Big innovation at a small campus heating plant

Integrating CHP enabled Adelphi University to strategically address environmental, financial and other goals.

Robert Shipley, Assistant Vice President, Facilities Management, Adelphi University; Marc Couture, Higher Education Project Development Manager, Ecosystem; and Max Lamirande, Senior Project Development Engineer, Ecosystem

Courtesy Adelphi University.

Panoramic view, Adelphi University district heating plant.

Universities are often at the forefront of technological advancement and cultural shifts. Climate change is one of today's most urgent challenges, and again, universities are leading the charge. Some campuses are already ahead of the curve in this and can inspire others. One example is Adelphi University in Garden City, N.Y. An early investor in energy conservation and sustainability, Adelphi has long purchased 100 percent green power, harnessed solar energy and developed geothermal systems to provide heating and cooling to some of its buildings.

Energy efficiency is also a priority for the university's hot water heating system, which currently supplies 16 campus buildings from a central plant located 30 ft below Woodruff Hall. Built in the 1920s, this plant has been renovated over the decades – most recently in 2016, with a project that replaced aging boilers and boosted efficiency with the installation of a 1.99 MW combined heat and power unit.

This solution was strategically designed to help the institution achieve not only its efficiency objectives but all its targeted sustainability and business outcomes, now and into the future. With its new natural gas reciprocating CHP plant, Adelphi has cut electric consumption, increased resiliency and reduced its environmental footprint, while generating positive cash flow for future infrastructure spending.

MEETING CAMPUS NEEDS

Adelphi University is Long Island's oldest private coeducational university. It serves almost 8,000 students at its beautiful main campus in Garden City, nestled in a quiet residential area and neighboring private golf course. The entire campus comprises 28 buildings across 75 acres.

The fundamental goal of Adelphi's latest plant renovation was to replace two World War II-era boilers and a 40-year-old unit that supplied the campus district heating network. However, as Adelphi's facilities team considered different approaches, including a simple boiler replacement, it also aimed to address other campus needs:

- correct deficient air flow rates and operational issues in the science labs
- accommodate the future energy needs of new buildings, including a LEED-certified building added to the campus and fed by the CHP system during the project
- improve campus resiliency
- maintain campus aesthetics by controlling the potential "sprawl" and increased noise levels of added buildings – key to allowing Adelphi to preserve its learning and living environment
- avoid increasing greenhouse gas emissions
- continue leadership in sustainability
- balance asset renewal needs with the ability to budget for more cutting-edge, innovative projects

By 2013, Adelphi had begun researching options for meeting these needs, including the possibility of adding cogeneration. In 2015, the university partnered with Ecosystem to design and deliver the central plant upgrade.

Courtesy Adelphi University.

Adelphi's central plant is located in the sub-basement of Woodruff Hall.

PROJECT DESIGN

When considering its options, Adelphi's facilities department chose to integrate self-generation via CHP as a strategy for meeting all of its design drivers. For the Adelphi community, one of the great benefits of self-generation would be the ability to run the campus under emergency conditions if there were no incoming utility power. The importance of uninterrupted power had become clear after Superstorm Sandy shut down the Adelphi campus for 36 hours. Today, equipped with CHP combined with standby diesel generators on critical buildings, university facilities can maintain 100 percent operability.

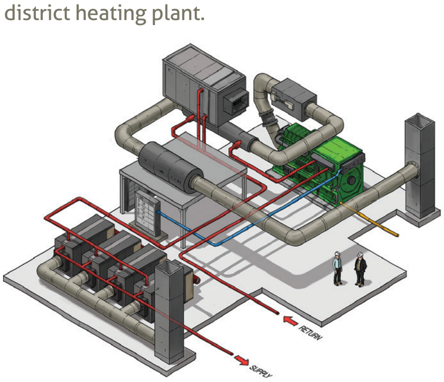
The sizing of the CHP plant was a critical step in the design process to ensure peak performance and maximum financial yield. Ecosystem developed a thorough analysis of the campus electrical and thermal load, optimizing the size to maximize revenue while ensuring the highest utilization factor. To perform this exercise, Ecosystem had to balance implementation costs with projected monetary savings generated by CHP.

