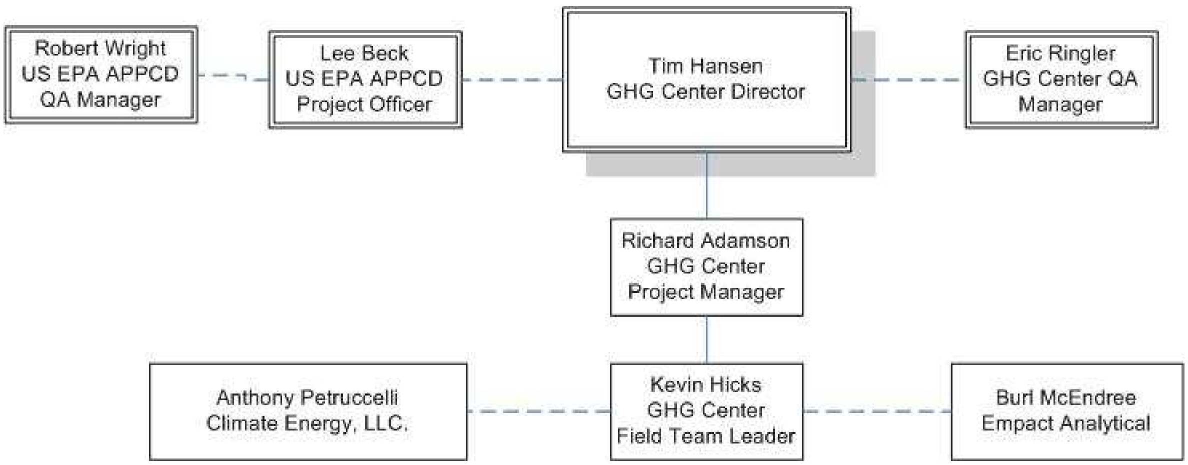

Figure 1-1: Test Participants

Tim Hansen is the GHG Technology Center Director. He will:

- ensure the resources are available to complete this verification
- review the test plan and verification report to ensure they conform to ETV principles
- oversee GHG Technology Center staff and provide management support where needed
- sign the verification statement, along with the EPA Office of Research and Development laboratory director.

Richard Adamson will serve as the Project Manager for the GHG Center. He will have authority to suspend testing in response to health or safety issues or if data quality indicator goals are not met. His responsibilities also include:

- drafting the test plan and verification report
- overseeing the field team leader's data collection activities
- ensuring that data quality objectives (DQO) are met prior to completion of testing
- maintaining effective communications between all test participants

Kevin Hicks will serve as the Field Team Leader. He will:

- provide field support for activities related to all measurements and data collected
- install and operate the measurement instruments
- collect gas samples and coordinate sample analysis with the laboratory

- ensure that QA / QC procedures outlined in this test plan are followed
- submit all results to the Project Manager to facilitate his determination that DQOs are met

If it is deemed necessary an additional field team member may accompany the Field Team Leader.

The GHG Technology Center QA Manager, Eric Ringler, is administratively independent from the GHG Center Director and the field testing staff. Mr. Ringler will:

- ensure that all verification tests are performed in compliance with the QA requirements of the GHG Center quality management plan, the generic protocol [1], and this test plan
- review the verification test results and ensure that applicable internal assessments are conducted as described in the test plan
- reconcile the DQOs at the conclusion of testing
- conduct or supervise an audit of data quality
- review and validate subcontractor-generated data
- report all internal reviews, DQO reconciliation, the audit of data quality, and any corrective action results directly to the GHG Center Director, who will provide copies to the project manager for corrective action as applicable and citation in the final verification report
- review and approve the final verification report and statement

Fuel gas analyses will be conducted by Empact Analytical of Brighton, Colorado under the management of Burl McEndree.

EPA Office of Research and Development will provide oversight and QA support for this verification. The Air Pollution Prevention and Control Division (APPCD) Project Officer, Lee Beck, is responsible for obtaining final approval of the Test Plan and Report. The APPCD QA Manager will review this test plan and the final Report to ensure they meet the GHG Center Quality Management Plan requirements and represent sound scientific practices.

Anthony Petruccelli of Climate Energy is responsible for the DG / CHP system design and will serve as the primary contact for the host facility. He will also work with the Southern field team leader to coordinate test activities.

1.3. TEST SCHEDULE

The host facility's design normally requires that the CHP module follows the thermal load as it varies throughout the day, switching on when heat is required and off when thermal demand reduces. The controlled test period, however, will require operations of the CHP module under controlled load conditions (forced thermal loading) during the test period. Normal operation will resume as soon as this test period is finished.

Southern will install electric power production and parasitic electric load monitoring as well as heat transfer fluid flow and temperature monitoring equipment for use during the controlled test period.

Table 1-1 illustrates the expected sequence of events during the controlled test period. Test dates will be coordinated with Climate Energy.

Table 1-1: Controlled Test Period

Controlled Test Schedule				
Day 1	Day 2	Day 3	Day 4	Day 5
Travel to area. Receive equipment.	Orientation & safety conference. Mobilize test equipment & perform preliminary setup. Hoist emissions monitoring equipment. Install emissions test stack. Install fluid flow & temperature sensors. Install power measurement equipment.	Complete installation. Perform pre-run instrument checks. Complete one set of three runs testing CHP only at full load. Perform data quality checks and preliminary analyses..	If necessary perform a second set of three runs. Remove emissions monitoring instrumentation. Set up for extended monitoring. Pack for shipment. Perform data quality checks and preliminary analyses on second data sets (if applicable).	Ship equipment & return to lab.

The extended test will commence on completion of the controlled test period. Instruments will be configured for continuous monitoring from Southern Research's facility in Durham, NC. This period will extend from a period during which no comfort heating load will be required on site (only domestic hot water) through a substantial portion of the cooling season, during which time the comfort heating load is expected to dominate. The data collection period will include at least two months of the heating season. The projected test schedule is illustrated in Figure 1-2.

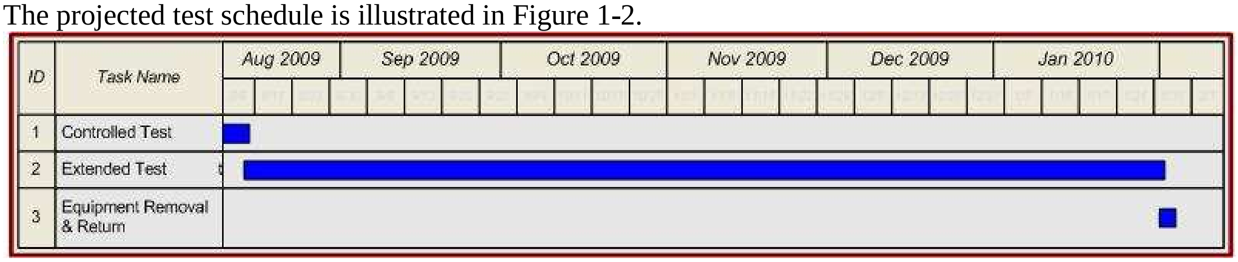

Figure 1-2: Extended Test Period

2.0 TEST PROCEDURES

The ETV program has published the Distributed Generation and Combined Heat and Power Field Testing Protocol [1] (generic protocol). The generic protocol contains detailed test procedures, instrument specifications, analytical methods, and QA / QC procedures. This test campaign will generally conform to the generic protocol specifications, with modifications or special considerations as listed in the following subsections. Appendix A provides field data forms as derived from the generic protocol.

The Environmental Technology Verification (ETV) program test of the freewatt combined heat and power (CHP) system will require the temporary installation of various sensors and instruments. The schematics presented in Figures 2-1 and 2-2 show generic mechanical and electrical layouts. This document assumes a hydronic heat demand-driven installation.

