The Power to Choose, and Save:

Residents of the Philadelphian High-Rise Condominium Cut Energy Costs by 25% with CHP

Figure 1. The Philadelphian high-rise condominium

The Philadelphian is a 1.4 million square foot, 22-story, 776-unit upscale condominium building in downtown Philadelphia adjacent to the Philadelphia Museum of Art. The Philadelphian Owners' Association (POA), wanting to save energy and be environmentally conscientious, decided to install an on-site cooling, heating and power (CHP) plant in 1989. To implement this change, POA took charge of its condominium's energy use by contracting with the Eastern Power Corporation to operate a plant that generated all the heating, cooling, water heating, and nearly all the electrical power for the building. This arrangement has resulted in energy cost savings of about $300,000 a year (about a 25 percent reduction from previous years). These savings can be passed on to the residents as a reduction in their monthly maintenance fees. Added benefits of the CHP system are near independence from the local utility, reduced fuel price risk, and lower staffing needs.

As a residence, the Philadelphian is open and occupied at all times, meaning that the space must be conditioned 24 hours a day and have a constant supply of outside air for ventilation. The building's cooling load is about 1,500 tons, and its heating load is about 38,163 million Btu (MMBtu) (4,893 MMBtu for domestic water heating, 630 MMBtu for pool water heating, and 32,640 MMBtu for space heating). Annual electricity consumption is about 10 million kWh, or 7.14kWh/square foot, coming primarily from resident plug load, the central plant pumping system, the cooling towers, and the electric chillers. Loads reach a high of 1.1 million kWh in July and August. Summertime peak demand is about 1,900 kW; winter peak demand is 1,200 kW.

Prior to installing the CHP system, the Philadelphian purchased all its electricity from the local utility. Heating and water heating were provided by two 200 HP (150 kW) and two 600 HP (448 kW) boilers (currently still in use). Two 850-ton (2,975 kW) chillers rated at 0.82 kW per ton provided cooling.

> "The CHP system has financial benefits for the condo owners because of the money that is saved by utilizing the steam that's produced."
>
> George Donofry,
> Chief Engineer, The Philadelphian

Project Overview

LOCATION
The Philadelphian
Philadelphia, PA

DATE INSTALLED
1989

FACILITY
1.4 million square feet

ELECTRIC & THERMAL
- 1.55 MW engine-driven generator (5 kVA)
- 200-ton absorption chiller
- Two 600 HP (448 kW) boilers (heating)
- Two 200 HP (150 kW) boilers (hot water and pool heating)
- Vapor-phase 2-pass vertical tube heat recovery boiler/HRSG (5.47 MMBtu/h)

PAYBACK
Recuperated costs in 3rd year of operation

ENVIRONMENTAL BENEFITS
- 2,618 lbs NO_x avoided*
- 8,093 lbs SO_2 avoided*
- 1,161,804 lbs CO_2 avoided*

*based on electricity consumption

UNIQUE ASPECTS
- Steam is utilized from generator and boilers to accommodate growth

System Technical Overview

The innovative building CHP plant at the Philadelphian consists of a 1.55-megawatt (MW) reciprocating engine-driven 5kVA generator, a series of tube-in-shell heat exchangers to recover available thermal energy, a heat recovery steam generator (HRSG), a hybrid steam absorption-electric centrifugal chiller plant, and dual-fuel boilers for heating and water heating. The hybrid chiller plant consists of a 200-ton steam-fired absorption chiller, and 650- and 850-ton (2,275 kW and 2,975kW, respectively) high efficiency electric chillers performing at 0.55 kW per ton.

By using more than 97 percent of the available "free" thermal energy from the engine-driven generator set and ancillary equipment, building engineers have substantially reduced the demand for electricity from the local utility and offset the purchase of thousands of gallons of #4 oil, resulting in cost-effective operation. Part of the energy savings is reinvested in plant upgrades.

System Design

Space heating and cooling is provided through a two-pipe system that feeds fan-coil units throughout the building. To allow for independent zone control, a three-tier distribution system was employed—the primary loop is located in the penthouse mechanical room, and four zoned secondary loops run all 22 stories of the building which feed tertiary loops on each floor.

High-pressure natural gas comes in from the local distribution company's street main, is regulated down to 4.5psi, then branches off to the steam boilers on the ground level and to the riser that travels up to the mechanical room in the penthouse. In the penthouse, the gas line branches again, serving the heating boilers and the gas compressor that feeds the engine-driven generator. Figure 2 illustrates the CHP and mechanical plant design at the Philadelphian.

System Performance

Less than 3 percent of the total steam produced in the CHP plant is discharged to the cooling tower. One of the most effective uses of this thermal energy is the base-loaded absorption chiller. This chiller displaces about 315,000 kWh of electric energy per year, and reduces peak summer load demand by about 106kW. On average days in summer, the Philadelphian purchases about 10 percent of its electricity from the local utility. On the hottest days, it imports up to 18 percent of its electricity. During the winter, 100 percent of the building's electricity is produced on-site.

The engineering staff at the Philadelphian records daily the amount of #4 fuel oil used for the water and steam boilers, as well as the amount of steam produced and where it is used. Additionally, data is collected on electricity produced and consumed, as well as consumption of #2 fuel oil and natural gas.

The most notable differences between the operation of the CHP plant as compared to the baseline plant are kWh purchased from the utility, load (kW), and the amount of #4 fuel oil consumed. Figure 3 illustrates these differences based on a representative year using actual data.