Size was also optimized based on the incentive programs available from the New York State Energy Research Development Authority (more on those incentives below). At the time of the project implementation, incentives were most favorable for system sizes up to 2 MW and decreased substantially beyond that point. The baseload-sized system still provided the level of on-site generation required to allow the campus to maintain continuity of operations in the case of another lengthy power outage such as had occurred during Superstorm Sandy.

The new, optimized district heating plant (fig. 1) includes the 1.99 MW CHP unit and four new 180-HP near-condensing hot water boilers. Combined with three existing boilers installed in 2003 – left in place during the 2016 upgrade – the four new boilers bring total campus hot water production capacity to 26.1 MMBtu/hr. A special variable-flow air-handling unit was designed for the CHP enclosure with a heat rejection coil and supply and return fans to aid with heat rejection in the confined, underground plant space. The project design prioritizes supplying the heating district network by using heat recovery, initially from CHP (free heat) and complemented by the new boilers.

Since September 2016 – after more than three years of operation – the CHP system has operated on average with an overall utilization factor greater than 75 percent, indicating a well-utilized asset. This efficient new CHP system, with its high energy-utilization rate, has also helped to lower emissions.

FIGURE 1. Diagram of Adelphi University's new district heating plant.



Hot water heating system supply and return
Cogenerated electricity

Source: Ecosystem.

MINIMIZED PARASITIC LOADS, MAXIMIZED EFFICIENCY

The increase in electric power consumption resulting from installation of CHP accounts for 1.5 percent to 3.5 percent of the power generation, which is below the 6 percent to 7 percent seen on a typical CHP design.

This is the result of two innovative heat dissipation/recovery strategies:

1. Along with 5,000 cfm of required combustion air, an additional 35,000 cfm is required to properly cool the CHP electronic components. Variable-speed drives were installed to allow modulation of the fans. During winter months when the cooling air is colder, the fan speed can be reduced for an equivalent heat dissipation.
2. When the hot water produced by the CHP jacket cooling system is not recovered for heating, a cooling device, such as a dry cooler, is typically installed with CHP packages. This equipment is an energy gobbler and quite noisy. Because of the nearby golf course, the CHP jacket cooling system had to be optimized to reduce both the noise level and parasitic load. Rather than using the usual dry cooler, coils to reject heat were installed in the CHP's air exhaust system, taking advantage of the air flow to ventilate the electronic components of the CHP plant. Aside from a slight pressure differential increase, this had little impact on the fan power requirement and kept the noise and parasitic load to a minimum.

INSTALLATION CHALLENGES

All decisions about equipment size and design had to account not only for campus expansion plans, changing energy usage and resiliency needs but also the physical limitations of the plant space itself. Bordering the private golf club, Woodruff Hall – the building housing the boilers – is also constrained in terms of noise and footprint. As a school where 50 percent of students commute to and from classes, Adelphi guards every available parking space – an issue that became a potential stumbling block when the design team searched for ways to interconnect the CHP plant with the local utility's (PSEG Long Island) infrastructure. Situated a significant distance from the main electric entrance, the new CHP unit's connection required extensive negotiation with PSEG Long Island to avoid trenching across the center of campus.

It was imperative for Adelphi to hide the CHP plant to fulfill its goal of preserving the scenic character of the campus. Therefore, from the start, it was clear that the CHP unit needed to be installed inside the boiler room. The challenge was that accessing the boiler room 30 ft below ground was complex. Given that most prepackaged CHP solutions just could not be delivered in this tight room, Ecosystem had to custom-design many CHP components to ensure that the 1.99 MW unit and seven boilers ranging from 50 to 180 HP (the four largest ones being new), and all the piping, pumps, plumbing components and air-handling unit would fit in a compact space of 60 ft by 38 ft. Installation had to be accomplished without affecting the campus district heating capability.

