DISTRIBUTED ENERGY PROGRAM
CASE STUDY BRIEF

Arrow Linen:
CHP Washes Away Energy Costs of Commercial Laundry

Arrow Linen Supply Company is a commercial linen service in Brooklyn, New York, that provides laundry service for restaurants in the New York Metropolitan Area including Long Island, New Jersey and Connecticut. They launder uniforms and linen for over 2,300 customers ranging from "mom and pop" pizza stores to large catering halls. Arrow Linen has been in business for 60 years, and moved to their current location about 30 years ago; a mixed use neighborhood that contains residential as well as commercial buildings.

The facility operates six days a week from about 4 am until about 4 pm, and uses a significant amount of electric power and steam in their operations. Electricity is used for lighting, general power, laundry cleaning and processing operations. Medium-pressure steam (115 psig) is used for washing and pressing the linens processed within the facility, as well as for heating the plant's hot water load. The peak electric demand typically ranges from 350 kW to 370 kW depending on the month, while the average demand during operating hours is approximately 260 kW.

Arrow Linen installed a combined heat and power (CHP) system in June of 2004 to manage rising energy costs. The CHP system is comprised of two reciprocating engine packages with a maximum total output of 300 kW. Arrow Linen's requirements for the CHP system were that it had to be efficient, clean, easily integrated into their operations, and it could not risk interrupting the plant's production. The system was sized to meet the average electrical load for the plant. This ensured that all power generated by the system could be utilized internally at the facility. The system recovers waste energy from the engines' cooling water and hot exhaust to supply most of the hot water needs at the plant. The system has operated exceptionally well since its installation, supplying approximately 70% of the plant's power needs and 15% of its thermal needs with an overall efficiency of 76%.

Project Overview

LOCATION
Arrow Linen Supply Company
Brooklyn, NY

FACILITY
Commercial Laundry - NAICS 812331

ELECTRIC & THERMAL
• Two 150 Coast Intelligen reciprocating engine packages; 300 kW gross total output
• 1.28 MMBtu/h thermal (hot water) energy recovered

ANNUAL SAVINGS & PAYBACK
$116,073 and 3.7 years

ENVIRONMENTAL BENEFITS
• Catalytic converters are installed on the engine packages
• 1.81 tons/yr NOx avoided
• 5.15 tons/yr SO2 avoided
• 665 tons/yr CO2 avoided

UNIQUE ASPECTS
• Achieved an availability of 98.9%
• Provides about 70% of the electricity and most of the hot water load (about 15% of total thermal needs) for an **overall CHP efficiency of 76 %**

