Magic in a Box:

CHP Benefits Made Transparent at 200 Market Street

Figure 1. Showcase window allowing passersby to view CHP system. Absorption chiller, heat recovery heat exchanger, microturbine and cooling tower on right foreground to background.

People walking by 200 SW Market Street, a commercial office building in Portland, Oregon, are often drawn to a street level showcase window to see what is inside. Unlike most energy systems that are installed "out-of-site" within a building, the cooling, heating, and power (CHP) system at 200 Market Street is housed outside in a viewer-friendly structure with live streaming data available on an onsite computer terminal. The equipment attracts not only passersby, but also groups of clean energy enthusiasts, energy providers, educators, legislators, environmentalists, and building owners.

A consortium of Russell Development Company, Inc. (the building owner), local electric and gas utilities, the Oregon and U.S. Departments of Energy, the City of Portland, power marketers, technology manufacturers, and engineering contractors envisioned an educational project to demonstrate how CHP can achieve significant energy efficiency gains. The Consortium then installed a CHP system in a showcase setting to make transparent the workings and benefits of this advanced energy technology.

The microturbine-driven CHP system uses a microturbine to generate electricity for the emergency and night lighting circuits for the entire office building. All available waste heat from the natural gas microturbine is used either directly for space heating or to generate chilled water for air conditioning. As a result, annual electricity use has been reduced by over 244,000 kilowatt-hours (kWh) and boiler gas use by over 13,000 therms. That translates to an annual savings of almost $18,000 in electricity costs (see the Economic Analysis section for more details).

> "We're extremely happy with the CHP system. It's so maintenance-free, it's been nicknamed 'magic in a box'."
>
> Marc Montgomery,
> Chief Engineer, 200 Market Street

System Technical Overview

A 30-kilowatt (kW) natural gas Capstone microturbine, a Unifin Microgen exhaust-to-water heat exchanger, and a Yazaki 9.7 RT hot water-powered absorption chiller comprise the CHP system at 200 Market Street. The electrical output is used 24/7/365; microturbine exhaust heat is recovered by an insulated exhaust duct and then transferred to the heat exchanger to produce 190°F hot water at 40 gallons per minute (gpm) used for heating or to power the absorption chiller; and flue gas exhaust from the heat exchanger is released to the atmosphere.

Project Overview

LOCATION

200 SW Market Street
Portland, Oregon

DATE INSTALLED

CHP System Completed September 2002

FACILITY

360,000 square feet
of commercial office space

ELECTRIC & THERMAL

- 30 kW Capstone Microturbine
- 150-200 MBtu/h Unifin Heat Recovery Heat Exchanger
- 10 ton refrigeration Yazaki Absorption Chiller

ANNUAL ENERGY SAVINGS

244,000 kWh, 13,000 therms

PAYBACK

Over 11 years due to the educational nature of the project.

ENVIRONMENTAL BENEFITS

- Less than 9 ppm NO_x, at 15% O_2
- 847 lbs NO_x avoided
- 1,278 lbs SO_2 avoided
- 458,010 lbs CO_2 avoided

UNIQUE ASPECTS

- The control system provides live streaming data on site and on the Web
- CHP system is housed outside with showcase window for first-hand viewing

System Design

The electric output of the Capstone microturbine is estimated to be 27 kW and is fed through an automatic transfer switch to a new sub-panel for night and egress (doorway/exit) lighting. Night lighting is a linear load that has a 24/7, 100 percent load factor. All egress fixtures have battery backup so there is no process interruption. Recovered heat is distributed through the building's existing HVAC system.

System Performance

The microturbine operated at an average electric efficiency of 20.3 percent Higher Heating Value (HHV) during the 13-month monitoring period shown in Figure 4 below. The CHP system's overall efficiency (electric plus heat output / fuel input) for the four month period November 2002 – February 2003 was 64.5 percent HHV. The table shows that as the ambient temperature decreases (during the winter months) the efficiency of the microturbine turbine increases, which is characteristic of all Brayton cycle machines. Maintenance costs for the microturbine averaged $183 per month.