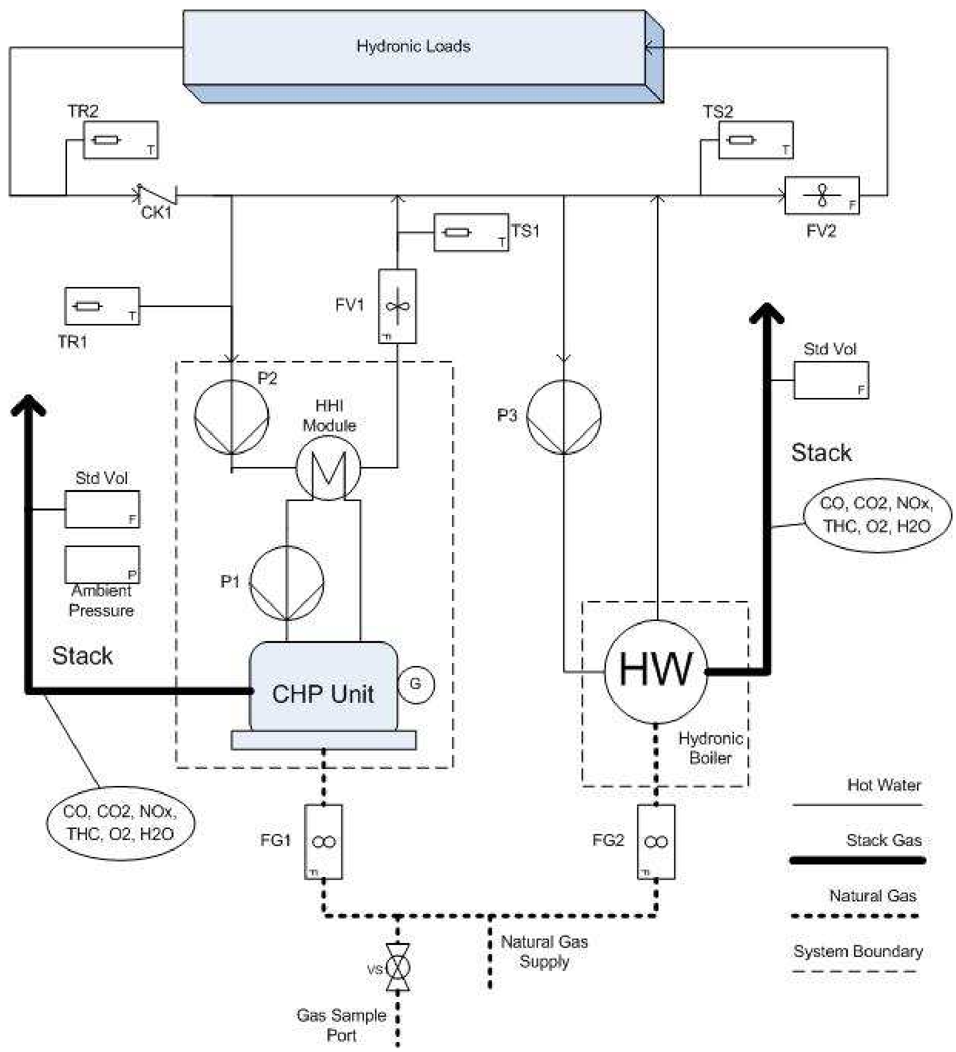

Figure 2-1: Mechanical Instrumentation Schematic

Table 2-1: Instrument Descriptions and Locations[1]

Index	Ch_ID (channel)	Parm_ID (parameter)	Description	Nominal rating / expected value	Location	Sensor manufacturer, model number
1	1	F_{V1}	Heat transfer fluid (water) flow rate	5 gallon per minute (gpm)	Outlet of CHP circulation pump and standby pump	Hedland model HTTF1-BA-NN ultrasonic flow meter (3/4" copper pipe)
3	02	T_{S1}	Supply temperature	80 - 140 ^oF	Outlet of CHP circulation pump	Omega SA-RTD-80-MTP 3-wire surface mount resistance temperature device (RTD)
4	03	T_{R1}	Return temperature	70 - 100 ^oF	Heat transfer fluid return line	Omega SA-RTD-80-MTP 3-wire surface mount RTD
6	04	F_{G1}	MCHP Natural gas consumption, 100 pulse per acf	31 pulse/min at 18,500 Btu/h	Revenue gas meter	Invensys R200 with IMAC pulse converter
7	05	F_{G2}	Boiler Natural gas consumption	144 pulse/min at 80,000 Btu/h	Revenue gas meter	Dresser Roots 8C175
8	06	F_{V2}	Main hydronic heating loop flow rate	10 gpm	Main hydronic loop	Hedland model HTTF1-BA-NN ultrasonic flow meter (3/4" copper pipe)
9	07	T_{S2}	Main hydronic heating loop supply temperature	80 - 140 ^oF	Main loop downstream of last heat source outlet (supply)	Omega SA-RTD-80-MTP 3-wire surface mount RTD
10	08	T_{R2}	Main hydronic heating loop return temperature	70 - 100 ^oF	Main hydronic loop upstream of first heat source inlet (return)	Omega SA-RTD-80-MTP 3-wire surface mount RTD
11	Lab Analysis	Fuel_LHV	Natural gas lower heating value	910 British thermal units per standard cubic foot (Btu/scf)	Gas Sample Port	Empact Analytical sampling bottles
12	Power Meter/ Logger	EP_{MCHP}	Generated real power, reactive power, power factor, voltage, current, frequency, total harmonic distortion	1.2 kW	Generator output	Power Logic ION 7500 with (2) Flex-core CTY-050A-1 CTs (controlled test only. See Index (14)/(15) below for extended monitoring.)
13	09	EP_B	Parasitic load (boiler controls and boiler circulating pump) real power consumption including boiler	0.2 kW, 8.9 pulse/min	Boiler subpanel	WattNode WNB-37-208P with (2) WattNode CTS-0750-015 split-core CTs
14	010	EP_{MCHP_in}	Consumed real power (extended monitoring only – see Index (12) above for controlled test power measurement.)	0.1 kW, 4.4 pulse/min	MCHP subpanel	WattNode WNB-37-208P with (3) WattNode CTS-0750-015 split-core CTs (P1 output)
15	011	EP_{MCHP_out}	Generated real power (extended monitoring only – see Index (12) above for controlled test power measurement.)	1.2 kW, 53 pulse/min	P2 output, same instrument as Index (14) above.	P2 output, same instrument as Index (14) above.

[1] See Appendix C1 for instrument and manufacturer details.

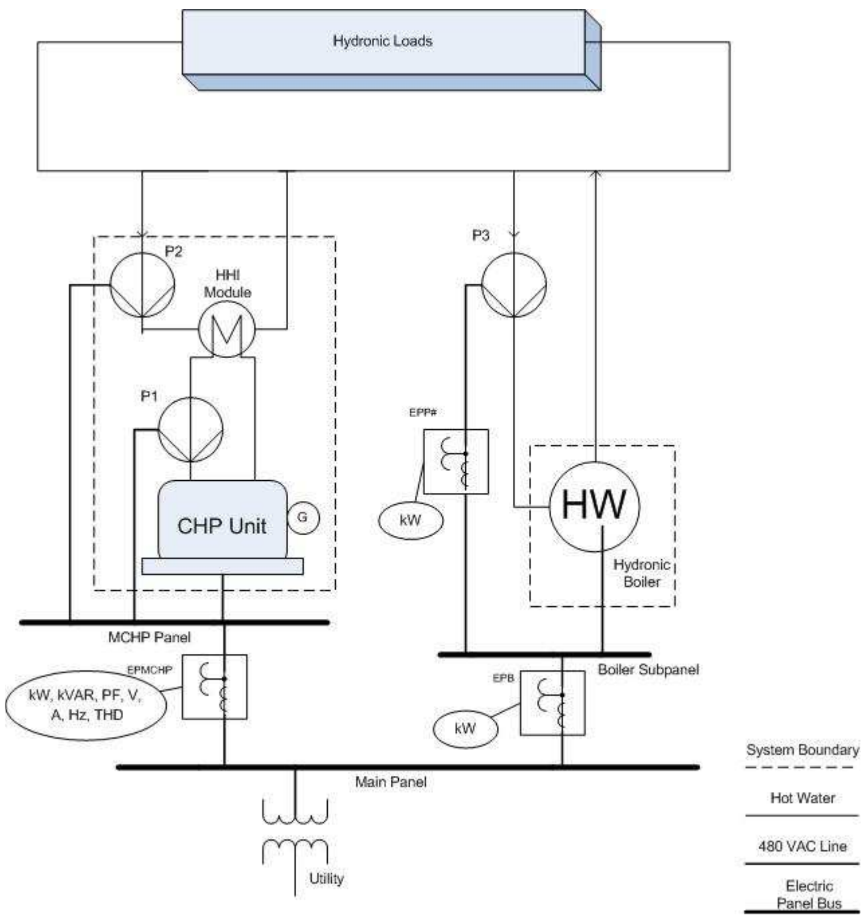

Figure 2-2: Electrical One-Line Drawing with Simplified Mechanical

This monitoring scheme will allow separate quantification of MCHP and total heat production. Hydronic boiler heat production will be the difference between the two. Southern Research Institute (Southern) will use non-intrusive ultrasonic fluid flow meters and surface-mounted temperature sensors. The flow meters and temperature sensors will require the installation of ¾" inner diameter (7/8" outer diameter) copper tubing metering sections at F_{V1} and F_{V2} as shown in Figure 2-1. Flow rate at each meter location will be between 1 and 55 gallons per minute. Measurements will be performed using Hedland ultrasonic flow meters (see Index 1 and 8 of Table 2-1 and Appendix C). Temperature sensors are surface mounted 3-wire 100 Ohm platinum RTD type, bonded to the surface of the copper pipe and insulated to prevent artifacts due to ambient conditions (see Index 3,4,9 and 10 of Table 2-2 and Appendix C)..

System designers have configured the natural gas piping to allow the temporary installation of Southern-supplied gas meters. The F_{G1} MCHP gas flow measurement instrument (Figure 2-1 and Index 6 of Table 2-1 and Appendix C) will be a Rockwell / Invensys R 200 standard household-type gas meter with top-mounted 1 ¼" NPT union-style fittings. The F_{G2} hydronic boiler gas flow instrument (Figure 2-1 and Index 7 of Table 2-1 and Appendix C) will be a Dresser Roots meter, model 8C175 with 1 ½" NPT male threaded fittings. Figures 2-3 and 2-4 provide photographs and dimensions. Each metering loop will incorporate shutoff and bypass valves to enable installation and removal of the meters without disrupting operations. The gas line will include one sample port, ½" NPT female coupler with a removable plug, shown as "Gas Sample Port – VS1" in Figure 2-2. Southern will supply the sampling petcock.