The Adelphi boiler room, originally built in 1928, had been through three renovations since construction, and obsolete piping and ducts were taking up a lot of room. Eliminating everything that was no longer useful – including the two enormous boilers dating back to World War II – restored useful space.

To accommodate all the equipment, a mezzanine was constructed to add square footage (fig. 2).

Installing the generating unit 30 ft below ground was made more difficult by the narrow width of the shaft created for access to the boiler room. To bring equipment in, the concrete ceiling had to be demolished, and new beams were installed to change the shape of the entryway and provide additional support to the structure. At 12 ft by 17 ft, the shaft was just large enough to allow the CHP unit to be lowered into the boiler room with inches to spare.

FINDING THE BEST FINANCING OPTION

From the beginning of Adelphi's CHP project, the university sought to invest in a solution that would not constrain its ability to finance future infrastructure improvements or expansion on its campus. Balancing output and cost was key to maximizing the financial investment to achieve an eight-year payback period.

Adelphi invested $13.5 million (total project cost) to modernize its heating plant and make other building-specific energy savings upgrades in the Science Building, including replacement of exhaust fans and installation of variable-speed drives on the main air-handling units. The project as a whole generates annual savings of $1.6 million. Ecosystem contractually guaranteed the savings, allowing Adelphi to decouple installation and financing and to source a competitive financing package independently.

Two-thirds of the savings ($1.2 million) were designated to pay back the loan, and the balance ($400,000) was allotted to finance other infrastructure projects across the campus annually.

The available financial incentive programs were also factored into the project design. The entire project, which included a few additional energy conservation measures in addition to the CHP, benefited from a $2.46 million incentive from the New York State Energy Research and Development Authority (NYSERDA), an amount also guaranteed by Ecosystem. The project received a $100,000 bonus incentive from NYSERDA in the first performance year because the CHP efficiency requirement (60 percent) was exceeded by over 15 percent. An additional (and final) $100,000 NYSERDA bonus incentive was received for the second performance year.

OUTSTANDING RESULTS

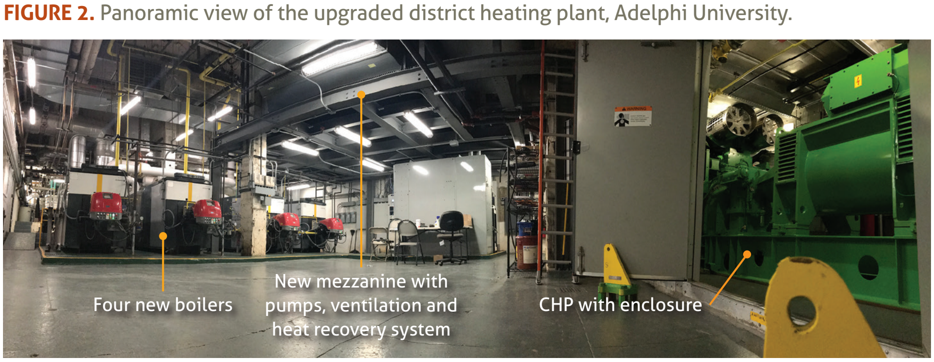
Since coming on line in September 2016, Adelphi's CHP plant has not only run at 75 percent efficiency, significantly exceeding the requirements for the NYSERDA incentives, but it has also resulted in a 40 percent decrease in the university's electric bill. The new CHP plant's efficiency drastically reduces greenhouse gas emissions, specifically when factoring in the utility source emissions. By producing some of its own electricity, Adelphi has reduced annual metric tons of greenhouse gas emissions by 28 percent since CHP startup. A look at the campus energy use intensity before and after installation of CHP demonstrates the