Figure 3. Microturbine, heat exchanger, and absorption chiller

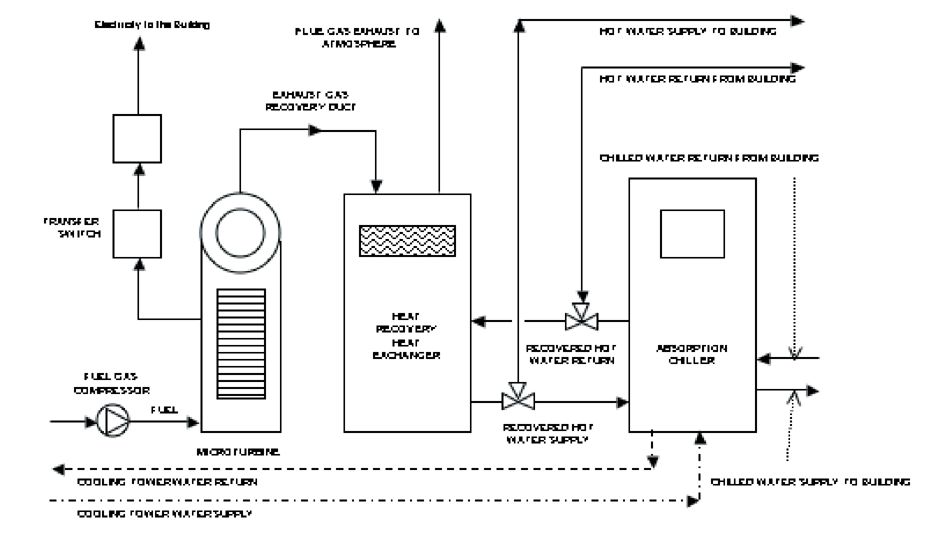


Figure 2. *Schematic of CHP System at 200 Market Street*

End-User Perspective

Lessons can be taken away from any project.

The consortium learned many lessons during their first CHP project. For example, when the Yazaki chiller arrived on site it was discovered that the maximum design working pressure of the chilled water-side of the unit was 85.3 pounds per square inch (psi) while the required operating pressure for the office building was 150 psi to be able to reach the top floors. Therefore, an additional plate heat exchanger needed to be installed.

This project underlined the need for experienced application assessments to select the right equipment for the site and ensure a proper installation. This site would have been better served by a microturbine and heat recovery heat exchanger providing boiler feed water preheating; adding the chiller should have been screened out to achieve superior economic performance. "We're getting more heating use out of it than we'd expected," says Chief Engineer Marc Montgomery.

The new DOE-supported Northwest CHP Application Center is designed to improve CHP applications and systems integration and will benefit the Consortium in its future CHP endeavors. Overall, the educational benefits of this CHP demonstration site have been far reaching, according to Christopher Galati of NW Natural, a local natural gas service provider. The Consortium members involved in the 200 Market Street project organize regular site visits and tours of the facility, with more and more people being turned on to the benefits that CHP can offer.

Figure 4. *Monthly Summary of Energy and Runtime Data*

	2002						2003						
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL
Logged Turbine Operating Hours	83	121	554	745	720	737	744	672	349	719	307	501	262
Net Power Output (kWh)	955	4,260	10,575	16,046	18,098	18,516	15,417	16,867	8,741	18,064	6,004	10,708	6,381
Avg Electric Efficiency (%HHV)	21	20.8	22	22	22.1	22.6	22.4	22.1	19.2	18	18.2	17.4	16.3
Avg Electric Efficiency (%HHV)	NA	NA	NA	NA	67.3	65.6	61.4	63.8	53.1	49.0	56.5	48.3	35.7
Parasitic Power (kWh)	103.3	206.7	69.9	146.1	307.1	457.9	176.1	272.6	146.4	558.7	253.8	418.5	340.9
Gas Use (Therms)	138.1	336.4	102.7	230.2	511.9	719.4	282.9	446.2	252.8	1,086.4	489.6	787.9	704.5
Unifin Recovered Heat (MMBtu)	1.9	16.1	4.7	10.6	23.1	31	11	16.6	9.6	33.7	18.7	24.3	9.7

NOTE: The absorption chiller was being installed during the summer of 2002; therfore there was no CHP overall efficiency.

Economic Analysis

Because the Market Street CHP installation was designed as a publicly visible demonstration project, it has a much longer projected payback (more than 11 years) than comparable systems would have. While the educational nature of the installation resulted in higher than normal capital expenditures, a comparably sized system housed within the building would be more cost competitive. Figure 7 below compares the energy use of the baseline building to the same building with CHP. Figure 6 shows cost savings. The similar trends in these graphs make clear the connection between the energy and cost savings realized by the CHP system.

As expected, due to very low electric rates from the Bonneville Power Administration, the CHP system did indeed save energy; it did not save money, however, using conventional gas rates. The microturbine, heat recovery system and chiller at 200 Market Street reduce electric costs by $9,939/year and save $7,939/year in boiler gas costs. However, these savings do not offset the added costs of gas for the turbine ($18,697/year) and additional maintenance costs ($2,201/year). On balance the CHP system increased annual operating costs by $3,020 per year using normal gas rates. However, the customer was only charged the commodity charge for the natural gas at $0.42/therm. Using this gas cost reduces operating costs by $5,800 per year and results in net savings of $2,782 per year.

The cost savings from the chiller are fairly modest in this application. The chiller reduces building energy use by 23,974 kWh per year during the four months of assumed summer operation. These electric savings are worth about $976 annually. In contrast, preheating the boiler hot water in the winter months saves 13,036 therms per year for cost savings of $7,939 per year. The ratio of gas and electric costs at this site clearly skews the benefits of heat recovery towards boiler preheating.

