ALLIED CONVERTERS CHP DEMONSTRATION PROJECT

Final Report

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PROJECT SUMMARY

The Allied Converters Cogeneration Project, co-funded by the New York State Energy Research and Development Authority, involved the installation and demonstration of a combined cooling, heating and electric power system (CCHP). Unlike the majority of the electric power generation plants operating in the United States, the system installed at Allied Converters utilizes a single combustion source for providing the majority of the facility's electric power, heating and cooling. The combustion source is provided by two 28 kilowatt natural gas fired Capstone MicroTurbines capable of generating electric power in grid parallel and stand alone mode. One Micogen heat recovery unit is utilized for producing hot water from the thermal energy derived from the microturbine exhaust. The hot water is used for heating the facility during Winter months and providing the thermal energy to operate two 10 ton Yazaki lithium bromide absorption chillers which produce chilled water for cooling the facility during Summer months. The cogeneration system is designed to remove approximately 56 KW of electric load during peak electric power demand during the Summer.

1. SITE DESCRIPTION

The Allied Converters facility is located approximately 4 miles North of New York City in New Rochelle, New York. The facility consists of manufacturing and storage areas, and moderately sized office space and specializes in plastic film processing. The hours of operation are typically 8:00 AM to 5:00 PM, Monday through Friday, and when necessary 8:00 AM to 1:00 PM on Saturday.

The production machinery and human activity in the manufacturing area produces a large amount of sensible and latent heat which requires operating large air conditioning equipment during Summer months. Continuous cycling of the existing vapor compression air conditioning equipment dramatically increases electric consumption and demand utility costs. Therefore, the cogeneration system provides cooling for the manufacturing area only.

Since the Allied Converters facility is located close to New York City it is susceptible to electric grid power failures caused by high electric power demand during Summer months.

Subsystem Description

A description of each major subsystem installed for this project is identified by the table below:

Subsystem	**Specifications**
Electric Power Microturbine Generators	Manufacturer: Capstone Turbine Corporation Model: C30 Number of Units: 2 Maximum Power Rating: 28 KW Fuel: Natural Gas Minimum Fuel Inlet Pressure: 0.2 psi Operating Modes: Grid Connect and Stand Alone
Dual Mode Controller	Manufacturer: Capstone Turbine Corporation Model: 208 VAC, 1600 Amp Number of Units: 1
Protective Relays	Manufacturer: Basler Model: BE3-GPR Manufacturer: Basler Model: BE1-32R
Heat Recovery Unit	Manufacturer: Micogen Model: MG2-C1 Number of Units: 1

Absorption Chillers	Manufacturer: Yazaki Model: H-10 Number of Units: 2
Air Handling Unit	Manufacturer: Carrier Corporation Model: 20 Tons Number of Units: 1
Computer Control and Data Acquisition System	Manufacturers: Agilent VeePro (DAQ Software) Measurement Computing (DAQ Boards)

Electricity and Natural Gas Service

The electric power and natural gas for the Allied Converters Facility are supplied by Consolidated Edison of New York, Inc. The electric service is rated for 208 VAC, 3 Phase, and 1,600 Amps and enters at the Northwest corner of the facility. The natural gas supplied at the service entrance is 8 inches of water and is delivered via a 4 inch steel pipe (and also enters at the Northwest corner of the facility). The two Capstone MicroTurbines, Micogen heat recovery unit and Yasaki absorption chillers are located in the basement of the facility as shown in the photograph below.

The Capstone MicroTurbines, each rated at 28 kW, use natural gas to generate electricity, and the thermal energy recovered from the exhaust by the Micogen heat recovery unit is used to produce hot water. The hot water is then either used for comfort space heating, or used to provide the thermal energy for two lithium bromide absorption chillers; which produce chilled water for comfort space cooling. The system can provide either comfort heating, or comfort cooling, depending on seasonal requirements, but not both simultaneously.

Grid Connect (GC) Mode

When operating in Grid Connect (GC) Mode, the two 28 KW microturbines are used to supplement the electric power provided by Consolidated Edison of New York, Inc. In this mode of operation, the protective relays installed as part of the objectives of this project, prohibit the export of electric power when the electric power requirements of the facility exceed the allowable utility electric power consumption value plus the facility's minimal electric power requirements.