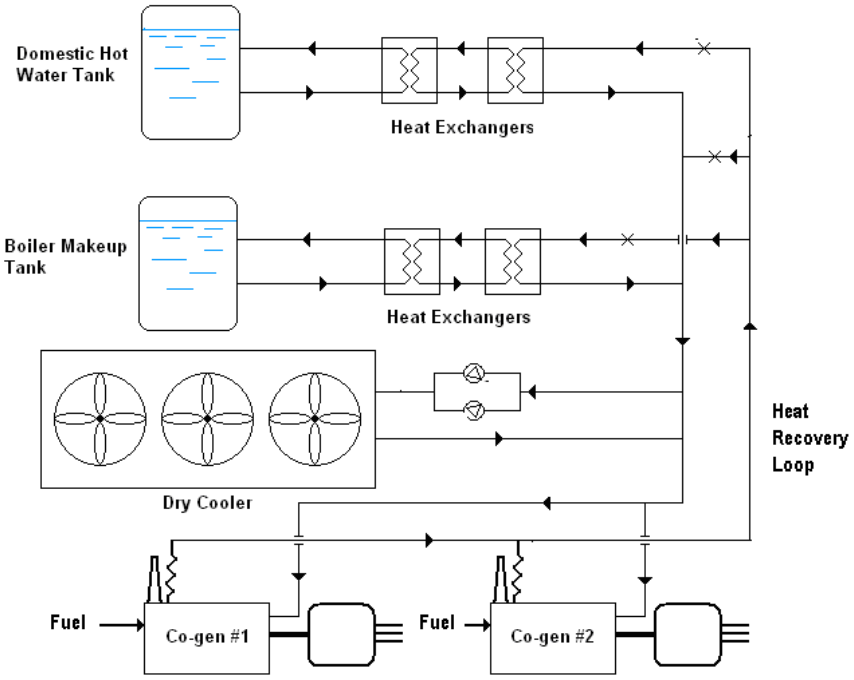
System Description

Prior to the installation of the CHP system, Arrow Linen purchased all their electricity from Consolidated Edison and their natural gas from National Grid. Overall, Arrow Linen's annual energy costs were around $600,000. Both the process steam and hot water loads were provided by a natural gas-fueled boiler. Approximately 80 to 85% of the boiler's steam output was used for direct injection into the washers and was not normally returned as condensate. The balance of the steam was used in the ironers for pressing and for heating hot water. About 15% of the 115 psig steam coming out of the boiler was stepped down to 15 psig through a pressure reduction valve and used to generate hot water through an indirect heating coil in the hot water tank and for preheating boiler feed water.

Photo: Arrow Linen Laundry Facility

The CHP system installed at Arrow Linen consists of two Coast Intelligen 150 kW reciprocating engine packages that use rich-burn Mann engines. A schematic of the system as installed is shown in Figure 1. Recovered heat from the engines is used to heat domestic hot water and preheat boiler feed water in priority order. Coolant is routed through the engine blocks to cool the engines (recovering heat in the process) and then through heat exchangers in the engines' exhaust to capture additional heat. The primary thermal load - the domestic hot water tank (3300 gal) - is heated by the energy recovered from the engines through an intermediate heat exchanger loop that runs at constant volume. If hot water demand falls below the energy available from the engines, the excess heat is used to preheat boiler make-up water through a second intermediate heat exchanger loop similar to the domestic hot water loop.

Figure 1: CHP System Schematic



The intermediate heat exchanger loops in both instances are to ensure that both domestic hot water and steam are absolutely clean for laundry operations. If the thermal demand for hot water or boiler makeup falls below the energy recovered from the engines, then excess energy is dumped from the engine coolant in the dry cooler.

The CHP system is designed to track the laundry's electric load by adjusting its output to correspond with facility demand. As the plant begins its operations the electric load starts to increase, and when the facility electric load exceeds 80 kW, the first engine starts. When the facility load exceeds 155 kW, the second engine starts. This process is reversed at shutdown. When the laundry's load falls below 155 kW, the first engine shuts down. When the load falls below 80 kW, the second engine shuts down.

One of the more interesting aspects of this installation has to do with the CHP system's location on top of the roof of the Arrow Linen building. The laundry's property is limited and all the space at ground level is required for laundry operations. Supporting the system's installation on the laundry's roof was a challenge. Most roofs are not designed to support such heavy weights, and re-enforcing the roof to accommodate the weight of the CHP system was deemed to be too costly. Instead, a cantilevered platform was constructed on four posts. These posts went down through the roof and into a very substantial foundation on the ground (the foundation was actually the foundation of the plant's original oil fired boiler stack). The system's location on the roof of the laundry and the closeness of adjacent residential properties (some within 150 feet) required extensive sound containment measures. An elaborate sound containment wall was installed around the CHP system to mitigate noise issues with the laundry's neighbors. A decibel meter was also installed at the property line to monitor the system's compliance with sound regulations.

System Performance

The CHP system at Arrow Linen was tied into a real-time monitoring program operated by Connected Energy Corp. Operating data and system parameters were continuously monitored over a period of several years. Performance of the CHP system was monitored by the Energy Solutions Center and analyzed for a twelve month period beginning in November 2005 and ending in October 2006. Table 1 shows the performance of the CHP system compared to the energy characteristics of the plant before installing CHP, and compared to an estimate of what the plant's energy use would have been over this period if the CHP system had not been operating. The CHP system operated a total of 4,475 hours during the twelve month period, generating 881,458 net kWh - about 70% of the plant's total power needs. The system also supplied 5,780 MMBtu of hot water to the facility, displacing about 14% of the plant's boiler fuel for that period. The system saved an estimated 5,631 MMBtu of total energy during that same period, assuming a displaced boiler efficiency of 80% and a utility heat rate of 10,000 Btu/kWh. The CHP system lowered Arrow Linen's annual energy costs by $116,000 through reducing the amount of purchased electricity.