Costing Information | Market Street CHP Consortium (Funds committed or being committed)

Equipment	Projected Costs	Partners	Capital
Microturbine	$39,000	NW Natural	$25,000
Unifin Heat Exchanger	10,000	Oregon Office of Energy	88,189
Yazaki Water Fired	14,000	City of Portland	4,000
Structural	5,000	BPA	25,000
Electrical	20,000	Pacific Power and Light	25,000
Mechanical	97,000	Russell Development	31,000
Controls	28,000	Industrial Center	2,000
Design	10,000	American Gas Foundation*	106,000
Turbine Building	83,000	(*American Gas Association and the Gas Technology Institute)	
	$306,000		$306,189

Figure 5. Capital cost expenditures

Financing

Funding for the capital costs of the project was provided by the 200 Market Street CHP Consortium members, as outlined in Figure 5. Funds from the Oregon Office of Energy represent a 35 percent tax credit that the state provides.

Figure 6. *Electric, Fuel, and Avoided Electric Costs*

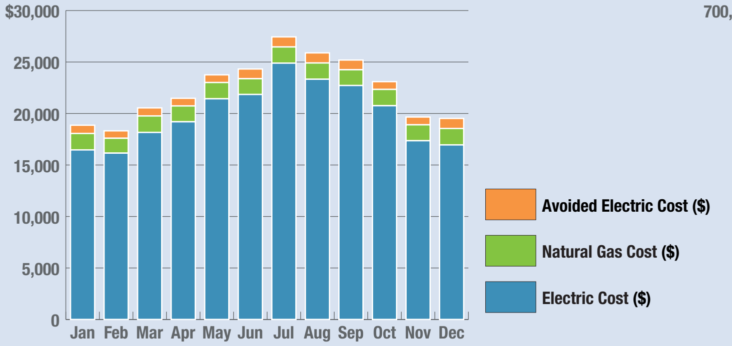
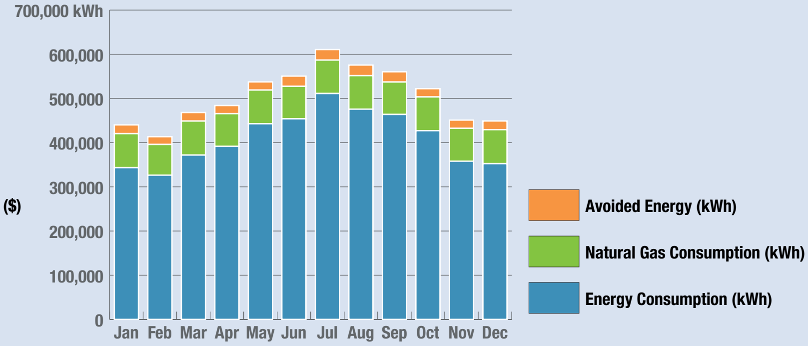


Figure 7. *Energy Consumption and Avoided Energy*



Replicability

The Distributed Energy (DE) Program selects projects that are highly replicable, or that can be duplicated in applications with characteristics similar to DE Program-supported projects.

Replication potential can be assessed by looking at various factors of the market and the site, including:

- DE/CHP potential within market sectors and subsectors, e.g. classified by the U.S. Census Bureau's North American Industry Classification System (NAICS)
- Industry growth and drivers
- Barriers and incentives
- Load profiles, e.g., electricity and thermal energy utilization patterns
- Technical and economic feasibility of the DE/CHP system
- Capital investment payback requirements

Figure 8. 200 Market Street Building

Several market analysis and DE/CHP feasibility studies that incorporate many of these factors have been completed. Analysis from the 2002 Integrated Energy Systems (IES) for Buildings: A Market Assessment report revealed that the potential building sector market for building integrated CHP is almost 17 GW in 2010, growing to over 35 GW by 2020, and includes CHP systems with absorption chillers, engine-driven chillers (EDCs), and CHP-only systems. This market potential is based on achievable economics, where CHP provides a minimum payback of 10 years compared with conventional HVAC systems and purchasing electricity from the grid. The potential for CHP is highest in office buildings, with over 10 GW of total IES, including significant opportunities for CHP with absorption units and engine-driven chillers (45 percent of the office potential). The building and CHP system were analyzed for Long Island, NY and Los Angeles using weather data and utility rates to evaluate the economics of this building CHP system in those locations. Both scenarios showed increased energy savings.

This first-of-its kind Pacific Northwest showcase has more than met the expectations of the Consortium to act as a learning tool for industry professionals and to educate both the public and private sector about the benefits CHP offers. 200 Market Street also brings into sharp focus Oregon's commitment to energy efficiency through the use of significant tax credits that were available for this CHP project. The 200 Market Street showcase and lessons learned from this project have already led to a new project installed at Lewis and Clark College in Portland at about a third of the cost and payback time. CHP systems with similar configurations can easily be integrated into most buildings. Larger turbines can be utilized to supply a greater electric load, and reciprocating engines can just as easily be used.

"I would advise any utility to do at least one marquee project like this one. It is a great education, sales, and marketing tool."

Christopher Galati, Northwest Natural Gas

Helpful Web Sites

- Distributed Energy Program
  www.eere.energy.gov/de/
- Northwest CHP Regional Application Center
  www.chpcenternw.org
- NW Natural
  www.nwnatural.com
- Bonneville Power Authority
  www.bpa.gov/energy/n/projects/dg_chp/200market/
- Exergy Partners Corp.
  www.exergypartners.com
- American Gas Foundation
  www.americangasfoundation.org/

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

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