District Energy

THIRD QUARTER 2007

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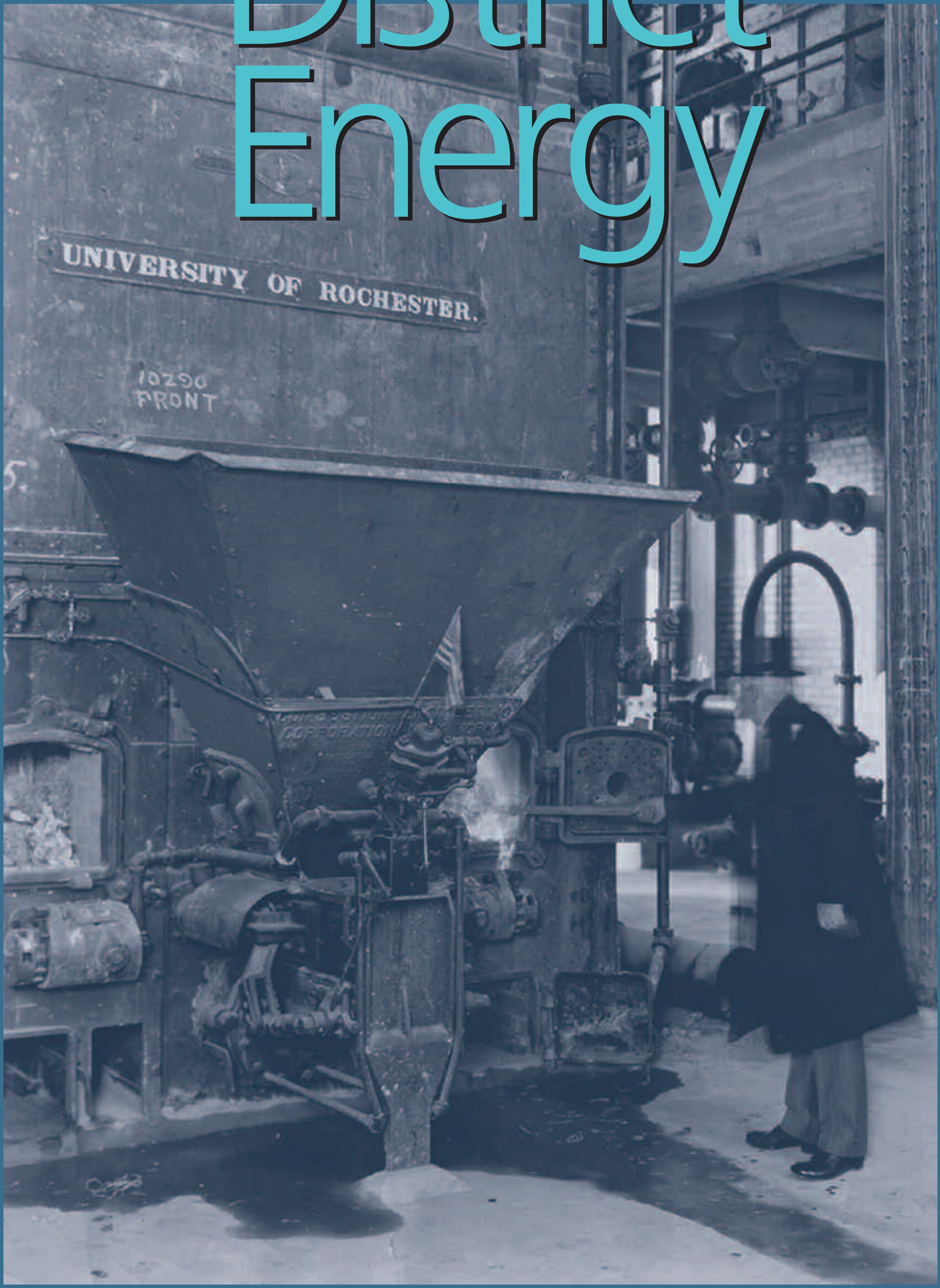

INTERNATIONAL DISTRICT ENERGY ASSOCIATION

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Cover Story

From Steam to Hot Water and CHP:

University of Rochester converts

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Modern district heating was born in the city of Lockport, N.Y., when Birdsill Holly launched the first commercially successful system in 1877. Less than 30 years later, just 60 miles away, the University of Rochester fired up a district heating operation of its own – laying the foundation for a system that today serves 7.7 million sq ft of space in 58 buildings on two of its six local campuses. The institution recently redesigned that system, incorporating combined heat and power and converting from steam to hot water as part of a plan to meet campus energy needs well into the future. The university's commitment to improving its heating infrastructure should come as no surprise: It's another example of the University of Rochester, one of the nation's leading private institutions, putting its motto – Meliora ('ever better') – into practice.

Courtesy University of Rochester.

The Genesee River winds along the University of Rochester's main campus, which, together with the adjacent Medical Center Campus (at right), is served by the new low-temperature hot water district heating system.