The average output of the CHP system over the twelve month period was less than the full load design values – average gross power output was 206 kW (197 kW net output) compared to the design output of 300 kW. Much of this difference was due to the duty-cycle of the system. Since the system at Arrow Linen is designed to track the electrical load of the facility, causing one engine to modulate constantly, the system rarely operates with both engines at full power given the daily load profile of the laundry. Engine generators typically lose some electrical and thermal efficiency when operated at part load conditions. Even with this duty-cycle, however, the system achieved a high overall thermal efficiency of 76%.

Table 1: Performance Summary

	June 2003 thru May 2004	W/O CHP November 2005 thru October 2006 (Calculated)	With CHP November 2005 thru October 2006 (Actual)
Energy Use			
CHP System Average Electric Output, kW	n/a	n/a	197
Facility's Peak Demand, kW	372	378	378
Average Monthly Grid Demand, kW	262	257	60
Average Monthly Peak Demand Reduction, kW	n/a	n/a	120
Purchased power, kWh	1,504,800	1,250,645	369,200
CHP Generated Power, kWh	n/a	n/a	881,458
CHP Thermal Recovery, MMBtu	n/a	n/a	5,780
Boiler Fuel, MMBtu	48,076	47,899	40,675
CHP Fuel, MMBtu	n/a	n/a	11,501
Energy Costs			
CHP Natural Gas Cost	n/a	n/a	$127,507
Boiler Natural Gas Cost	$431,795	$667,497	$567,670
Total Fuel Cost	$431,795	$667,497	$695,177
Total Purchased Electricity Cost	$167,906	$231,947	$74,973
Incremental CHP O&M	n/a	n/a	$13,222
Total Costs	$599,701	$899,444	$783,372
Annual Savings	n/a	n/a	$116,073

Economic Analysis

Overall installation costs of the CHP system were approximately $1,021,000. This represents a total installed cost of approximately $3,400/kW. It should be noted that the Arrow Line installation included a number of cost items that would not necessarily be incurred in a more typical installation. These costs totaled $316,000 and included such things as improvements that were made to the laundry at the time of construction, instrumentation costs occasioned by the CHP system's role as a demonstration site for NYSERDA, and the additional costs necessitated by the CHP system's location on the laundry's roof as well as sound containment. With adjustments made for these costs, the total installed cost of the system corresponds to approximately $2,350/kW.

Arrow Linen received a number of financial incentives that enhanced the overall economics of the project. These included a grant from the New York State Energy Research and Development Authority (NYSERDA) as part of NYSERDA's CHP demonstration program designed to promote the installation of high efficiency CHP systems in commercial or industrial applications. This was used to reduce the capital cost of the system to Arrow Linen by almost $1,400/kW. Arrow Linen also receives a production incentive from the Energy Cost Savings Program initiated by New York City to support increased investment in energy efficiency and support the use of clean on-site generation systems. The program initially provides $.0444/kWh for power generated for up to 13,140,000 kWh annually, and provides a rebate for thermal energy recovered based on 58% of the regulated delivery charge for natural gas. The incentive lasts for 12 years and begins to decrease by 20% per year in the eighth year. This incentive is actually credited toward Arrow

Linen's natural gas bill on a retroactive basis. Finally, the natural gas consumed by the CHP system is provided at a discount compared to the gas used in the existing boiler. New York allows an incentive gas rate that discounts transportation and distribution costs for CHP gas consumption for systems below 1 MW. In the case of Arrow Linen, this discount is approximately $0.20/therm or $2.00/MMBtu.