Load Following and GC Operation

The Capstone MicroTurbine is equipped with a electronic load following power management feature when operating in GC Mode. To enable this feature the installation of a utility grade power meter which transmits a pulsed 5 VDC signal to the master microturbine is required. The procurement and installation of the power meter, along with the additional control wiring is well worth the cost. When the load following power management feature is enabled, the microturbines will follow the electric power demand of the facility. The quantity of power supplied by the utility can be programmed by adjusting the “Utility Power Set Point” and the “Minimum Power Shutoff” parameters, each of which are field adjustable.

Stand Alone (SA) Mode

The Capstone MicroTurbine can be manufactured to generate electric power in GC, SA or GC and SA Modes. When operating in SA Mode the microturbine does not require the utility voltage and frequency as a reference. Hence, the microturbine is essentially the same as an emergency back-up generator when operating in SA Mode. The microturbines will produce up to their maximum rated electric output of 56 kW, and will load follow the facility's electric power requirements.

Dual Mode Control

When equipped with GC and SA capabilities, the proper operation of the equipment requires the installation of the Capstone Dual Mode Controller (DMC) as shown in the photograph below.

Dual Mode Operation. The dual mode operating transition sequence is described below:

GC to SA

- The microturbines are operating in GC mode.
- A utility power abnormality is detected (typically a voltage or frequency excursion).
- The electrically operated circuit breaker located in the DMC opens, isolating the microturbines and protected electric loads from the utility.
- The microturbine output contactors open.
- The microturbines initiates a warm shutdown. In contrast to a normal shutdown (cooldown), which involves a motor assisted self cooling process, a warm shutdown causes the microturbines to utilize the available thermal energy to achieve a controlled shutdown.
- The microturbines start in Stand Alone Mode using the internal batteries for achieving the necessary rotational speed.
- The microturbine output contactors close.
- Electric power is supplied to the protected loads.

SA to GC

- Utility power is restored.
- The microturbine output contactors open.

- The electrically operated circuit breaker located in the DMC closes, allowing the utility to supply electric power to the facility.
- The microturbines initiate an internal battery recharge cycle.
- When the batteries are sufficiently charged, the microturbine initiates a normal shutdown (cooldown). Note that during this recharge cycle the facility is fully dependent on the utility for electric power. This typically increases the demand charge by approximately 15 KW for the corresponding billing period.
- After 1 minute (minimum), the microturbines re-start in GC Mode.

Multi-Pac Feature

The three microturbines installed at the Allied Converters Facility are configured in a multi-pac arrangement, whereby one unit acts as the master and the other unit act as slave and follows the instruction of the master. The Multi-Pac feature offered by Capstone Turbine Corporation enables the two 28 KW Capstone MicroTurbines to operate as one 56 KW unit. If the operating parameters for each microturbine are the same, the electric load will be shared equally. However, microturbine number 1 (identified as the master for this system) will supply a greater amount of electric power than microturbine number 2, if the combustion air temperature entering microturbine number 1 is lower. An attractive feature of the multi-pac configuration is that power can be delivered by one microturbine should the other microturbine experience a problem. In fact, even if the master microturbine experiences a problem, the slave will continue to operate, and will provide an equivalent amount of electric power as if one microturbine was operating, limited of course by the maximum power output of each microturbine (for this situation the maximum total power output of one unit is 28 KW).

2. OBSERVATIONS, FINDINGS AND RECOMMENDATIONS

Interconnection Requirements

List of Engineering Firms Specializing in Relay Protection. The completion of this project was delayed by approximately nine months because of difficulties obtaining electric interconnection approval with utility.

Recommendation: A possible solution to this problem is for the New York State Public Service Commission to publish a list of qualified engineering firms specializing in relay protection for grid parallel electric generation equipment.

