Micro Combined Heat and Power – An analysis of the Climate Energy freewatt™ System

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ABSTRACT

The need to save on energy costs and reduce greenhouse gas emissions has become a priority for homeowners. High efficiency appliances provide homeowners options to reduce their energy consumption and subsequently save on energy costs and reduce greenhouse emissions; however, more extensive options such as alternative energy generation has not been readily available or affordable for homeowners.

The electric grid connected, Climate Energy Micro Combined Heat and Power system, the freewatt™, is a space heating system with a 1.2kW electricity output capacity. The system is heat led and provides 12,000 BTUs of thermal energy while generating 1.2kW of electricity when there is a demand for heat. The MCHP freewatt system offers a solution to the lack in alternative energy options for homeowners.

KeySpan Energy (now National Grid), a natural gas utility in the Northeast, partnered with Climate Energy to field test a number of MCHP installations throughout eastern Massachusetts. Nineteen (19) beta units of the Climate Energy freewatt have been installed in residential test sites and operating for over one year. Due to the length of the heating season, the net metering environment and the energy prices in the Northeast region of the country, the freewatt presents tremendous opportunities for carbon reduction and energy savings for homeowners. This paper will explore the results of the field tests and discuss the future implications of the MCHP for energy savings, energy stability and the heating market.

Introduction to MCHP

Micro combined heat and power, or MCHP, refers to cogeneration smaller than 5 kW. Until recently, small scale cogeneration has not been a practical or feasible application. The emergence of accessible MCHP offers single family homes and small businesses another option to save on energy costs by replacing a standard appliance: the heating system. The MCHP system can provide a home or small business the heat they need during the heating season, and simultaneous energy savings, without modifying the home or making a tremendous investment.

The MCHP system can replace the home or business's heating system without much change to the footprint of the system and it can utilize the existing ducts and distribution system. It is a fairly simple installation process for properly trained heating contractors.

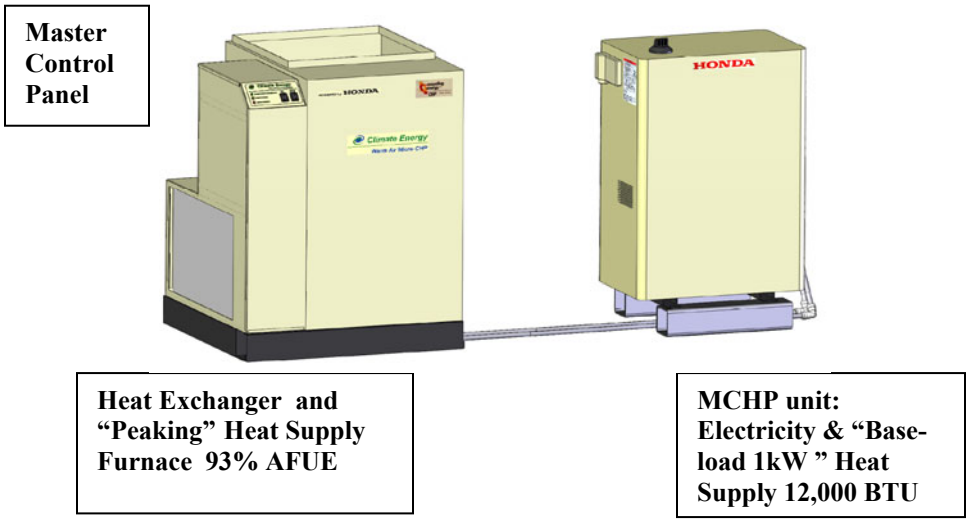
The Climate Energy freewatt™ MCHP system

The freewatt system replaces the home's heating equipment, and utilizes the same heat distribution system, either through the ductwork with a hot air system, or the piping in hydronic systems. When the home calls for heat through the thermostat, it triggers the generator, or MCHP. The freewatt MCHP system combines heat production with electricity generation. In the electricity generation process, waste heat is recovered and utilized for space heating, creating tremendous efficiencies. Due to the avoidance of transmission losses experienced with grid supplied power, the freewatt achieves an optimal conversion of primary fuel to useful heat and power. The freewatt also results in reduced emissions as compared to conventional sources of heat and power such as the power plant and standard heating equipment.

The generator begins to generate electricity and the consequent waste heat is recovered. Through net-metering, the generated electricity is absorbed by the home's need for power. The excess electricity that is generated, during the night or low use periods, goes back to grid. The recovered waste heat is transferred to the heating system through coolant lines and a heat exchanger. The heating system (furnace) distributes the waste heat and upon need for additional heat, will supplement the heating load through standard operations.

The freewatt beta system is a 1 kW generator manufactured by the Honda Motor Company and the furnace component is a 93% AFUE condensing natural gas fired, furnace manufactured by ECR International. The production version of the freewatt is now a 1.2kW generator with a 95% AFUE condensing furnace.