8C175	Overall Length		Overall Height		Width (Flange/Flange)		Centerline to Accessory End (CL-AU)		Request Detailed
Series B3	inches	mm	inches	mm	inches	mm	inches	mm	Drawing Number
CTR / TC	14-9/32	363	6	153	6-3/4	172	11-13/32	290	D054516-000
CD / TD	18-3/32	460	6-9/32	160	6-3/4	172	13-7/16	341	D054430-000
CPS / TPS	16-13/32	417	6	153	6-3/4	172	13-17/32	344	D054669-000
VCC	16-1/2	419	8-1/16	205	6-3/4	172	11-31/32	304	D054236-000
VTC	16-29/32	429	6	153	6-3/4	172	12-7/32	310	D054180-000

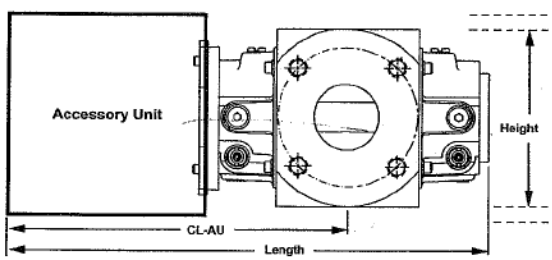

Figure 2-3: (Dresser) Roots 8C175 Gas Meter

Figure 2-4: Invensys R200 Gas Meter

The circulation pump "P3" in Figure 2-2, is not be considered a parasitic load because all hydronic heating systems require a circulation pump. The illustrated metering scheme will allow for netting out the P3 load if desired.

The MCHP exhaust stack is 2" diameter PVC pipe and the hydronic boiler stack is 3" diameter PVC pipe. Southern will use a portable emissions monitoring system (PEMS) for the exhaust emissions tests. The PEMS should function effectively with the existing stacks, but temporary installation of test ducts, at least 10 diameters long, may be required.

2.1. TEST CONCEPTS AND OBJECTIVES

The test campaign will consist of a controlled test period and an extended. The controlled test incorporates emissions testing for the MCHP and hydronic boiler as well as electric power quality, electrical efficiency and thermal efficiency under controlled conditions. The extended test does not include emissions monitoring, focusing instead on energy performance under normal operating conditions over an extended period of time.

2.1.1. Controlled Test Period

The Field Team Leader will be on-site during the controlled test period to perform the following determinations on the freewatt unit under test:

- electrical performance (see generic protocol §2.0 for parameters and specifications; Appendix D1 for definitions and equations)
- electrical efficiency (see generic protocol §3.0 for parameters and specifications; Appendix D2 for definitions and equations)
- thermal performance (see generic protocol §4.0 for parameters and specifications; Appendix D3 for definitions and equations)
- Atmospheric emission performance gaseous carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_X) and total hydrocarbons (THC) emissions performance (see generic protocol §5.0 for parameters and specifications; Appendix D4 for definitions and equations)

The generic protocol recommends testing at 100, 75, 50, and 25 percent of capacity, but the freewatt unit operates in an on/off mode only. Power levels during the controlled test period will therefore be 100 percent of capacity only. The generic protocol recommends 1-hour test runs for internal combustion engines and 30-minute test runs for microturbines. Southern has found that 30-minute test runs provide stable data with narrow confidence intervals for both types of power plants. The controlled test period will therefore consist of three (3) test runs, each 30 minutes long. A 10-minute warm-up and equilibration period will precede each test run.

Southern will coordinate the temporary installation of independent electrical power analyzers on the CHP unit output bus. Figure 2-1 shows the instrument locations. The analyzers will record the electrical performance parameters at 1-minute intervals or shorter. These instruments will allow proper quantification of the generator, circulation and electronics parasitic loads.

Two sets of three measurements electrical, thermal and emissions readings will be performed. In the first, the boiler will be turned off, so that the only heat source on the system is the MCHP unit. The second set of electrical, thermal and emissions readings will be performed with the boiler and MCHP systems both operational. Emission measurements will be performed on the boiler system for this set of three runs.

Three repetitions of measurements under identical conditions will provide data quality and repeatability checks.

Southern will determine gaseous emissions as CO, CO_2, NO_X, and THC concentrations with a Horiba OBS-2200 portable emissions monitoring system (PEMS). The PEMS also measures exhaust gas flow with a stack flow tube. The field team will temporarily install the PEMS and flow tube (Figure 2-1, Std Vol – standard volumetric flow measurement) on the exhaust stack. The mean concentration for each gas during each individual test run, integrated with the mean exhaust gas volumetric flow rate observed during that test run, will yield the run's gaseous emission rate in pounds per hour. Reported results will consist of the mean of three valid test runs.

Southern will log natural gas consumption data for the MCHP unit from the Rockwell/Invensys R200 gas meter (Figure 2-1, FG1) and gas consumption for the boiler unit from the Dresser Roots 8C175 meter (Figure 2-1, FG2). Both meters provide pulse outputs for collection using data logging equipment. The field team will also collect natural gas samples for lower heating value (LHV) analysis off-site.

2.1.2. Extended Test Period

After the controlled test is complete the thermal and power measurement instrumentation will be left on site, logging data and periodically transmitting the data to the Southern Research lab facility. This will take place over a period of not less than five months encompassing at least two months of the typical heating season in New York. The instrumentation that will be removed from the site prior to the extended test relates to emissions measurements only.

Southern will log natural gas consumption from the MCHP unit and the boiler unit, as well as hot water supply and return temperatures, circulating flow, and electric power flow, including both production and consumption.

2.1.3. Instrument Specifications

The generic protocol provides detailed specifications for all instruments or analyses. Table 2-2 provides a synopsis of measurement accuracies, while Table 2-1, above, provides manufacturer and model number as well as channel assignments to the data acquisition system (data logger). Appendix C provides additional details regarding instrument manufacturers.

Table 2-2: Instrument and Analysis Accuracy Specifications[a]

Parameter	Accuracy
Voltage	± 0.5 %
Current	± 0.4 %
Real Power	± 0.6 %
Reactive power	± 1.5 %
Frequency	± 0.01 Hertz (Hz)
Power Factor	± 2.0 %
Voltage total harmonic distortion (THD)	± 5.0 %
Current THD	± 4.9 % to 360 Hz
Current transformer (CT)	± 0.3 % at 60 Hz
CT	± 1.0 % at 360 Hz
Temperature	± 1 °F
Barometric pressure	± 0.1 inches of mercury (± 0.05 pounds per square inch, absolute)
Gas flow	± 1.0 %[b]
LHV analysis by ASTM D1945 [2] and D3588 [3]	± 1.0 %
Heat transfer fluid flow	± 1.0 %
T_{supply}, T_{return} temperature sensors	± 0.6 °F
Gaseous emissions concentrations	± 2.0 % of span[c]
Method 2 volumetric flow rate	± 5.0 %

[a]All accuracy specifications are percent of reading unless otherwise noted.
[b]Utility gas meter is temperature- and pressure-compensated.
[c]PEMS conforms to or exceeds Table 1 of Title 40 CFR 1065.915 specifications.

2.2. SITE-SPECIFIC CONSIDERATIONS

Section 6.0 of the generic protocol lists step-by-step procedures for the controlled test period. This subsection considers site-specific testing, safety, or other actions which the field team will implement. Appendix A of this test plan provides the necessary field data forms.

Emissions testing

Southern will coordinate hoisting the PEMS, heated umbilical, calibration gases, and power supply to the level of the roof for the controlled tests. This will require a personnel lift.

The 2" diameter exhaust stacks for the CHP module exit the building through the original chimney. Each stack terminates in a U-bend section located about 24" above the roof surface. The field team will temporarily remove the U-bends and install a stack extension with integrated pitot and sampling probe that is included as part of the Horiba OBS 2000 system. The stack extension will provide 10 upstream diameters to the closest disturbance, as recommended by the PEMS manufacturer.

Electrical power monitors

Southern will coordinate the temporary installation of the electric power sensors by a qualified electrician. The generic protocol, Figure F-1 of Appendix F2, provides a wiring schematic. Southern will provide the power monitors, shorting switches, current transmitters (CT), and miscellaneous supplies. These tests will employ both split-core CTs, eliminating the need to break existing electrical connections. The power meters will require direct voltage connection to each phase. The electrical feeds must be shut down briefly during the connection procedure and while installing the CTs and voltage connections.

Natural gas sampling

Southern will collect three natural gas samples during the controlled test. Southern will coordinate installation of sampling petcocks if required. The expected 12 - 20 inches of water column (" H_2O) pressure will require the use of Southern's low pressure gas sampling pump and manifold. The field team will temporarily connect the sampling manifold inlet to the petcock. They will connect an evacuated sample bottle to the outlet port and purge the bottle for at least 60 seconds prior to capping and sealing during each sampling event. Analysts will use the mean LHV in the electrical and CHP efficiency determinations. Appendices A6 and A7 provide a sampling log and chain of custody form, respectively.

Gas utility data for heating values will be collected for the period from before the controlled test to the end of the extended monitoring period. The values sampled nearest to the controlled test will be compared to the independent lab analyses. These secondary values will be used in estimating the variability in the fuel supply and to identify any potential artifacts due to heating value fluctuations.

3.0 DATA QUALITY

Southern operates the GHG Technology Center for the EPA ETV program. Southern's analysis and QA / QC procedures conform to the Quality Management Plan, Version 1.4, developed for the GHG Technology Center.

3.1. DATA ACQUISITION

The field team will collect the following electronic data files:

- power output and power quality parameters
  - ION 7500 power meter database (during controlled test only)
  - data logger – WattNode™ power meter (power input during idle cycles and output during generating cycles through the extended monitoring period only)
- parasitic loads
  - data logger – WattNode™ power meter
  - clamp-type real power meter for manual measurements of controls power consumption
- emissions concentrations
  - PEMS
- heat transfer fluid temperature and flow rate
  - data logger

The power meters and data logger will poll their sensors once per second during the controlled test period. The power meters will then calculate and record one-minute averages. The field team leader will download the one-minute power meter and one second data logger data directly to a laptop computer. Extended monitoring data will be periodically collected remotely.

The field team will record printed or written documentation on the log forms provided in Appendix A, including:

- daily test log, including test run starting and ending times, notes, gas meter readings, etc.
- appendix A forms which show the results of QA / QC checks
- copies of calibrations and manufacturers' certificates

The GHG Center will archive all electronic data, paper files, analyses, and reports at their Durham, NC office in accordance with their quality management plan.