Testing Required. The Standard Interconnection Requirements (SIR) established by the New York State Public Service Commission is a general document describing the responsibilities of the electric utility and the customer for distributed generation systems. For situations where the SIR document does not address the precise technical features for the required equipment, reference is made to review the electric utility's distributed generation documents. For the Allied Converters Cogeneration Project, the electrical relay protection system was designed to comply with the requirements of Specification EO-2115, as published by Consolidated Edison of New York, Inc (Con Edison). However, Specification EO-2115 did not adequately describe the requirements necessary for conducting a utility power failure simulation, and the testing of the system's ability to transition from GC to SA and finally to GC. This delayed the completion of the project by approximately two months.

<u>Recommendation</u>: The New York State Public Service Commission should revise the SIR and require the electric utility to publish a more detailed specification for testing GC to SA systems.

Project Results and Lessons Learned

Problems Encountered with Equipment Suppliers. Capstone Turbine Corporation delivered a 480 VAC, 1600 Amp DMC; even though a 208 VAC, 1600 Amp DMC was ordered (this was a specially manufactured DMC). This mistake delayed the completion of the project by two months, and the DMC had to be modified at the work site.

<u>Recommendation</u>: For future projects NYSERDA may want to publish a generalized list of potential problems that have been experienced, without identifying manufacturers.

Payments from NYSERDA. The completion of a CHP Project is time critical. That is, the sooner the system becomes operational, the sooner the building owner or end user can benefit from the economic projections anticipated for the system.

<u>Recommendation</u>: NYSERDA might consider establishing a payment schedule that provides more funding during the initial phase of the project to offset the late deliveries usually experienced with state-of-the-art equipment. NYSERDA might consider providing a 5% to 10% contingency payment added to the grant. After acquiring the knowledge required to install a cogeneration system, it would be tragic if a contractor could not survive the unexpected financial burdens often encountered with this type of technology.

Noteworthy Lessons. Noteworthy lessons learned during the design and construction of the Allied Converter's Cogeneration Facility include:

1. Future grants should emphasize the importance of highly qualified skills required to complete these projects. There were a few issues that could have potentially inhibited the success of the project. These issues resulted from a lack of attention to detail on the part of the tradesmen installing the equipment for this project. The possession of a license

issued by a government organization is an important requirement; however, a conscientious workforce is equally as important.
2. The engineering firms involved with design of innovative cogeneration systems must confirm the manufacturers recommended specifications. For the project described herein, the natural gas filter assemblies supplied by the manufacturer imposed a pressure drop that negatively affected the performance of the microturbines. The inlet and outlet ports of these filter assemblies are ½ inch NPT. Installing a less restrictive filter assembly with inlet and outlet ports of 1¼ inch NPT has increased the total power output of the two microturbines by 3 KW (see appendix for photos).
3. The cost of the demand charge resulting from the failure of an igniter is greater than the cost of the igniter. A cost benefit evaluation of preventive maintenance should be conducted for future projects. For the two microturbines installed as part of this project, two igniters have failed for each unit (total of four). The cost of periodically replacing these igniters would have been less than the cost of the increased monthly demand change.
4. Whenever possible, reduce the amount of labor required at the work site. That is, purchase equipment pre-assembled by a reputable manufacturer.
5. During project scoping, expend sufficient time evaluating the benefits and disadvantages of: a) installing the equipment outside of the building (environmental consequences for reliable equipment operation may not be that consequential), b) pumping and electric distribution losses associated with long distances between subsystems, and c) the cost of labor and material associated with the items a and b.

3. OPERATING, ENERGY, ENVIRONMENTAL, AND ECONOMIC DATA

Monthly electric and natural gas load profiles presenting consumption and demand characteristics for one year are presented by Charts 1, 2 and 3 and Table 2 in the Appendix. Baseline Data is based on the billing period beginning on May 2002 and ending in April 2003. The CHP System Data is based on the billing period beginning on May 2004 and ending in April 2005. The 12 months during the two aforementioned periods involved system installation and commissioning. This data is summarized below.