Below is a basic schematic of the freewatt system with the warm air heating component:



The master control panel is connected to the Internet for remote monitoring, control, troubleshooting, diagnostics and service messages. A broadband or DSL Internet

service is required. This interconnectivity and remote monitoring creates many possibilities for interested parties. Service contractors may be authorized to diagnose the system remotely, homeowners may control the system remotely, and utilities may utilize the equipment in demand response situations.

KeySpan - Climate Energy Demonstration Program

KeySpan investigates new technologies through its Building Technology and Demonstration Program, a subset of its energy efficiency programs. KeySpan partnered with Climate Energy, a Massachusetts based organization, on an installation project with Climate Energy's Micro Combined Heat and Power freewatt system. The first system to be introduced through the beta testing was the MCHP-furnace combination.

Overall, 22 beta sites, all residential homes in eastern Massachusetts, received the freewatt as a replacement to their home heating system and monitoring continued for over one year. Installations began in February 2006 and participants were almost exclusively existing homes in Massachusetts, with one new construction, a model home. Basic information was collected for KeySpan's purposes such as:

- size of the home
- use of a set back thermostat
- runtime hours for the MCHP
- runtime hours for the furnace
- electric generation
- gas consumption for the MCHP
- gas consumption for the furnace

More comprehensive parameters such as: operating mode status, coolant temperatures, room temperature, set point temperature, outdoor temperature, engine temperature, engine RPM and the operating times for the engine and the auxiliary burners were collected for Climate Energy's ongoing product development requirements.

Net Metering

The freewatt connects to the electric grid using Honda's integrated electronic inverter. The net metering mode of the freewatt occurs when the system generates more electricity than the home requires and then feeds back to the grid. Net metering with the electric utilities in the area; Braintree Municipal Power, NStar Electric and National Grid allow for customers to draw power from the grid and supply power to the grid, while the customer only pays for the 'net' energy consumed during a billing period.

Net metering laws play a critical role in whether MCHP or the freewatt acts as an alternative energy solution for consumers. Net metering policy also determines the credit that a small power producer may receive if power goes back to the grid. Only ten states

currently require net metering for small power producers using CHP, which limits the areas where MCHP can benefit homeowners through energy savings.

It is to the homeowner's advantage to utilize all of the power generated by the MCHP, as under most net metering agreements, the excess power that goes back to the grid only gets credited the wholesale value of the electricity. The freewatt is sized so that the cogeneration can meet most of the electrical needs of the home during the heating season.

Massachusetts's net metering law allows for a simplified process of interconnection less than 10kW. There are no fees and there is a 15 day process period for applications. Some utilities require external disconnects to the system and require witness testing of the disconnect system before they grant approval to operate the system.

Field Test Results

The data from each system was transferred to Climate Energy through the freewatt's internet connection. The following table represents the high, low and average data points for the 22 installations from September 2006 through May 2007.

Period: September 1, 2006 through May 30, 2007
Data for Honda MCHP YM1 1.0KW Generator

	Electric Generation (KW-Hr)[2]	Gas Consumption MCHP (Therms)[1]	Gas Consumption Furnace (Therms)[3]	Total Gas Consumption	Runtime MCHP (Hours)	Runtime Furnace (Hours)	Setback?	House Size (Sq. Ft.)
Electrical Generation (KW-Hr)								
Hi	3968	X	732	360	1092	3968	450	N	1680
Low	2286	X	422	348	770	2287	580	Y	1152
Avg	3325	X	614	356	970	3325	474	44%	1593
Gas Consumption MCHP (Therms)								
Hi	732	3968	X	360	1092	3968	450	N	1680
Low	422	2286	X	348	770	2287	580	Y	1152
Gas Consumption Furnace (Therms)								
Hi	846	3915	722	X	1568	846	846	N	2850
Low	138	2741	506	X	644	2741	231	Y	1438
Runtime MCHP (Hours)								
Hi	3968	3968	732	360	1092	X	450	N	1680
Low	2286	2287	422	348	770	X	580	Y	1152
Runtime Furnace (Hours)								
Hi	867	2919	539	694	1233	2919	X	N	2000

Low	179	3489	644	143	787	3489	X	Y	2307

1. Gas consumption data is derived by the run hours, not measured at the meter. Run hours are multiplied by 18,450 BTU/hr then divided by 100,000 BTU/therm to get the gas usage.
2. MCHP electric generation is also derived by run hours multiplied by the generation rate. Run hours are then multiplied by 1.0kW
3. Gas consumption of the furnace is derived by run time hours, not measured at the gas meter. Run hours are multiplied by the input rating for each furnace installed then divided by 100,000 BTU/therm to get gas usage. The input ratings range from 60,000 BTUs/hr to 100,000 BTUs/hr.

Comparison to previous year's gas usage was only evaluated in three sites and accuracy is difficult to determine based on meter data alone.

Electrical generation demonstrated savings from $390 annually, up to $700 annually based on the regional, residential electric rate of $0.17/kWh. Some rates in the area may reach higher than $0.20/kWh, where small cogeneration impacted more on energy costs. In the field sites, the high generation case also shows the highest in total natural gas consumption, however, the overall consumption of natural gas on the high case is not considerably more than the average case (1092 vs 970 therms with a slightly larger house).

