THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

ETV Joint Verification Statement

TECHNOLOGY TYPE:	Gas-Fired Internal Combustion Engine Combined With Heat Recovery System
APPLICATION:	Distributed Electrical Power and Heat Generation Using Climate Energy freewatt™ Micro-Combined Heat and Power System
TECHNOLOGY NAME:	Climate Energy freewatt™ Micro-Combined Heat and Power System
COMPANY:	Climate Energy, LLC.
ADDRESS:	Utica, New York
WEB ADDRESS:	www.freewatt.com

The U.S. Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV program is to further environmental protection by accelerating the acceptance and use of improved and cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the purchase, design, distribution, financing, permitting, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations, stakeholder groups that consist of buyers, vendor organizations, and permitters, and with the full participation of individual technology developers. The program evaluates the performance of technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests, collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

The Greenhouse Gas Technology Center (GHG Center), one of six verification organizations under the ETV program, is operated by Southern Research Institute in cooperation with EPA's National Risk Management Research Laboratory. A technology of interest to GHG Center stakeholders is distributed

generation (DG) sources, especially when they include combined heat and power (CHP) capabilities. The improved efficiency of DG/CHP systems makes them a viable complement to traditional power generation technologies.

The GHG Center collaborated with the New York State Energy Research and Development Authority (NYSERDA) to evaluate the performance of the 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.

TECHNOLOGY DESCRIPTION

The following technology description is based on information provided by Climate Energy and does not represent verified information. The freewatt micro combined heat and power (MCHP) system is a nominal 1.2 kW natural gas-fueled engine driven generator from which excess heat is recovered for use on-site. This technology provides 240v single phase electrical power in parallel with the utility supply. The engine is a liquid-cooled 4-cycle unit that drives a permanent magnet generator and inverter. Waste heat produced by the engine is recovered in engine coolant, from the engine block, the oil sump, and the exhaust gases and supplies first stage space and water heating for the host site's hydronic space and water system.

With the freewatt system, heat is captured from the generator engine and passed to domestic heat loads via a closed heat transfer loop. In this installation, the CHP system provides domestic hot water via an indirectly-heated hot water heater 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 about 12 thousand British thermal units per hour (MBtu/h) to the local heating loads while producing 1.2 kW of electric power. The supplementary boiler can provide up to an additional 190 MBtu/h.

VERIFICATION DESCRIPTION

Field testing was conducted on September 9 and 10, 2009. The defined system under test (SUT) was tested to determine performance for the following verification parameters:

- Electrical performance and power quality
- Electrical efficiency
- CHP thermal performance
- Atmospheric emissions performance
- Nitrogen oxides (NO_X) and carbon dioxide (CO_2) emission offsets.

The verification included a series of controlled test periods in which the GHG Center maintained steady system operations for 3 thirty-minute test periods to evaluate electrical and CHP efficiency and emissions performance, heat and power output, power quality, and efficiency.

Rationale for the experimental design, determination of verification parameters, detailed testing procedures, test log forms, and QA/QC procedures can be found in the ETV Generic Verification Protocol (GVP) for DG/CHP verifications developed by the GHG Center. Site specific information and details regarding instrumentation, procedures, and measurements specific to this verification were detailed in the Test and Quality Assurance Plan titled *Test and Quality Assurance Plan – Climate Energy freewatt™ Micro-Combined Heat and Power System.*

VERIFICATION OF PERFORMANCE

Results of the verification represent the freewatt system's performance as installed at the host residence in Lake Ronkonkoma, NY on the two days tested. Quality Assurance (QA) oversight of the verification testing was provided following specifications in the ETV Quality Management Plan (QMP). The GHG Center's QA manager conducted an audit of data quality on at least 10 percent of the data generated during this verification and a review of this report. Data review and validation was conducted at three levels including the field team leader (for data generated by subcontractors), the project manager, and the QA manager. Through these activities, the QA manager has concluded that the data meet the data quality objectives that are specified in the Test and Quality Assurance Plan.