System snapshot: Adelphi University

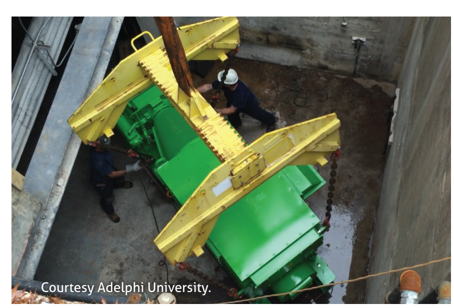
	Hot water/combined heat and power system
Startup year	1928 – Hot water heating system started up 2016 – Combined heat and power added
Number of buildings served	16
Total square footage served	1.22 million sq ft
Plant capacity	26.1 MMBtu/hr hot water, 1.99 MW electricity
Number of boilers/chillers	7
Fuel types	Natural gas, fuel oil
Distribution network length	1.5 miles
Piping type	Buried plastic
Piping diameter range	4 to 12 inches
System pressure	60 psig
System temperatures	155 F-170 F (outside air reset)
System water volume	21,000 gal

Source: Adelphi University.

FIGURE 2. Panoramic view of the upgraded district heating plant, Adelphi University.



Source: Adelphi University.



Courtesy Adelphi University.

The CHP unit was lowered into the boiler room with inches to spare.

TABLE 1. Comparison of energy use intensity (EUI), Adelphi University, before and after startup of the combined heat and power plant.

	Before CHP (reference year 2013)	First year of CHP performance (October 2016-September 2017)
Site EUI	124 kBtu/sq ft/year	143 kBtu/sq ft/year
Source EUI (considering the utility efficiency)	266 kBtu/sq ft/year	211 kBtu/sq ft/year

Source: Adelphi University.

impact of the project (table 1). The result is a source EUI reduction of 21 percent.

With this successful project, Adelphi University has demonstrated that environmental, infrastructure and financial considerations are not necessarily conflicting priorities; rather, they can be addressed in an integrated project. For Adelphi, CHP is a transition technology as the campus progresses further toward decarbonization of its utility grid.

Although this project was specifically designed for the Adelphi campus – and each university has a different set of circumstances that needs to be tackled in a unique way – it is also highly replicable and customizable for all district networks. The holistic approach and integrated delivery method capture and leverage the optimized financial savings, which generate additional funding for other campus improvements.

Editor's note: *In June 2019, Adelphi University's new CHP system was recognized by the Long Island Chapter of the Association of Energy Engineers, which named it Energy Project of the Year.*

Robert Shipley *is assistant vice president, Facilities Management, Adelphi University. He is responsible for the planning, construction, renovation, maintenance and repair of the university's buildings and facilities. His department provides oversight of central power plant and utilities, building systems, grounds maintenance, housekeeping and custodial services, trash removal and recycling services, as well as maintains all athletic facilities. Adelphi has been at the forefront in sustainability over the years, with Facilities Management the catalyst for many campus programs and initiatives. Shipley can be contacted at shipley@adelphi.edu.*

Marc Couture, *higher education project development manager for Ecosystem, is an expert at diagnosing complex energy ecosystems and developing transformational energy retrofits. Passionate about sustainable development, he works closely with his clients to design innovative energy solutions that respond directly to their needs while offering an attractive return on investment. Couture has honed his understanding of the challenges faced by real estate owners when renewing capital infrastructure and improving energy performance. He can be reached at mcouture@ecosystem-energy.com.*

How do we measure up?

IDEA survey reveals member engagement, content preferences

As an organization dedicated to informing, connecting and advancing the district energy industry, IDEA is always eager to know what's on the minds of the people we serve. This fall we reached out to our active members and nonmembers who engage with IDEA, asking them to participate in the IDEA Industry Survey.

As IDEA Chair Scott Clark mentioned in his column, the results of the survey were very encouraging. Many of the topics and initiatives that we focus on – such as peer exchange, access to case studies, best practice presentations and connecting with emerging technologies – ranked among the top priorities of our 580 survey respondents. We also learned about areas where we can make improvements and new topics that we should consider for future programming.

INTERNATIONAL DISTRICT ENERGY ASSOCIATION

Learn what your peers think about IDEA by viewing the full survey results at **www.districtenergy.org.** If you have any questions, please contact Jason Beal at jason.idea@districtenergy.org.