Operating Data

For the one year period beginning in May 2004 and ending in April 2005, the CHP System operating and performance data is as follows:

- Accumulated Hours of System Operation = 2,540
- Average Annual System Efficiency = 60.3%
- Annual Electric Efficiency = 21.7%
- Annual Thermal Utilization = 38.6%

Component Failures

During this period the following CHP System component failures occurred:

1. Igniter failure in microturbine no. 1 (June 2004)
2. Cooling Tower 2 HP Fan Motor failure (July 2004)
3. Igniter failure in microturbine no. 2 (July 2004)
4. Igniter failure in microturbine no. 2 (January 2005)
5. Igniter failure in microturbine no. 1 (February 2005)

A microturbine igniter failure completely disables the turbine. As shall be described later in this document, microturbine igniter failures had negative energy and economic consequences. Until the cooling tower fan motor was replaced, this component decreased the cooling capacity of the absorption chillers for approximately 3 days. The decreased cooling capacity was difficult to quantify; however, the chilled water outlet temperature increased from 45 to 53 degrees F during this failure.

Energy Data

Baseline

Annual Electric Energy Consumed (from the utility) = 154,200 KWH
Annual Natural Gas Consumed for Building Heat = 4646 Therms (136,158 KWH)
Total Energy Consumed = 290,358 KWH

CHP System

Annual Electric Energy Consumed (from the utility) = 70,900 KWH
Annual Electric Energy Generated by Microturbines = 89,470 KWH
Total Annual Electric Energy Consumed = 160,370 KWH
Annual Natural Gas Consumed for Building Heat = 1554 Therms (45,542 KWH)
Total Energy Consumed = 205,912 KWH

Environmental Data

Environmental benefits are projected to accrue and be attributable to the displacement of emissions that would otherwise be produced onsite by the existing Boilers and Domestic Hot Water Heater which operate on natural gas, and the displacement of regional emissions from central power stations due to the decreased consumption of grid-supplied electricity (decreased consumption of grid-supplied electricity occurs due to self-generation of electricity, and due to displacement of electric-driven cooling by waste-heat-driven absorption cooling). Westchester County is one of several ozone (O_3) non-attainment areas in New York State. Oxides of nitrogen (NO_X) emissions, produced by coal, diesel, and natural gas power plants, contribute to the formation of ground level ozone (O_3).

O_3 is formed photochemically from a mixture of hydrocarbons (HC), NO_X, and ultraviolet solar radiation. The significant human health issues associated with exposure to O_3 include eye and throat irritation, lung tissue damage, and increased susceptibility to respiratory illness.

Reduced emissions of SO_2 and NO_X are the major environmental benefits resulting from the installation of the CHP system. Together, SO_2 and NO_X are the major precursors to acidic deposition (acid rain), which is associated with the acidification of lakes and streams, accelerated corrosion of buildings and monuments, and reduced visibility. The table below presents mass emission data based on power production, and annual emissions based on facility energy consumption. The Capstone MicroTurbine Model C60 emits less of these gaseous pollutants per kilowatt hour than the average utility operated fossil fuel (i.e., coal, diesel, or natural gas) electric power plant in New York State. Further improvements in air quality can also be achieved with the CHP system because the thermal energy recovered shall: 1) eliminate pollutants normally emitted by burning fossil fuel for the facility's heating system and provide domestic hot water, and 2) drive the absorption chillers, thus eliminating the pollutants associated with generating the electric energy required to operate the vapor compression air conditioning system.

Table 1 Power Plant Emissions Comparison

Pollutant	**Averaged Emissions for Fossil Fueled Electric Power Plants in New York State** [a]		**Emissions for Capstone MicroTurbine operating on Natural Gas at Full Power**	
	lb/MWh	lb/year (based on annual consumption for the facility)	lb/MWh	lb/year (based on annual consumption for the facility)
NOX	1.13	814	0.507	365
SO2	3.32	2390	negligible [b]	negligible

[a] Source: U.S. Department of Energy (DOE). Emission data for New York State in 1999. Emission data for New York State in 2000 not available at time of initial writing.

[b] Hydrogen Sulfide (H_2S) is removed from natural gas prior to its use as a fuel; therefore a negligible quantity of SO_2 is measured in the combustion products.