Figure 2. Schematic of CHP and Mechanical Plant at the Philadelphian

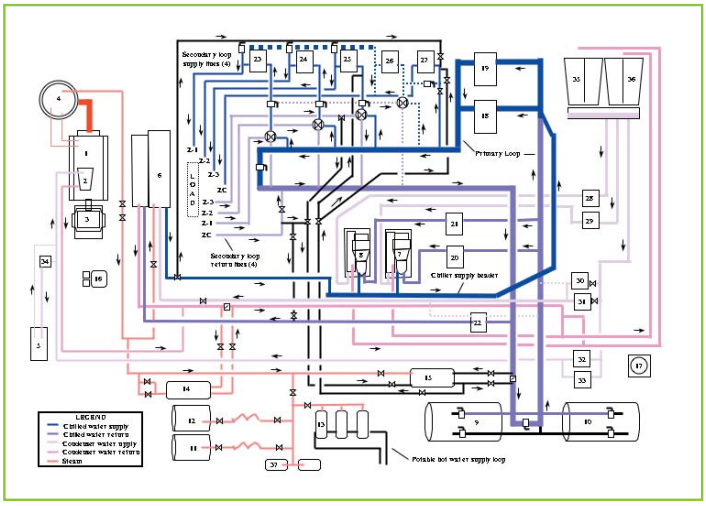

Figure 3. Representative yearly energy parameters of baseline and conventional alternative vs. CHP

	BASELINE	CHP	CONV. ALT
ELECTRICITY			
kWh consumed	11,004,295 kWh	10,033,159 kWh	10,345,386 kWh
kWh produced	0	9,193,230 kWh	0
kWh purchased	11,004,295 kWh	1,723,870 kWh	10,345,386 kWh
kWh exported/sold	0	883,941	0
kWh net purchased	11,004,295 kWh	839,929 kWh	10,345,386 kWh
Bldg peak kW demand	2,531 kW	2,143 kW	2,249 kW
Billed peak kW demand	2,531 kW	593 kW	2,249 kW
NATURAL GAS			
ccf used	0	933,361 ccf	0
MMBtu	0	96,136 MMBtu	0
#2 FUEL OIL			
US gallon used	0	69,960 gallons	0
MMBtu	0	9,445 gallons	0
#4 FUEL OIL			
Total US gallon used	333,412 gallons	197,435 gallons	333,412 gallons
MMBtu	48,345 MMBtu	28,628 MMBtu	48,345 MMBtu

Financing

The Philadelphian Owners' Association financed the project using a 15-year guaranteed energy savings contract with Cogeneration Partners of America in 1989. In 1996, POA purchased the engine, generator, heat recovery steam generator, absorption chiller, and related equipment as part of an agreement to buy out the contract. POA paid $1 million for the system – less than it would have paid for a new installation. This price represented the "fair market value" of the 7-year old system.

Figure 4. *Comparative economic analysis of baseline and conventional alternative vs. CHP plant of representative year*

	BASELINE	CHP	CONV. ALT
ELECTRICITY - TOTAL	$907,888	$174,297	$852,320
kWh - Supplementary	601,147 kWh	13,550 kWh	564,565 kWh
kWh - Scheduled Maintenance	0	16,367 kWh	0
kWh - Back-Up Power	0	58,042 kWh	0
kWh - Exported	0	-26,518 kWh	0
kW - Demand	306,721 kW	59,576 kW	287,755 kW
kW - Standby Demand	0	53,280 kW	0
Natural Gas	0	373,344 kW	0
#2 Fuel Oil	0	$56,668	0
#4 Fuel Oil	$296,737	$175,717	$296,737
Maintenance	$19,821	$99,105	$19,821
Total Cost	$1,224,426	$879,131	$1,168,878
Oper. Premium vs. BCHP	$345,295	-	$289,747

Economic Analysis

For a CHP installation like the one at the Philadelphian to be economically viable, the annual cost of owning and operating the system should be significantly lower than the alternative. The primary expenses of operation are maintenance, repairs, fuel and energy costs. The principal components of the fuel costs are natural gas, #2 and #4 fuel oil. Additionally, cost of operation also depends largely on load demand, and the timing of the purchase. Maintenance costs for the entire plant run $99,105 per year, including labor and materials. The CHP plant accounts for about 80 percent, or $79,250 of that total. Figure 2 summarizes the costs associated with the baseline plant as compared with the CHP plant.

The services provided by the CHP plant are delivered at a net yearly energy savings of $0.20/sq. ft. The system paid for itself in its third year of operation and continues to save between $275,000 and $400,000 per year.

End-User Perspective

The Philadelphian is a pioneer in on-site energy production for condominiums. POA's innovative approach to the power plant design yielded a showcase energy system. The Philadelphian serves as an excellent example of how applying existing, conventional technologies in a creative way can lead to significant energy and cost savings, and important environmental benefits. Equally important to the success of the project as the design and layout of the plant are the excellent operations and maintenance practices.

According to the building's chief engineer, George Donofry, a key to the success of this project is having someone on-site who understands not only the engine-driven generator, but the building's mechanical plant as well. He also noted that it is equally important to have "someone on the administrative end who is familiar with handling a high-tension tariff," the contract they have with the local electric company. The Philadelphian's CHP plant provides its management with a variety of fuel source options to meet their heating, cooling and water heating needs, which gives them increased negotiating leverage with energy service providers.

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

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. Currently, Pennsylvania's CHP market generates 7.2% of its total energy market, amounting to a capacity of 36,627 MW. Commercial applications at 37 facilities account for 587.5 MW of the total market through different facilities. Residential applications represent a small, but vital amount of the energy generated through CHP.

As facilities planners, developers, designers and operators become more aware of the economic and environmental consequences of their energy decisions, the efficiency, reliability, flexibility and economic benefits of CHP systems make them an excellent choice for today's and tomorrow's buildings.

Helpful Web Sites

- Distributed Energy Program
  www.eere.energy.gov/de/
- Mid-Atlantic CHP Application Center
  www.chpcenterma.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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