Max Lamirande is senior project development engineer at Ecosystem. Having been responsible for project development in the New York City area, Lamirande is now spearheading Ecosystem's growth in California. He is responsible for building relationships with clients on both coasts, qualifying opportunities and figuring out what value he can bring to their projects. As part of the Ecosystem project development team, Lamirande has worked on many different types of projects, including Adelphi University, and has been exposed to a wide range of innovative solutions. He can be contacted at mlamirande@ecosystem-energy.com.

CHP: VERSATILE AS A TRANSITION TECHNOLOGY

Adelphi University envisioned CHP as a powerful tool for achieving its sustainability, resiliency, growth and financial goals. CHP systems can also play a role in the transition to a clean economy. Looked at as a versatile asset, a CHP system and its value can be leveraged over time by changing the operating strategies and by introducing new technologies.

In the short term, while the electrical grid is still relatively carbon-intensive, the CHP system can continue to provide cheaper, cleaner baseload energy while contributing to resiliency in emergency mode.

In the medium term, once the grid cleans up a bit more, the CHP system could either shift to a demand-response or peak-shaving tool, operating only when needed to curb electrical demand. CHP can also be used for grid services and resiliency.

The electric grid in Ontario demonstrates another strategy. With coal decommissioned in the province in 2014 and a greater portion of the energy replaced with renewables, the value of peak shaving has risen dramatically. Peak shaving and demand response in the Ontario market have been so lucrative over the past five years that CHP owners have been incentivized to use the asset only for coincident peak-shaving and resiliency purposes.

OTHER CHP APPLICATIONS COULD PROVE FRUITFUL – E.G., USING CHP TO SUPPORT INTRODUCTION OF HEAT PUMP TECHNOLOGY IN A HEATING ELECTRIFICATION SCENARIO.

Additionally, there will still be a need for dispatchable electricity generation to compensate for solar and wind energy, at night or when air is still (before battery technologies are sufficiently affordable for mass penetration). On a broader scale, if there is still a need for dispatchable gas-generated electricity, it is a smarter choice to rely on distributed, smaller CHP plants rather than central, larger power-only and less energy-efficient plants.

Other potential applications of CHP could prove to be fruitful – for example, the use of CHP to support the introduction of heat pump technology in a heating electrification scenario for further decarbonization. Heat pumps have the unique ability to generate low-carbon heat, but they run on costly electricity. CHP could be the solution that feeds them with cheap electricity. The value of combining CHP and heat pumps would be at its highest in winter when heating demand is peaking and the technologies do not compete for the same thermal loads.

Finally, there is the potential to run CHP on zero- or low-carbon fuels, such as biogas, liquid biofuels or hydrogen. Carbon sequestration represents yet another potential long-term way that CHP could provide low-carbon energy.

The introduction of more energy storage technologies will certainly impact the use of CHP. A combination of various strategies is possible: peak demand management in summer, use with heat pumps in winter and backup emergency mode whenever needed (especially needed if heat pumps are the sole source of heating, raising the question of how to provide heat to occupants in case of a power outage without on-site generation).

It is impossible to predict what the breakthrough technologies or price of energy sources will be in 2050; there is a tendency, however, to underestimate the rate of technological change. Therefore, flexibility, adaptability and the ability to envision versatile use of technologies in different market conditions in the future will be important assets. Table 2 outlines potential CHP strategies as the grid becomes greener.

TABLE 2. Potential combined heat and power strategies and their benefits as the grid becomes greener.

Gradual decarbonization of the electrical grid		
	Short-term	**Medium-to-long term**
Potential CHP operation strategies	• Baseload operation • Emergency mode	• Demand management • Combination with heat pumps • Low-/zero-carbon fuels (biofuels, hydrogen)/carbon sequestration
Benefits	• Cleaner electricity • Energy cost savings • Increased resiliency	• Demand savings • Alternate decarbonization solutions

Source: Ecosystem.