The set back thermostat plays a role in the runtime on the MCHP, and the runtime on the furnace (lowest runtimes had set backs), and subsequently the electrical generation. Contrary to New England philosophy on home heating, the set back thermostats that were set significantly back during the day, canceled the benefits of the electricity generation achieved with a constant temperature demand. A large set back in the temperature shut down the MCHP for long periods of time. At the point in the day when the set temperature returned to the 'living space temperature', both the MCHP and auxiliary burner were needed to achieve the increase in temperature. The trade off of the MCHP unit, which generates 12,000 BTUs of thermal energy for the auxiliary burner canceled out substantial kWh production.

Detailed information on temperature control is not available; however, it is worth further examining the benefits of using a set back thermostat and saving on the natural gas use, versus not using the set back and realizing higher electrical savings. Electricity costs in different areas will influence the realized benefit of running the freewatt for longer periods of time. In most areas, electricity is more costly for a homeowner than natural gas.

In addition, the ECM or electronically commutated motor in the furnace enhanced electrical savings by delivering the 12,000 BTUs of thermal energy at a very high electrical efficiency compared to a standard furnace model.

In the three sites where previous year's gas usage was taken into consideration, two of the three sites had actually reduced the overall gas consumption from the previous year, yet ranked the highest for runtime on the furnace unit, and two used the set back thermostat, while the other did not. Of the three sites that did have a comparison of annual gas consumption, the increase or decrease does not amount to more than 5%.

If this data were superimposed over the production model's output of 1.2kW, the electrical savings would look something like a low electrical savings of $460 to more than $800 for the high user, considering eastern Massachusetts electricity pricing. This savings yields simple paybacks from 9 to 14 years, over the standard heating system replacement, without incentives or considering the increasing cost of energy.

The environmental benefits are more difficult to quantify, however, the avoided emissions from the electrical generation plant in combination with the natural gas fired, advanced combustion system yield extremely low emission rates. An interesting perspective is to look at the 19 sites as an aggregate system where the electrical production reached over 9,000 kWh during the months of January and February. This is also significant in terms of avoided carbon emissions.

Maintenance

The freewatt MCHP needs a tune-up after every 6,000 operating hours, which is less than every 2 years in New England, based on the field test data. The system controller can alert the owner and or the dealer when the service interval is approaching. The MCHP has an expected life of 15 years.

Future Implications

The warm air system with integrated domestic hot water is currently undergoing product testing. The additional heating demand for the hot water is expected to increase the power production of the freewatt system by 20%. The hot water component will also provide electrical power throughout the summer, and into the shouldering months of the heating season. Climate Energy is also releasing a hydronic model to the freewatt, for homes with baseboard or radiant heating systems. The hyrdonic systems will have indirect hot water.

The addition of a standby generator (10 - 25 kW) to the Climate Energy is also undergoing testing. The stand by generator will provide the homeowner automatic full-house standby power in the event of a power outage.

The freewatt system is an effective technology for the Northeast, given the length of the heating season and the energy prices in the region. Net Metering in Massachusetts and Rhode Island also make the technology accessible for homeowners. New York State is currently reviewing net metering policy for small CHP systems.

The warm air freewatt system became market ready with the 1.2kW version in the Spring of 2007. KeySpan-National Grid offers customers in its Massachusetts service territory a $1600 rebate on the freewatt MCHP and the 95% AFUE furnace is also eligible for a $400 rebate. The rebate will bring the simple payback down to 6-7 years, not considering increasing energy prices.

Natural gas customers in Rhode Island will also be eligible for a rebate, however, New Hampshire and New York currently do not yet permit net metering for MCHP applications.

Conclusion

The Climate Energy freewatt system offers a lot of potential for energy savings and creates more opportunities for heating contractors to enhance their service portfolio. Climate Energy is currently hosting demonstrations of the freewatt system to contractors who may be interested in training on the technology.

The unit sells for $13,000 installed cost, whereas a high efficiency furnace may cost between $5,000 and $6,000 installed cost. The system needs early adopters or other ways of mediating the high first cost before the system will come down in price in the market.

The field tests demonstrated the freewatt to be practical, reliable and efficient. In regions with long heating seasons, high energy costs and appropriate net metering environments, the freewatt system offers considerable potential for the heating industry to add to their product portfolio, utilities for demand response, energy savings and carbon reduction goals and homeowners can save on energy costs.

The energy savings were proven, the emissions avoidance is another benefit. The interconnection process is simple in Massachusetts and the installation process is straight forward. The next phase of the freewatt system with integrated water heating will provide even more energy savings, on a continuous basis throughout the year. The freewatt MCHP bridges an important market gap between energy efficiency and energy generation that can ultimately play a role in both efficiency efforts and demand side response as well as carbon reduction initiatives.

References

1. The Climate Energy Micro-CHP System – Powered by Honda: Interim Field Test Results. Mayer, Karl. 2006 ACEEE Summer Study on Energy Efficiency in Buildings.
2. Climate Energy Program Report. Demonstration of Freewatt Home Heating System. Climate Energy. 2006-2007 Home Heating Season.