Economic Data

Baseline Data

Monthly Average Demand = 58.85 KW
Annual Cost for Demand Charge = $13,237
Annual Cost for Consumption = $15,393
Annual Cost for Natural Gas (Building Heat) = $5,511
Total Energy Cost = $34,141

CHP System Data

Monthly Average Demand = 33.60 KW
Annual Cost for Demand Charge = $6,190
Annual Cost for Consumption = $6,247
Annual Cost for Natural Gas (Building Heat) = $1,668
Annual Cost for Natural Gas (Microturbines) = $13,969
Total Energy Cost = $28,074

Additional Savings

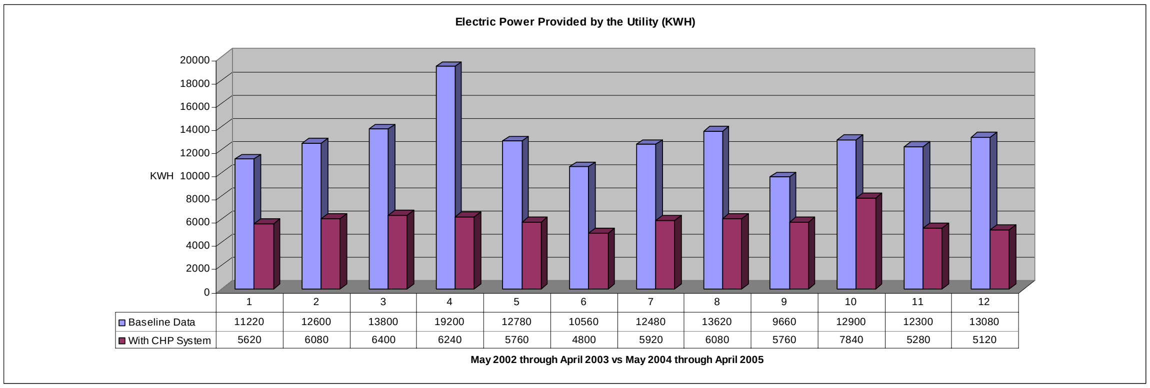
Projected additional savings resulting from increasing the electric power output of the microturbines and thereby reducing electric demand are:

- A total of $2,300 for replacing the natural gas filter assemblies (this has already been completed as described previously) and reducing the ambient air temperature in the microturbine room. These system improvements are projected to increase electric power output by 9 KW.
- $2,800 by eliminating microturbine igniter failures.

APPENDIX

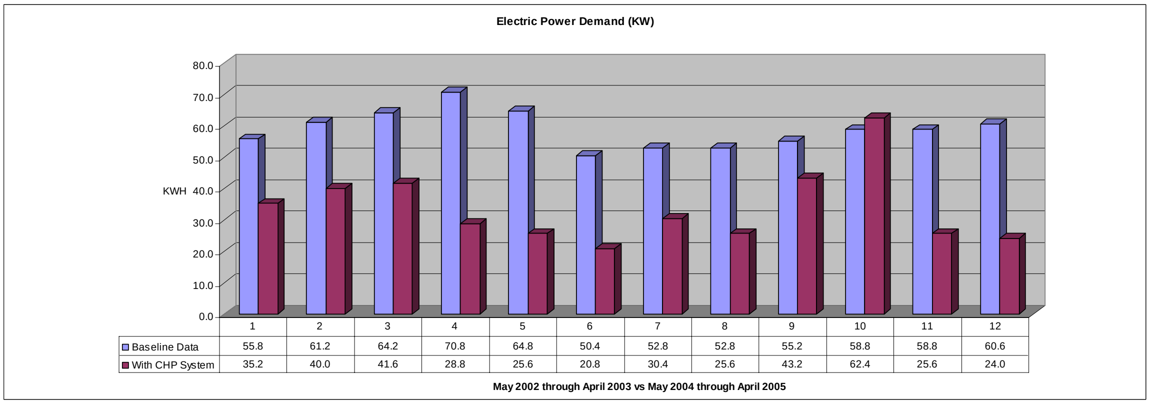
Figure A1 Dual ½ Inch Natural Gas Filter Assembly