Electrical and Thermal Performance

Table S-1. freewatt MCHP Electrical and Thermal Performance

Test ID	Fuel Input (MBtu/h)	Electrical Power Generation Performance		Heat Recovery Performance		Total CHP System Efficiency[a] (%)
		Power Delivered (kW)	Efficiency [a] (%)	Heat Recovered (MBtu/h)	Thermal Efficiency[a] (%)	
Run 1	15.8	1.00	21.6	9.17	58.3	79.8
Run 2	15.7	1.00	21.6	8.93	56.7	78.3
Run 3	15.7	1.00	21.6	7.58	48.2	69.7
Avg.	**15.7**	**1.00**	**21.6**	**8.56**	**54.4**	**76.0**

[a] Based on actual power available for consumption at the test site (power generated less parasitic losses). LHV Based.

Key findings for freewatt MCHP electrical and thermal performance were:

- After parasitic losses, electrical efficiency averaged approximately 22 percent at this site.
- The amount of heat recovered from the MCHP and used for water heating at the residence averaged 8.56 MBtu/hr. Corresponding thermal efficiency was 54.4 percent and combined heat and power efficiency averaged 76.0 percent.

- Boiler heat production, tested separately, averaged 43.7 MBtu/h, or 12.8 kW_t. Boiler fuel utilization efficiency (AFUE) during these forced control test conditions averaged 96 percent.

Emissions Performance

Table S-2. MCHP Emissions during Controlled Test Periods

	CO2 Emissions			THC Emissions			NOx Emissions		
Test ID	ppm	lb/hr	lb/MWh	ppm	lb/hr	lb/MWh	ppm	lb/hr	lb/MWh
Run 1	99343	1.35	1358	177	2.42E-03	2.43	5.90	8.04E-05	0.081
Run 2	100741	1.35	1356	183	2.45E-03	2.46	5.47	7.33E-05	0.074
Run 3	98242	1.35	1352	175	2.40E-03	2.41	6.54	8.96E-05	0.090
Avg.	**99442**	**1.35**	**1355**	**179**	**2.42E-03**	**2.43**	**5.97**	**8.11E-05**	**0.081**

(Consistent with the GVP, results are based on electrical output only).

Table S-3. Freewatt Boiler Emissions during Controlled Test Periods

	CO2 Emissions			THC Emissions			NOx Emissions		
Test ID	ppm	lb/hr	lb/MMBtu	ppm	lb/hr	lb/MMBtu	ppm	lb/hr	lb/MMBtu
Run 1	87470	6.36	153	8.08	5.88E-04	0.014	20.1	0.001	0.035
Run 2	88755	7.07	139	4.23	3.37E-04	0.007	25.2	0.002	0.040
Run 3	89793	8.38	216	3.41	3.18E-04	0.008	28.0	0.003	0.067
Avg.	**88673**	**7.27**	**170**	**5.24**	**4.14E-04**	**0.010**	**24.4**	**0.002**	**0.047**

Key findings for freewatt MCHP emissions and power quality performance were:

- For the MCHP, NO_X emissions averaged 0.081 lb/MWh. CO_2 and THC emissions averaged 1,355 and 2.43 lb/MWh.

- Boiler NO_X emissions averaged 0.047 pounds per million Btu (lb/MMBtu) heat delivered to the residence. CO_2 and THC emissions averaged 170 and 0.01 lb/MMBtu.

- Test results for CO emissions were invalidated after completion of testing and data analysis. The data were invalidated due to excessive variability in analytical results caused by the use of an inappropriate analyzer range. An identical freewatt unit was tested for CO emissions in a laboratory setting by the Gas Technology Institute (GTI) in early 2010 [6]. Results from the GTI testing indicate average CO emissions of 0.23 lb/MWh for the MCHP and 0.07 lb/MWh for the MCHP and boiler combined. These CO emissions data are not independently verified ETV results but are indicative of freewatt CO emissions performance under controlled operating conditions.

- Average electrical frequency was 60.00 Hz and average power factor was 99.2 percent.

Details on the verification test design, measurement test procedures, and Quality Assurance/Quality Control (QA/QC) procedures can be found in the Test Plan titled *Test and Quality Assurance Plan – Climate Energy freewatt™ Micro-Combined Heat and Power System* (SRI 2009). Detailed results of the verification are presented in the Final Report titled *Environmental Technology Verification Report for Climate Energy freewatt™ Micro-Combined Heat and Power System* (SRI 2010). Both can be downloaded from the GHG Center's web-site (www.sri-rtp.com) or the ETV Program web-site (www.epa.gov/etv).

Signed by Cynthia Sonich-Mullin (3/7/2013)

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