3.2. DATA QUALITY OBJECTIVES

The generic protocol [1] provides the basis for the data quality objectives (DQO) to be achieved in this verification. Previous DG / CHP verifications and peer-reviewed input from EPA and other stakeholders contributed to the development of those specifications. Tests which meet the following quantitative DQOs will provide an acceptable level of data quality to meet the needs of technology users and decision-makers. The DQO specifications are in terms of relative measurement uncertainty.

Verification Parameter	DQO (relative uncertainty)
electrical performance as generated power	± 2.0 %
electrical efficiency	± 2.5 %
CHP thermal efficiency	± 3.5 %

Each test measurement that contributes to a verification parameter has stated measurement quality objectives (MQO) which, if met, ensure achievement of that parameter's DQO. Table 2-2 summarizes the generic protocol MQOs as accuracy specifications for each instrument or measurement.

The gaseous emissions DQO is qualitative in that this verification will produce emission rate data that satisfies the QA / QC requirements for EPA Title 40 CFR 1065 field test methods [4]. The verification report will provide sufficient documentation of the QA / QC checks to evaluate whether the qualitative DQO was met.

The completeness goal for this verification is to obtain valid data for 90 percent of each controlled test period.

A fundamental component of all verifications is the reconciliation of the collected data with its DQO. The DQO reconciliation will consist of evaluation of whether the stated methods were followed, MQOs achieved, and overall accuracy is as specified in the generic protocol and this test plan. The Field Team Lead and Project Manager will initially review the collected data to ensure that they are valid and consistent with expectations. They will assess the data's accuracy and completeness as they relate to the stated QA / QC goals. If review of the test data shows that QA / QC goals were not met, then immediate corrective action may be feasible, and will be considered by the Project Manager. DQOs will be reconciled after completion of corrective actions. As part of the internal audit of data quality, the GHG Center QA Manager will include an assessment of DQO attainment.

3.3. DATA REVIEW, VALIDATION, AND VERIFICATION

The Project Manager will initiate the data review, validation, and analysis process. Under the guidance of the Project Manager, Southern Research analysts will validate the data, employing the QA / QC criteria specified in §3.5 to classify all collected data as valid, suspect, or invalid.

In general, valid data results from measurements which:

- meet the specified QA / QC checks
- were collected when an instrument was verified as being properly calibrated
- are consistent with reasonable expectations, manufacturers' specifications, and professional judgment

The report will incorporate all valid data. Analysts may or may not consider suspect data, or it may receive special treatment as will be specifically indicated. If the DQO cannot be met, the project manager will decide to continue the test, collect additional data, or terminate the test and report the data obtained.

Data review and validation will primarily occur at the following stages:

- on site -- by the Field Team Leader
- upon receiving laboratory deliverables
- before writing the draft report -- by the Project Manager

- during draft report QA review and audits -- by the GHG Center QA Manager

During the extended monitoring period, downloaded data files will be checked by analysts against DQOs and conformance with reasonable expectations of the equipment performance. In case of failure to meet DQOs or reasonableness checks, potential sources of error will be investigated remotely. If they are unresolved or instrument/data acquisition equipment failure is determined to be the cause then Southern Research will arrange for local support or, if necessary, will travel to the site to correct the problem. Should the data set be reduced and it is determined that meeting the DQOs will require extending the measurement period, the equipment will continue to be monitored beyond the projected term.

3.4. INSPECTION AND ACCEPTANCE OF SUPPLIES, CONSUMABLES, AND SERVICES

Procurement documents shall contain information clearly describing the item or service needed and the associated technical and quality requirements. Consumables for this verification will primarily consist of calibration gases. Fuel analysis will be the only purchased service. The procurement documents will specify the QA / QC requirements for which the supplier is responsible and how conformance to those requirements will be verified.

Procurement documents shall be reviewed for accuracy and completeness by the Project Manager and QA Manager. Appropriate measures will be established to ensure that the procured items and services satisfy all stated requirements and specifications.

3.5. CALIBRATIONS AND PERFORMANCE CHECKS

Sections 7.1 through 7.3 of the generic protocol specify a variety of technical system audits and QA / QC checks for the electrical performance, electrical efficiency, and CHP performance determinations. This test campaign will perform those that are applicable to the host facility. The final test report will cite the results for each QA / QC check.

3.5.1 Calibration Gases

Calibrations (zero and span) will be performed in the field using Certified Standards with a single point audit check against EPA Protocol Gases before mobilization and after demobilization. Records will be maintained of all calibrations and audit checks. Suitable gases will be procured from Airgas Industries.

> *EPA Protocol Gases are manufactured and analytically certified in strict accordance with the most recent EPA traceability guideline document entitled "EPA Traceability Protocol for Assay and Certification of Gaseous Standards".*
>
> Airgas Industries

The generic protocol specifies Title 40 CFR 60 Appendix A source test methods to determine gaseous pollutant emissions. This test campaign, however, will employ a Horiba OBS-2200 PEMS that meets Title 40 CFR 1065 [4] specifications. Southern will also deploy a Testo 350 multi-gas combustion analyzer as a backup instrument. The field team will conduct the technical system audits, calibrations, performance checks, and cross checks listed in Table 3-1.

Table 3-1: Recommended Calibrations and Performance Checks

System or Parameter	Description / Procedure	Frequency	Meets Spec.?	Date Completed
Pressure transducers	Cross-check with NIST-traceable[a] transfer standard	Within 12 months	☐	
Temperature transducers (T_{S1}, T_{S2}, T_{R1}, T_{R2})	Ice bath / boiling water bath (adjusted for altitude) cross check	Within 12 months	☐	
CHP heat transfer fluid flow meter	NIST-traceable[a] calibration	Within 12 months	☐	
All gas analyzers	11-point linearity check	Within 12 months	☐	
CO_2 (NDIR detectors)[b]	H_2O interference	Within 12 months	☐	
CO (NDIR detectors)	CO_2, H_2O interference		☐	
Hydrocarbon analyzer (FID)[c]	Propane (C_3H_8) calibration		☐	
	FID response optimization		☐	
	C_3H_8 / methyl radical (CH_3) response factor determination		☐	
	C_3H_8 / CH_3 response factor check		☐	
	O_2 interference check		☐	
NO_X analyzer	CO_2 and H_2O quench (CLD)[d]		☐	
NO_X analyzer	Non-methane hydrocarbons (NMHC) and H_2O interference (NDUV detectors)[e]	Within 12 months	☐	
NO_X analyzer	Ammonia interference and NO_2 response (zirconium dioxide detectors)	Within 12 months	☐	
	Chiller NO_2 penetration (PEMS with chillers for sample moisture removal)		☐	
	NO_2 to NO converter efficiency	Within 6 months or immediately prior to departure for field tests	☐	
Complete PEMS	Comparison against laboratory CVS system	At purchase / installation; after major modifications	☐	
	Zero / span analyzers (zero ≤ ± 2.0 % of span, span ≤ ± 4.0 % of point)	Before and after each test run	Refer to Appendix A2, "Test Run Record"	
	Perform analyzer drift check (≤ ± 4.0 % of cal gas point)	After each test run		
	NMHC contamination check (≤ 2.0 % of expected conc. or ≤ 2 ppmv)	Once per test day		
	100 ppm CO cal gas crosscheck with Testo	At least once per test day		
Testo (if used)	Zero / span analyzers (zero ≤ ± 2.0 % of span, span ≤ ± 4.0 % of point)	Before and after each test run	☐	
	Perform analyzer drift check (≤ ± 4.0 % of cal gas point)	After each test run	☐	
	100 ppm CO cal gas crosscheck with PEMS	At least once per test day	☐	
Exhaust gas or intake air flow measurement device	Differential pressure line leak check (delta-P stable for 15 seconds at 3 " H_2O)	Once per test day	☐	
Digital Electric Power Meters	Reverification Cross-check (0.01A, 0.2 V between ION qualified meters)	Reverification – every 10 years Cross-check – before and after each field mission	☐	

[a]National Institutes of Standards and Technology (NIST)
[b]non-dispersive infrared (NDIR)
[c]flame ionization detector (FID)
[d]chemiluminescence detector (CLD)
[e]non-dispersive ultraviolet (NDUV)

3.6. AUDITS OF DATA QUALITY

The reported results will include many contributing measurements from numerous sources. Data processing will require different algorithms, formulae, and other procedures. Original data logger text files, power meter database Excel-format file outputs, signed logbook entries, signed field data forms, and documented laboratory analyses for fuel LHV will be the source for all Excel worksheets used as analysis tools. The GHG Center QA manager will:

- manually check the formulae and results for each data stream from raw data to results
- compare the spreadsheet results with data that is reported in the draft report
- in the event that errors are found, the auditor will track problems to their source and resolve the errors.

3.7. INDEPENDENT REVIEW

The GHG Center QA manager will examine this test plan, the report text, and all test results. The analyst or author who produces a result table or text will submit it (and the associated raw data files) to him or to an independent technical or editorial reviewer. Reviewers will be Southern employees with different lines of management supervision and responsibility from those directly involved with test activities.

3.8. DATA PACKAGE SUBMISSION

In addition to the draft report a supplementary data package will be submitted to the Project Officer. In accordance with the Quality Management Plan [5] this package will include:

- Test Report;
- Audit of Data Quality Memo;
- Results of calibrations and instrument performance checks; and
- Analysis spreadsheets with a representative sample data set.

Raw data sets will be maintained by the GHG Center and will be made available to the EPA on request.