Figure A2 Single 1¼ Inch Natural Gas Filter Assembly



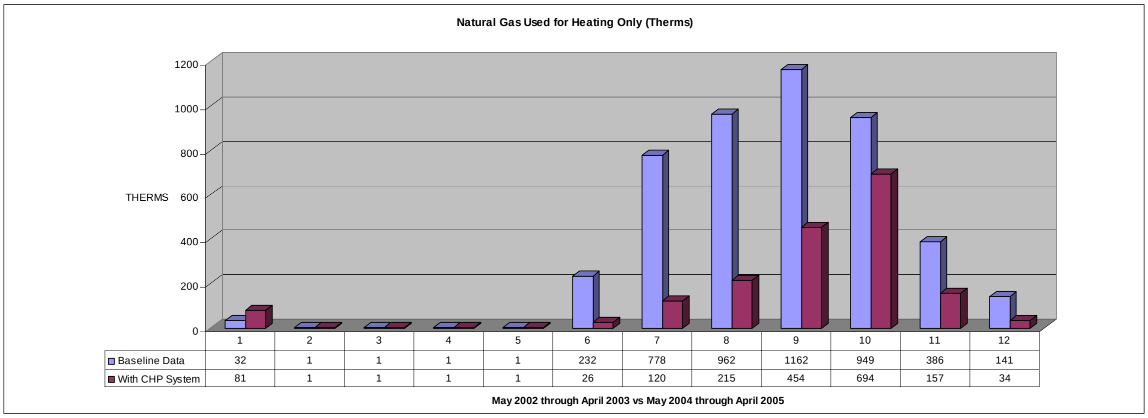
	1	2	3	4	5	6	7	8	9	10	11	12
Baseline Data	11220	12600	13800	19200	12780	10560	12480	13620	9660	12900	12300	13080
With CHP System	5620	6080	6400	6240	5760	4800	5920	6080	5760	7840	5280	5120

Chart 1 Electric Consumption



	1	2	3	4	5	6	7	8	9	10	11	12
Baseline Data	55.8	61.2	64.2	70.8	64.8	50.4	52.8	52.8	55.2	58.8	58.8	60.6
With CHP System	35.2	40.0	41.6	28.8	25.6	20.8	30.4	25.6	43.2	62.4	25.6	24.0

Chart 2 Electric Demand



	1	2	3	4	5	6	7	8	9	10	11	12
Baseline Data	32	1	1	1	1	232	778	962	1162	949	386	141
With CHP System	81	1	1	1	1	26	120	215	454	694	157	34

Chart 3 Natural Gas Consumption

Notes: 1. For the months of June (2), July (3) of 2004 and January (9) of 2005 an igniter failure occurred in one of two microturbine.

2. For the month February (10) of 2005 an igniter failure occurred in both microturbines.

Table 2 Allied Converters Energy Data and Utility Cost Comparison - Baseline vs. CHP System

	Baseline Data May 2002 through April 2003	CHP System Data May 2004 through April 2005	Adjusted Baseline Data May 2002 through April 2003	Adjusted CHP System Data May 2004 through April 2005	Savings ($)	Comments (see below)
Consumption (KWH)	154200.00	70900.00				700 KWH
Cost for Consumption ($)	13868.00	6941.00	15393.48	6246.90	9146.58	
Unit Cost for Consumption ($)	0.09	0.10				
Demand (KW)	706.20	403.20				82 KW
Cost for Demand ($)	11925.00	7462.00	13236.75	6189.93	7046.82	1520
Unit Cost for Demand ($)	16.89	18.51				
Natural Gas used for Building Heat (Therms)	4646.00	1554.00				490
Cost for Natural Gas used for Building Heat ($)	4965.00	2198.00	5511.15	1667.99	3843.16	690
Unit Cost for Natural Gas used for Building Heat ($)	1.07	1.41				
Natural Gas used for MicroTurbines (Therms)	0.00	14082.00				
Cost for Natural Gas used for MicroTurbines ($)	0.00	13969.00		-13969.00	-13969.00	
Unit Cost for Natural Gas used for MicroTurbines ($)	0.00	0.99				
Total Annual Savings ($)					6067.56	
Projected Additional Savings if Igniter Failures did not Occur						2800
Projected Additional Savings Current Maximum Power Output = 43 KW Increased Power Output Resulting from Improved Air Circulation in MicroTurbine Room = 5 KW Increased Power Output Resulting from Installing Natural Gas Filters with Larger Ports = 4 KW						2300
Projected Annual Savings Neglecting Igniter Failures and Conducting Improvements						11168