Table 2 shows the simple payback for the project calculated several different ways to show the impact of varying capital costs as well as the impact of economic incentives. The table shows the costs and simple payback that Arrow Linen experienced (Arrow Linen Costs), as well as what the cost and simple payback would have been without the additional capital cost items described above (Typical Installation Costs) - the installed cost and payback without the additional capital costs are more representative of CHP systems in this size range. Simple payback for the CHP system without including any economic incentives range from 6.1 years for the Typical Installation Costs case to 8.8 years for Arrow Linen's specific costs. Including the NYSERDA CHP demonstration funding incentive and the New York City energy production incentive (Energy Cost Savings Program) reduces Arrow Linen's payback on the system to 3.7 years; applying these same incentives to the Typical System Costs results in a 1.8 year payback.

Table 2: Simple Payback

	Arrow Linen Costs	**Typical Installation Costs**
Total Installed Costs, $	$1,021,000	$705,000
Total Installed Costs, $/kW	$3,403	$2,350
Operating Savings (no incentives), $	$116,073	$116,073
Simple Payback (no incentives), years	*8.8*	*6.1*
NYSERDA Capital Cost Incentive, $	$417,831	$417,831
Net Installed Costs, $	$603,169	$287,169
NYC Production Incentive, $/year	$47,726	$47,726
Net Operating Savings (w/incentives), $	$163,799	$163,799
Simple Payback (w/incentives), years	*3.7*	*1.8*

Project Implications

Overall, the CHP system at Arrow Linen has performed exceptionally well. It has exceeded the expectations of both the facility and the system developers in terms of reliability, and has generated significant savings of energy and dollars. Reciprocating engine systems typically have availabilities in the 90 to 98% range. The availability of the CHP system at Arrow Linen was calculated to be 98.9%, much higher than typical systems. A sound design strategy and a good maintenance contract were the primary reasons for this exceptional performance.

According to Frank Park, the plant manager for Arrow Linen, several valuable lessons were learned in the course of this project and several key issues became apparent for optimizing the performance of a CHP system in this industry. First is the need for trained service personnel being available on a timely basis and the importance of regularly scheduled maintenance. Operation of the CHP system is largely automatic at Arrow Linen. Under the full service maintenance contract, Coast Intelligen is automatically notified by the CHP facility's control system if there is a fault needing attention and they dispatch service personnel upon such notification. Second is the advantage of doing background research on CHP before installation. Park stated that he was helped by doing research into the installation of other CHP systems,

including listening to experienced people and attending a number of seminars in order to understand successful strategies for applying CHP technology. Finally, it is clear that sizing the CHP system appropriately is a key factor for success. Park is concerned that even today project developers are often focusing only on electric demand when sizing CHP projects, and wrongly ignoring the need for thermal energy. Arrow Linen's project was sized with both the thermal load and power demand in mind.

Replicability

According to the 2002 Economic Census, there are 2,630 linen supply and industrial laundry facilities (NAICS 812331,) in the United States employing 136,000 workers. These facilities represent about $3 billion in annual payroll and $9.2 billion in annual revenue. Almost 40% of the 2,630 plating facilities can be found in the states of California, Texas, New York, Florida, Ohio, and Georgia. Based on the results of this demonstration and case study, laundry facilities appear to be good candidates for CHP. Efficient generation of both electricity and thermal energy on-site can result in significant reduction in energy use, operational cost savings, and enhanced reliability. While early design and operational issues impacted initial CHP system operation at the demonstration site, continued experience with CHP in this industry and improving technologies should enhance the value of this technology to users looking to improve their competitive position.

Arrow Linen can serve as a showcase installation for smaller, engine-based CHP systems. Despite demanding operating conditions, the system at Arrow Linen provides extremely reliable and cost-effective power and process heat for the laundry operation. Attention to sound design strategies, community and environmental needs, and effective maintenance practices should be a model for the replication of CHP installations at similar sites.

Energy Solutions Center

The Energy Solutions Center (ESC) acknowledges the distributed energy resources support provided by the U.S. DOE Office of Energy Efficiency and Renewable Energy/Oakridge National Laboratories, National Grid, and the ESC.DG consortium of utilities.

The Energy Solutions Center itself supports the commercial introduction of new technologies to help build value-added markets for natural gas in North America. The Energy Solutions Center and its members identify, evaluate, and prioritize industrial markets and products for the opportunities they offer.

The Energy Solutions Center then coordinates market development programs to specific products from R&D success to market acceptance and ultimate commercial success.

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