4.0 ANALYSIS AND REPORTS

The test report will summarize field activities and present results. Attachments will include sufficient raw data to support the findings and allow reviewers to assess data trends, completeness, and quality. The report will clearly characterize the test parameters, their results, and supporting measurements as determined during the test campaign. It will present raw data and analyses as tables, charts, or text as is best suited to the data type.

The report will group the results separately for the controlled test runs and long-term monitoring period.

Reported results from the controlled test will include:

- run-specific mean, maximum, minimum, and standard deviation
- run-specific assessment of the permissible variations within the run for the controlled test period

- Reported results from both the controlled test and extended monitoring include:

- overall mean, maximum, minimum, and standard deviation for all valid test runs
- ambient conditions (temperature, barometric pressure) observed during each controlled test run
- description of measurement instruments and a comparison of their accuracies with those specified in the generic protocol
- summary of data quality procedures, results of QA / QC checks, the achieved accuracy for each parameter, and the method for citing or calculating achieved accuracy
- copies of fuel analysis and other QA documentation, including calibration data sheets, duplicate analysis results, etc.
- results of data validation procedures including a summary of invalid or suspect data and the reasons for the validation status
- information regarding any variations from the procedures specified in this test plan
- narrative description of the DG installation, site operations, and field test activities including observations of site details that may impact performance. These include thermal insulation presence, quality, mounting methods that may cause parasitic thermal loads etc.

The following subsections itemize the reported parameters. Appendix D of the generic protocol provides the relevant definitions and equations.

4.1. ELECTRICAL PERFORMANCE

The electrical performance test reports (for controlled test period) will include the mean:

- total real power without external parasitic loads, kW
- total reactive power, kilovolt-amperes reactive
- total power factor, percent
- voltage (for each phase and average of all three phases), volts (V)

- current (for each phase and average of all three phases), amperes (A)
- frequency, Hertz (Hz)
- Voltage total harmonic distortion (THD), percent
- Current THD percent
- real power consumption for the external parasitic loads, kW
- total real power including debits from all external parasitic loads, kW

4.2. ELECTRICAL EFFICIENCY

Electrical efficiency test reports (for both the controlled test period and the extended monitoring period) will include:

- electrical generation efficiency ($\eta_{e,LHV}$) without external parasitic loads
- electrical generation efficiency ($\eta_{e,LHV}$) including external parasitic loads
- heat rate (HR_{LHV}) without external parasitic loads
- heat rate (HR_{LHV}) including external parasitic loads
- total kW
- heat input, British thermal units per hour (Btu/h) at a given electrical power output
- fuel input, standard cubic feet per hour (scfh)

The report will quote all laboratory analyses for the fuel LHV in Btu/scf.

Note that electrical generation efficiency uncertainty will be reported in absolute terms. For example, if $\eta_{e,LHV}$ for gaseous fuel is 26.0 percent and all measurements meet the accuracy specifications, the relative error is ± 3.0 percent (see generic protocol Table 7-4). The absolute error is 26.0 times 0.030, or ± 0.78 percent. The report, then, will correctly state $\eta_{e,LHV}$ as "26.0 ± 0.8 percent".

4.3. CHP THERMAL PERFORMANCE

The thermal performance report for the CHP system in heating service will include the mean:

- thermal performance (Q_{out}), Btu/h
- thermal efficiency ($\eta_{th,LHV}$)
- total system efficiency ($\eta_{tot,LHV}$) as the sum of $\eta_{th,LHV}$ and $\eta_{e,LHV}$
- heat transfer fluid supply and return temperatures, degrees Fahrenheit (^{o}F), and flow rate, gallons per minute (gpm)

The report will cite the achieved accuracies for η_{th} and η_{tot} in absolute terms.

4.4. ATMOSPHERIC EMISSIONS

Reported parameters for each test run will include the following:

- emission concentrations for CO, NO_X, and THC evaluated in volume parts per million (ppmv) corrected to 15 percent oxygen (O_2)
- emission concentration for CO_2 corrected to 15 percent O_2
- Note: the correction equation is:

$$c_{corr} = c_i \left[\frac{20.9 - 15}{20.9 - O_2} \right]$$

Where:

c_{corr} = concentration corrected to 15 percent O_2, ppmv or percent
c_i = mean concentration of the constituent i, ppmv or percent
20.9 = atmospheric O_2 content, percent
O_2 = mean exhaust gas O_2 content, percent

- emission rates for CO, CO_2, NO_X, and THC evaluated as pounds per hour and normalized to generated power as pounds per kilowatt-hour
- exhaust gas dry standard flow rate, actual flow rate, and temperature
- exhaust gas composition, moisture content, and molecular weight

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5.0 REFERENCES

[1] *Generic Verification Protocol -- Distributed Generation and Combined Heat and Power Field Testing Protocol, Version 1.0*, SRI/USEPA-GHG-GVP-04, Southern Research Institute and US EPA Environmental Technology Verification (ETV) Program, available at: <http://www.epa.gov/etv/pubs/sriusepaghggvp04.pdf>, Washington, DC 2005

[2] *ASTM D1945-98—Standard Test Method for Analysis of Natural Gas by Gas Chromatography*. American Society for Testing and Materials, West Conshohocken, PA. 2001

[3] *ASTM D3588-98—Standard Practice for Calculating Heat Value, Compressibility Factor, and Relative Density of Gaseous Fuels.* American Society for Testing and Materials, West Conshohocken, PA. 2001

[4] *Engine-Testing Procedures*, Title 40 CFR 1065, Environmental Protection Agency, Washington, DC, adopted at 70 FR 40410, 13 July, 2005

[5] *Quality Management Plan*, Version 1.4, March 2003, Southern Research Institute, Greenhouse Gas Technology Center. Available at: <http://www.epa.gov/nrmrl/std/etv/pubs/GHG_QMP_0303.pdf>

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Appendix A
Field Data Forms

Appendix A1: Distributed Generator Installation Data

Project Name: NYSERDA Climate Energy 12494.03 Date: ____________________

Compiled by: Southern Research Institute Signature: ______________________________

Site Information

Address 1: Not for publication Owner Company: __Resident: ____

Address 2: _____________________________ Contact Person: _Tony Petrucelli (Climate Energy, LLC)

City, State, Zip: Lake Ronkonkoma, NY 11779 Address (if different): 93 West St, Medfield MA 02052

Op'r or Technician: ______________________ Company Phone: _508-359-4500__ Fax: __________

Site Phone: __Not for publication_________ Utility Name: _________________________________

Modem Phone (if used): __________________ Contact Person: ________________________________

Altitude_________(feet) Utility Phone: _________________________________

Installation (check one): Indoor_X Outdoor__ Utility Enclosure__ Other (describe)__________________

Sketch of HVAC systems attached (if Indoor) ______ Controls: Continuous ____ThermostaticX Other____

Primary Configuration, Service Mode, and CHP Application
(check all that apply; indicate secondary power and CHP application information with an asterisk, *)

Delta		Wye		Grounded Wye	X
Single Phase	X	Three Phase			
Inverter	X	Induction		Synchronous	
Grid Parallel	X	Grid Independent		Peak Shaving	
Demand Management		Prime Power		Load Following	
		Backup Power		VAR Support	
Hot water	X	Steam		Direct-fired chiller	
Indirect chiller		Other DG or CHP (describe)			

Site Description (Check one)

Hospital	
University	
Resident'l	X
Industrial	
Utility	
Hotel	
Other (desc.)	
Office building	

Fuel (Check one)

Nat'l Gas	X
Biogas	
Landfill G	
Diesel #2	
Other (desc.)	

Generator Nameplate Data

Date: _____________Local Time (24-hour): ____________ Hour meter: ___________

Commissioning Date: ___________

Manufacturer: ____________________ Model: __________________ Serial #: __________________

Prime mover (check one): IC generator_____ MTG _____

Range: ____ to ____ (kW; kVA) Adjustable? (y/n) ____Power Factor Range: ___ to ___ Adjustable? (y/n) ____

Nameplate Voltage (phase/phase): ______ Amperes: _____Frequency: _______ Hz

Controller (check one): factory integrated _____ 3rd-party installed _____ custom (describe)_________________

Appendix A1: Distributed Generator Installation Data (cont.)

CHP Nameplate Data

BoP Heat Transfer Fluid Loop

Describe: ____

Nominal Capacity: ________ (Btu/h) Supply Temp. ______ (°F) Return Temp. ______ (°F)

Low Grade Heat loop

Describe: ____

Nominal Capacity: ________ (Btu/h) Supply Temp. ______ (°F) Return Temp. ______ (°F)

Chilling loop

Describe: ____

Nominal Capacity: ________ (Btu/h) Supply Temp. ______ (°F) Return Temp. ______ (°F)

Other loop(s): Describe: ____

Nominal Capacity: ________ (Btu/h) Supply Temp. ______ (°F) Return Temp. ______ (°F)

Parasitic Loads

Enter nameplate horsepower and estimated power consumption. Check whether internal or external. Internal parasitic loads are on the CHP unit-side of the power meter. External parasitic loads are connected outside the system such that the energy production power meter does not measure their effects on net DG power generation. Additional power meters or procedures are required to quantify external parasitic loads.

Description	kW, A, or hp	Internal (✔)	External (✔)
CHP heat transfer fluid pump, one per CHP module	n/a	✔	
generator coolant pump	n/a	✔	
control system	30 W	✔	

[a]To be manually logged with clamp-type real power meter (see field book).

Appendix A2. Power Meter Commissioning Procedure

1. Obtain and read the power meter installation and setup manual. It is the source of the items outlined below and is the reference for detailed information.
2. Verify that the power meter calibration certificate, CT manufacturer's accuracy certification, supplementary instrument calibration certificates, and supporting data are on hand.
3. Mount the power meter in a well-ventilated location free of moisture, oil, dust, corrosive vapors, and excessive temperatures.
4. Mount the ambient temperature sensor near to but outside the direct air flow to the DG combustion air inlet plenum but in a location that is representative of the inlet air. Shield it from solar and ambient radiation.
5. Mount the ambient pressure sensor near the DG but outside any forced air flows. Note: This test will use the Horiba OBS-2200 ambient pressure sensor.
6. Ensure that the fuel consumption metering scheme is in place and functioning properly.
7. Verify that the power meter supply source is appropriate for the meter (usually 110 VAC) with the DVM and is protected by a switch or circuit breaker.
8. Connect the ground terminal (usually the "Vref" terminal) directly to the switchgear earth ground with a dedicated AWG 12 gauge wire or larger. Refer to the manual for specific instructions.
9. Choose the proper CTs for the application. Install them on the phase conductors and connect them to the power meter through a shorting switch to the proper meter terminals. Be sure to properly tighten the phase conductor or busbar fittings after installing solid-core CTs.
10. Install the voltage sensing leads to each phase in turn. Connect them to the power meter terminals through individual fuses.
11. Trace or color code each CT and voltage circuit to ensure that they go to the proper meter terminals. Each CT must match its corresponding voltage lead. For example, connect the CT for phase A to meter terminals I_{A1} and I_{A2} and connect the voltage lead for phase A to meter terminal V_A.
12. Energize the power meter and the DG power circuits in turn. Observe the power meter display (if present), datalogger output, and personal computer (PC) display while energizing the DG power circuits.
13. Perform the power meter sensor function checks. Use the DVM to measure each phase voltage and current. Acquire at least five separate voltage and current readings for each phase. Enter the data on the Power Meter Sensor Function Checks form and compare with the power meter output as displayed on the datalogger output (or PC display), power meter display (if present), and logged data files. All power meter voltage readings must be within 2% of the corresponding digital volt meter (DVM) reading. All power meter current readings must be within 3% of the corresponding DVM reading.
14. Verify that the power meter is properly logging and storing data by downloading data to the PC and reviewing it.

Appendix A2a. Power Meter Sensor Function Checks

Project Name: NYSERDA Climate Energy 12494.03 Location (city, state): Lake Ronkonkoma, NY

Date:________________________ Signature:____

DUT Description: freewatt (Honda IC engine) CHP Power output

Nameplate kW: 1.2 Expected max. kW: 1.2 kVA at unit

Type (delta, wye): 1-ph Voltage, Line/Line: 220 Line/Neutral: 110

Power Meter Mfr:________________________ Model:__________________ Serial No.: ________________

Last NIST Cal. Date: ____________________

Current (at expected max. kW): 5.45A Conductor type & size: #12 at unit;

Current Transformer (CT) Mfg: FlexCore Model: ______________________________

CT Accuracy: (0.3 %, other): 0.3% Ratio (100:5, 200:5, other):___________________________

Sensor Function Checks

Note: Acquire at least five separate readings for each phase. All power meter voltage readings must be within 2% of the corresponding digital volt meter (DVM) reading. $\%Diff = ([PowerMeter/DVM] - 1) * 100$

Voltage

Date	Time (24 hr)	Phase A			Phase B			Phase C		
		Power Meter	DVM	%Diff	Power Meter	DVM	%Diff	Power Meter	DVM	%Diff

Note: Acquire at least five separate readings for each phase. All power meter current readings must be within 3% of the corresponding DVM reading.

Current

Date	Time (24 hr)	Phase A			Phase B			Phase C		
		Power Meter	DVM	%Diff	Power Meter	DVM	%Diff	Power Meter	DVM	%Diff

Appendix A2b. Power Meter Sensor Function Checks

Project Name:___NYSERDA Climate Energy 12494.03__Location (city, state):_Lake Ronkonkoma, NY___

Date:__________________________ Signature:____

DUT Description: _______freewatt (Honda IC engine) CHP Power___________________________________

Nameplate kW:_________________ Expected max. kW:___________________

Type (delta, wye):_______1-ph____ Voltage, Line/Line:___220____________ Line/Neutral:________110____

Power Meter Mfr:_________________________ Model:___________________ Serial No.: _________________

Last NIST Cal. Date: _____________________

Current (at expected max. kW):___5.5A___________Conductor type & size:_________________________

Current Transformer (CT) Mfg:___FlexCore______________________Model: _______________________

CT Accuracy: (0.3 %, other): ___0.3 %_______ Ratio (100:5, 200:5, other):_________________________

Sensor Function Checks

Note: Acquire at least five separate readings for each phase. All power meter voltage readings must be within 2% of the corresponding digital volt meter (DVM) reading. $\%Diff = ([PowerMeter/DVM] - 1) * 100$

Voltage

Date	Time (24 hr)	Phase A			Phase B			Phase C		
		Power Meter	DVM	%Diff	Power Meter	DVM	%Diff	Power Meter	DVM	%Diff

Note: Acquire at least five separate readings for each phase. All power meter current readings must be within 3% of the corresponding DVM reading.

Current

Date	Time (24 hr)	Phase A			Phase B			Phase C		
		Power Meter	DVM	%Diff	Power Meter	DVM	%Diff	Power Meter	DVM	%Diff

Appendix A3. Horiba OBS-2200 Test Run Record

Project Name: NYSERDA Climate Energy 12494.03 Test_ID: CntrlTest Date: _____________

Site_ID: Lake Ronkonkoma Residence Equip_ID: ___________ Run_ID: ________

Name (printed): ______________________________ Signature: _______________________________

PEMS S/N:__________ Last 11-point Calibration Date: __________ Filename: ______________________

Test Run Host facility operator name: ____________________________________

Start time (hh:mm:ss; use 24-hour clock): ______________ End time: _______________

Describe ambient conditions: ____

Wind speed (estimate): ____________ Direction: ______________ ☐ Fair ☐ Overcast ☐ Precipitation

IMPORTANT: Refer to the OBS-2200 "..._b.csv" worksheets after each test run for the following entries. Cell references are provided.
Enter "✓" if a parameter is acceptable, "Fail" if it is unacceptable. Discuss all "Fail" entries and indicate whether the run is invalid because of them in the Notes below.

PEMS Zero and Span Drift Checks					
Analyte	**Cal. Gas Value and Span (ppmv or %)**	**2 % of Span**	**✓ if Zero drift OK (≤ ± 2 % of span Cells I3 : I6)**	**4 % of Span**	**✓ if Span drift OK (≤ ± 4 % of span Cells J3 : J6)**
CO					
CO_2					
THC					
NO_X					

Parameter	**Criteria**		✓ if OK
Allowable ambient temperature range (see _b.csv worksheet Cells M16 : EOF)	within ± 10 °F (6 °C) for T_{amb} ≤ 80 °F (27 °C)		
	within ± 5 °F (3 °C) for T_{amb} > 80 °F (27 °C)		
Allowable barometric pressure range (see _b.csv worksheet Cells N16 : EOF)	within ± 1" Hg (3.4 kPa)		
Allowable "Hangup" (NMHC contamination) (see _b.csv worksheet Cell Z5)	Enter expected THC concentration, ppmv as C		
	Enter 2 % of expected concentration		
	"Hangup must be < 2 % of expected concentration		

NMHC contamination and background check ≤ 2ppmv or ≤ 2 % of conc. ΔP line leak check must be stable for 15 seconds at 3" H_2O. Mean P_{bar} within ± 1.0" Hg of mean for all test runs. Mean T_{amb} within ± 10 °F of mean for all test runs if T_{amb} is < 80 °F. Mean T_{amb} within ± 5 °F of mean for all test runs if T_{amb} is ≥ 80 °F. Drift = (Post-test span minus Pre-test span); must be ≤ 4.0 %.

Notes: ____

____

____

____

Appendix A4: Load Test Run Log

Project Name: NYSERDA Climate Energy 12494.03 Location (city, state): Lake Ronkonkoma, NY

Date:________________________ Signature:________________________

SUT Description: freewatt (Honda IC engine) CHP Power Run ID:________ Load Setting: %_____ kW_____

Clock synchronization performed (Initials):________ Run Start Time:_____ End Time:________

Data file names/locations (incl. path): File:________________________

IMPORTANT: For ambient temperature and pressure, record one set of readings at the beginning and one at the end of each test run. Also record at least two sets of readings at evenly spaced times throughout the test run.

B3-1. Ambient Temperature and Pressure

Time (24-hr)	Amb. Temperature, °F	Ambient Pressure	
		" Hg	PSIA = " Hg * 0.491
Average			

Permissible Variations

1. Each observation of the variables below should differ from the average of all observations by less than the maximum permissible variation.
2. Acquire kW and Power Factor data from the power meter data file at the end of the test run. Transfer fuel flow data from the Fuel Flow Log form. Obtain ambient temperature and pressure from Table A3-2 below. Obtain gas temperature and pressure from Appendix B4.
3. Choose the maximum or minimum with the largest difference compared to the average for each value.
4. Use the maximum or minimum to calculate the %Diff for kW, Power Factor, Fuel Flow, and Ambient Pressure:

$$\%Diff = \left(\left(MaxorMin \right) - Average \big/ Average \right) * 100 \qquad \text{Eqn. B3-1}$$

5. For Ambient Temperature, *Difference = (Max or Min)-Average*

Variable	Average	Maximum	Minimum	%Diff or Difference	Acceptable? (see below)
Ambient air temperature					
Ambient pressure					
Fuel flow					
Power factor					
Power output (kW)					
Gas pressure					
Gas temperature					

Permissible Variations

Measured Parameter	MTG Allowed Range	IC Generator Allowed Range
Ambient air temperature	± 4 °F	± 5 °F
Ambient pressure (barometric station pressure)	± 0.5 %	± 1.0 %
Fuel flow	± 2.0 %[a]	n/a
Power factor	± 2.0 %	n/a
Power output (kW)	± 2.0 %	± 5.0 %
Gas pressure	n/a	± 2.0 %[b]
Gas temperature	n/a	± 5 °F[b]

[a]Not applicable for liquid-fueled applications < 30 kW.
[b]Gas-fired units only

Appendix A5: Fuel Consumption Determination

Project Name: NYSERDA Climate Energy 12494.03 Location (city, state): Lake Ronkonkoma, NY

Date: ______ Signature: ______

Test Description: freewatt-Honda IC engine Run_ID: ______ Load kW: ______

Meter A Mfg: ______ Model: ______ S/N: ______

This procedure assumes that the 11M roots meter odometer resolution is 1 scf. This means that the meter reading error will be ± 1 scf. Use the following time durations between each meter reading to ensure that the relative meter reading error will be approximately ± 1.0 % throughout the operating range.

Time duration between each odometer reading depends on the CHP array power setting as follows:

# of CHP modules online	Nom. kW	Nom. scfm	Minutes between readings	✓ used for this run
1	50 - 100	11 - 21	8 - 4	
2	200	43	3	
3	300	64	2	
4	400	85	1	
5	500	107	1	
6	600	128	1	

1. Start the test run by logging an initial gas meter reading and the exact time of day to 1 seconds. The initial reading consists of the last 3 or 4 odometer digits. The last digit to the right on the meter reads as "0.01" Ccf. This means that each integer reading amounts to 1 scf. The odometer wheel to the right of the last digit has a hash mark which, when it passes by the window, indicates the exact instant of the integer reading. Log that time of day by holding a timepiece next to the odometer and watching for the hash mark. Try to be as consistent as possible in determining where the hash mark crosses the window.
2. Observe the timepiece according to the interval specified in the table above. Log the exact time of day, to 1 seconds, and the meter integer reading when hash mark crosses the window.
3. Continue until at least 7 complete readings (including the first reading) have been collected.
4. Perform the calculations as indicated.

Ref. (n)	Odometer (scf)	Time (mm:ss.s)	Time (decimal minutes)	Gas Used (scf) (Odm_n - Odm_{n-1})	Elapsed Time ($Time_n$ - $Time_{n-1}$)	Rate (scfm) (Gas Used / Elapsed Time)
1 (initial)						
2						
3						
4						
5						
6						
7						
8						
					Average	
					Standard Dev.	
					COV (Std.Dev / Avg)	

Appendix A6: Fuel Sampling Log

IMPORTANT: Use separate sampling log and Chain of Custody forms for each sample type (gas fuel, liquid fuel, heat transfer fluid).

Project Name: NYSERDA Climate Energy 12494.03 Location (city, state): Lake Ronkonkoma, NY

Date:________________________ Signature:________________________

SUT Description: freewatt-Honda IC engine Run ID:________ Load Setting: %_____ kW_____

Fuel Source (pipeline, digester): pipeline

Sample Type (gas fuel, liquid fuel, heat transfer fluid): gas fuel

Fuel Type (natural gas, biogas, diesel, etc.): natural gas

Note: Obtain fuel gas sample pressure and temperature from gas meter pressure and temperature sensors or sampling equipment.

Gas Fuel Samples						
Date	**24-hr Time**	**Run ID**	**Canister ID**	**Initial Vacuum, " Hg**	**Sample Pressure (from gas meter pressure sensor or sampling train pressure gage)**	**Sample Temperature (from gas meter temperature sensor or estimated)**

Appendix A7: Sample Chain-of-Custody Record

Important: Use separate Chain-of-Custody Record for each laboratory and/or sample type.

Project Name: NYSERDA Climate Energy 12494.03 Location (city, state): Lake Ronkonkoma, NY

Test Manager/Contractor Southern Research Institute Phone: 919.282.1050 Fax: 919.282.1060

Address: 5201 International Drive City,State / Zip: Durham, NC 27712

Originator's signature:________________ Unit description: freewatt-Honda IC engine

Sample description & type (gas, liquid, other.):________________

Laboratory: Empact Analytical Phone: 303.637.0150 Fax: 303.637.7512

Address: 365 S. Main City: Brighton State: CO Zip: 80601

Run ID	Bottle/Canister ID	Sample Pressure	Sample Temp. or T_{Avg}, (°F)	Analyses Req'd
				ASTM D1945, D3588

Relinquished by:________________ Date:________________ Time:________________
Received by:________________ Date:________________ Time:________________

Relinquished by:________________ Date:________________ Time:________________
Received by:________________ Date:________________ Time:________________

Relinquished by:________________ Date:________________ Time:________________
Received by:________________ Date:________________ Time:________________

Notes: (shipper tracking #, other)

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Appendix B
Hydronic Freewatt System Model 1.2 HDZFN

Climate Energy freewatt™ POWERED by HONDA

TECHNICAL SPECIFICATION

Hydronic Freewatt System
Model freewatt-1.2HDZFN

MICRO-COMBINED HEAT AND POWER SYSTEMS

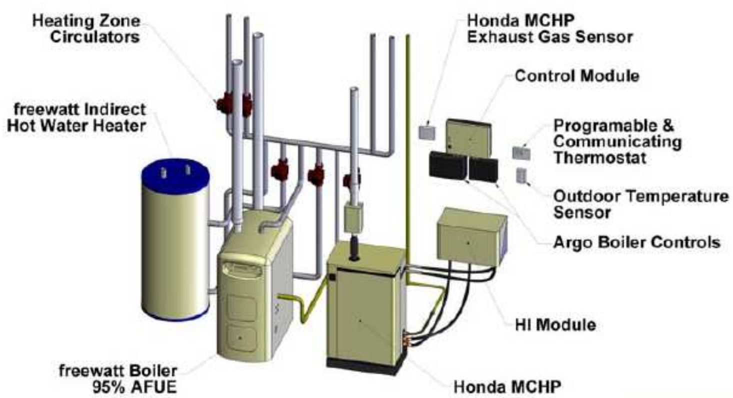
Climate Energy's Freewatt™ System combines two technologies, an advanced boiler and a natural gas-fired engine-generator. This hybrid heat and power generation package provides unrivaled total energy efficiency in combined heat and power delivery to the home. The Freewatt™ System is designed to be installed in the place of a typical boiler and uses the same ductwork system to deliver the heat to the home.

FREEWATT™ SYSTEM FEATURES

- **Honda MCHP Power Generation Technology**
  - Honda Reliable
  - Quiet (47 dBA)
  - Efficient (85%+ = Heat And Power)
  - 1.2 kW of Electric Power Production
  - UL 1741 Certified for Grid Interconnection
  - Proven Technology
  - PVC Exhaust Venting
- **Advanced Boiler**
  - Energy-Star Qualified
  - High Efficiency (95% AFUE)
  - Condensing Appliance
- **Hybrid Integration Module**
  - Permanent Magnet Pump
  - Compact Brazed Plate Heat Exchanger
- **Control Module**
  - Freewatt™ System Controller
  - Advanced Heat And Power Algorithm
  - Communicating Thermostat
  - Internet Connection
- **Simple Installation**
- **Compatible with Conventional Baseboard and Radiant Heat Emitters**

FREEWATT™ SYSTEM BENEFITS

- Reliable Power Generation, Powered by Honda™
- Significantly Reduces:
  - Home's Carbon Footprint Using Energy Conservation
  - Monthly Electric Bill by Net-Metering Power Generation & Use
- Enhanced Comfort
  - Low Level of Continuous Heat Delivery
- Increases house value by $5,000 to $20,000 (National Appraiser's Institute)
- Return on Investment (ROI) of up to 20% annually
- System Monitoring through the Internet Connection
- Breakthrough Home Energy Technology
- Simplified Grid Interconnection



Popular Mechanics BREAKTHROUGH AWARDS 2006

PATH PARTNERSHIP FOR ADVANCING TECHNOLOGY IN HOUSING PARTNER

The Boiler and HI Module assembly is design certified in the US and Canada by the Canadian Standards Association.

ENERGY STAR

As an Energy Star partner, Climate Energy has determined that the boiler included as part of the Freewatt system meets Energy Star guidelines for energy efficiency.

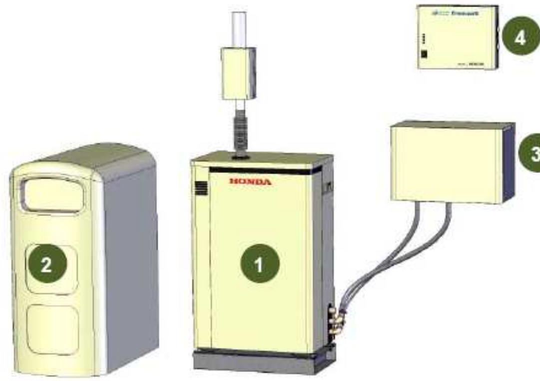
The Honda MCHP is an Underwriter's Laboratory (UL) Listed, "Utility Interactive, Cogeneration, Stationary Engine-Generator Assembly, File Number FTSR.AU2004 (U.S.) and FTSR7.AU2004 (Canada)."

Climate Energy **freewatt**™ POWERED by HONDA

Hydronic freewatt System
Model freewatt-1.2HDZFN

Engineered for High Efficiency

1. Honda MCHP Unit
   - Delivers a steady-state efficiency of 85%+ while producing power and heat, thereby reducing the amount of energy consumed to generate your power
   - Delivers exhaust through PVC Venting
2. Advanced Hot Water Boiler
   - Delivers 95% AFUE with a corrosion resistant aluminum block heat exchanger
   - Outdoor reset increases efficiency and indoor comfort
3. Hybrid Integration Module
   - Consumes under 30 watts to deliver heat from Honda MCHP unit to air coil heat exchanger
4. Control Module
   - Advanced heat and power algorithm optimizes power production of Honda MCHP unit



Hydronic freewatt System

Advanced Technology

5. Onboard Inverter
   - Integrated inverter delivers high quality power to the home's main circuit panel
   - UL 1741 Certified for Grid Interconnection
6. Exhaust Heat Exchanger
   - High efficiency heat exchanger reduces exhaust products to 140° F, allowing use of PVC venting
   - Three-way catalytic converter significantly reduces emissions
7. Combustion Control System
   - Oxygen sensor feedback allows for excellent emissions control
   - Stepping gas valve offers almost unlimited control of gas:air mixture

Honda MCHP Unit

Quiet Operation & Comfort

Honda MCHP Unit
- Generates heat & power at a noise level of only 47 dBA

Advanced Hot Water Boiler
- Ultra quiet operation while delivering heat in Low Heat mode
- Low Heat mode drastically reduces temperature swings and increases overall comfort

freewatt System
- Low Heat mode – MCHP operates
- High Heat mode – MCHP and furnace operate

Reliability

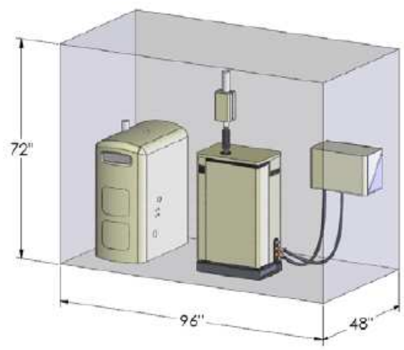
Honda's commitment to bringing products to market that improve the quality of people's life goes well beyond cars and motorcycles. Since 1953, Honda has manufactured over 40 million power products worldwide and continues as a leader in the development of low-emission, fuel efficient, environmentally friendly 4-stroke engines for use several power equipment applications. Now Honda's unwavering reliability, quality, durability and environmentally conscious efficiency combines with Climate Energy's Freewatt System to bring micro-combined heat and power to the home.

Climate Energy **freewatt**™ POWERED by HONDA

Hydronic Freewatt System
Model freewatt-1.2HDZFN

Model freewatt-1.2HDZFN

Typical Hydronic freewatt System Footprint



Model freewatt-1.2HDZFN

Connections

Boiler

Electrical: 120 Volts AC, 60 Hz, 1 phase, Less than 12 amps
Air Intake/Vent: 3" Sch 40 PVC
Natural Gas: ½" NPT
Condensate Drain: ½" PVC
Internet Connection: RJ45

Honda MCHP

Electrical: 240 Volts AC, 60 Hz, 1 phase, Less than 5 amps
Vent: 2" Sch 40 PVC
Natural Gas: ½" NPT w/ flexible connector
Condensate Drain: ½" Tube

Consult Installation Manuals for more details.

Model freewatt-1.2HDZFN

System Clearances

Dimensions	Boiler	Honda MCHP	Service
Top	1"	20"	8"
Left Side	1"	12"	24"
Right Side	1"	12"	-
Base	C - Note 1	B – Note 2	-
Front	0"	21"	24"
Back	6"	2"	-
Intake/Vent Piping	0"	0"	-
Near Boiler HW Piping	1"	0"	-

Note: 1. Combustible floor approved, but not carpet.
2. MCHP is attached to base that is anchored to concrete floor.

Model freewatt-1.2HDZFN

Boiler Dimensions & Locations

Dimensions	Boiler
Height	39 3/8"
Width	18"
Depth	30 7/8"
Return Connections	Back/Right/Left
Supply Connection	Top
Exhaust Vent	Top
Air Intake	Back/Left
Fuel Gas	Back/Right/Left

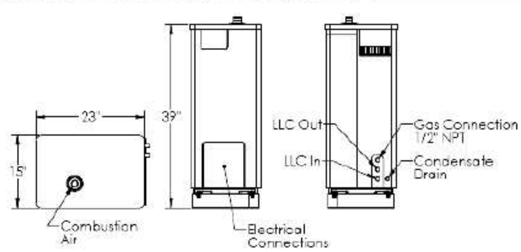
Model freewatt-1.2HDZFN

Honda MCHP Unit - Std YM2A Model

CONCRETE FLOOR REQUIREMENTS:
THICKNESS: 3" MINIMUM
FLATNESS: ½" IN 10 FEET CLASS CX
DROP-IN ANCHOR: 3/8" OD x 1.75" LONG (5/16"-18 THREAD) QUANTITY 4

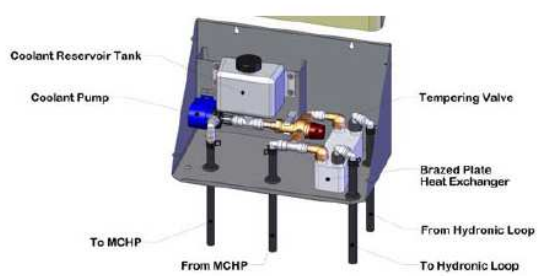
Clearance to Combustibles

Top:	20 Inches
Front:	21 Inches + Service
Sides:	12+ Inches
Rear:	2 Inches
Bottom:	Concrete Floor



Model freewatt-1.2HDZFN

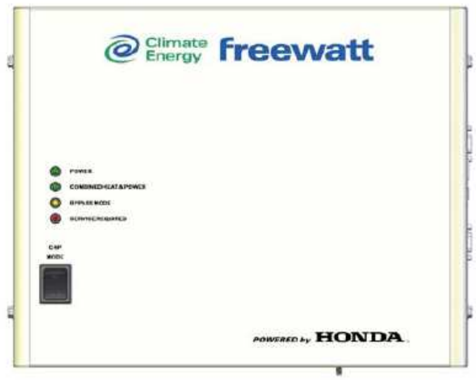
Hydronic Hybrid Integration Module Details



HEATING CAPACITIES – NATURAL GAS	
Model	CE95M-200
Efficiency (AFUE)	95%
Stage 1 - Micro-CHP Mode (Low)	
Input (MBH) 0-2,000'	18.5
Output (MBH) 0-2,000'	12.0
Stage 2 – Min Heat Mode (High)	
Input (MBH) 0-2,000'	80
Output (MBH) 0-2,000'	76
Stage 2 – Max Heat Mode (High)	
Input (MBH) 0-2,000'	200
Output (MBH) 0-2,000'	190
BOILER CONNECTION DIMENSIONS	
Supply	1 ½"
Return	1 ½"
MAXIMUM VENTING LENGTHS (EACH ELBOW EQUALS FIVE FEET)	
Venting Length (ft.) – Boiler (3")	100 ft.
Venting Length (ft.) – Honda MCHP (2")	90 ft.

Model freewatt-1.2HDZFN

Control Module Details



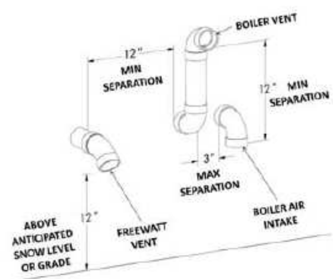
Model freewatt-1.2HDZFN

Typical Roof Vent/Intake Terminations

Consult Installation Manuals for more details.

Model freewatt-1.2HDZFN

Typical Sidewall Vent/Intake Terminations



Consult Installation Manuals for more details.

Model freewatt-1.2HDZFN

Grid Interconnection

The grid interconnection of the Honda MCHP unit is required to operate the system. Depending on the state's regulations and the electric utility, different grid interconnection application processes are required. Climate Energy is actively educating state governments and electric utilities about the benefits of Micro-CHP and how the freewatt System can be a critical component in their energy conservation portfolio. If any questions surface during the grid interconnection process, please contact your Climate Energy product technician or Climate Energy at 508-359-4500.

recycling energy™ CHP It's time

Climate Energy

For More Information:
www.climate-energy.com 1.508.359.4500

Appendix C
Instrumentation and Instrument Manufacturer Data

Parameters	Manufacturer	Model	Vendor	Mfr Location
F_{V1}, F_{V2}	Racine Federated, Inc.	Hedland HTTF1-BA-NN ¾"ultrasonic flow meter	Racine Federated, Inc.	Racine, WI
T_{S1}, T_{S2}, T_{R1}, T_{R2}	Omega Engineering	SA-RTD-80-MTP	Omega Engineering, Inc.	Stamford, CT
FG1	Dresser, Inc.	Roots 8C175	Dresser, Inc.	Addison, TX
FG2	Invensys	Rockwell R200	Sensus	Raleigh, NC
EP_{MCHP}	Power Logic (now Schneider Electric)	ION 7500	Power Logic	British Columbia, Canada
CTs for ION 7500	Flex-Core, Div. of Morlan Associates, Inc.	Flex-Core CTY-050A-1	Flex-Core	Hilliard, OH
EP_B, EP_{MCHP_in}, EP_{MCHP_out}	Continental Control Systems	WattNode Pulse WNB-2Y-208P	Continental Control Systems	Boulder, CO
CTs for WattNodes	Continental Control Systems	CTS-0750-015	Continental Control Systems	Boulder, CO
Data Logger	Dataq Instruments, Inc.	Dataq Instruments Model DI715B	Dataq Instruments, Inc.	Akron, OH