Tapping Combined Heat and Power Potential

In 1903, university President Rush Rhees was instrumental in building a coal-fired central steam heating plant on the original campus just east of downtown Rochester. By the mid-1920s, the University of Rochester expanded to include a site south of the city for its new School of Medicine and Dentistry, plus an adjacent parcel of land along the Genesee River – today the main campus, known as the River Campus. To keep pace with growth, President Rhees added a second steam plant in 1924 (personally lighting the first boiler to kick off a large fundraising campaign). Located between the River and Medical Center campuses, this plant distributed steam to buildings on both campuses through underground tunnels. (The only part of the original campus owned by the university today is the Memorial Art Gallery; the 1903 heating plant was eventually torn down. For more history, see sidebar "Support From the Top.")

In the 1970s, the university's second boiler plant was expanded; in 1998, four of its five boilers were converted to burn natural gas and distillate fuel oil. The two 150,000-lb/hr and two 100,000-lb/hr boilers were more than adequate to meet the university's peak steam load of 250,000 lb/hr. A chiller plant with steam turbine-driven centrifugal chillers was also built in the '70s to serve a new district cooling network.

Although the university had given some consideration to CHP through the years (many local industries like Eastman Kodak were already using CHP in the university's early days), it was not until 2003 that the institution conducted an in-depth internal evaluation of its CHP potential. This evaluation included three different CHP options that were considered individually and in various combinations with steam and hot water distribution systems. The first was a 30 MW gas turbine. The second was a high-pressure boiler and back-pressure steam turbine exhausting at 165 psig. The third option was a low-pressure steam turbine with an inlet of 165 psig and exhausting between 5 to 10 psia to supply a new low-temperature hot water district heating system

University of Rochester Fast Facts

- Founded 1850 as a private institution in Rochester, N.Y.
- Six campuses (600 acres total) include
  - main 85-acre River Campus
  - Medical Center, including Strong Memorial Hospital, the School of Medicine and Dentistry, School of Nursing and Eastman Dental Center
  - prestigious Eastman School of Music, ranked first among U.S. graduate music programs
  - Memorial Art Gallery, with a permanent collection of 10,000 works spanning 50 centuries
  - South Campus, home to the Laboratory for Laser Energetics
  - Mt. Hope Campus, including houses of the university president and provost
- Ranks among nation's top research universities, yet one of the smallest research-intensive universities based on enrollment (4,608 undergraduates, plus 4,090 full- and part-time graduate students).
- Has produced eight Nobel Prize winners and 12 Pulitzer Prize winners.
- Notable alumni include Francis Bellamy, author of the original Pledge of Allegiance published in 1892; conductor Mitch Miller; former U.S. Surgeon General David Satcher; Renee Fleming, Grammy Award-winning operatic soprano.

Source: www.rochester.edu.

Support From the Top

The University of Rochester's first home was a former hotel until it opened its new Prince Street campus in 1861. The university had 10 buildings and 500 students by the early 1920s when John D. Rockefeller's General Educational Fund offered to contribute $5 million toward the construction of a new medical school if the university could obtain a matching contribution. Eastman Kodak founder George Eastman provided the matching funds and planning began. The existing site was not large enough for the added medical buildings, and after considering several local sites for expansion, the university selected the former county fairgrounds. The university's new School of Medicine and Dentistry opened there in 1925, and the adjacent River Campus for Men opened five years later; the older campus became the Campus for Women.

Rush Rhees, university president from 1900 to 1935, was involved in developing the campus heating infrastructure. He had a coal-fired central heating plant built in 1903, and he is said to have visited there every day! Another boiler plant was constructed in 1924, receiving coal at its own rail siding connected to two adjacent railroads. The plant was expanded and a new chiller plant was added in the early 1970s.

Records do not indicate if combined heat and power was considered in the 1924 boiler plant design, although many area industries were using the technology. Yet several engineering students who studied the steam plant in 1933 recommended CHP be added.

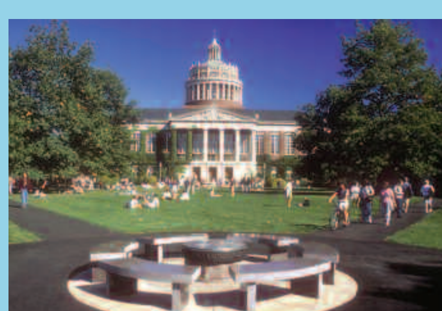
In 1938 the university proposed to install a cogeneration prime mover, and the local electric utility responded with a point-by-point refutation of the university's proposal. The university did not proceed with the project, although no specific reasons have been found for this decision. Likewise there is no record showing that cogeneration was considered when the plant was expanded in the late 1960s and early 1970s.

The combination of the oil shocks of the 1970s, enormous cost overruns on nuclear generation plants and growing environmental awareness led to the passage of the Public Utility Regulatory Policy Act of 1978 (PURPA), which required utilities to allow qualifying nonutility generators to connect to their networks and also purchase the electric output at their 'avoided cost' of generation. New York passed a law implementing PURPA at a minimum payment of 6 cents/kWh. The utilities did not object, as they believed their generation cost was at least that high.

Numerous 'PURPA machines' were built in New York to take advantage of what turned out to be a wildly inflated avoided cost calculation, since for many hours of the year coal, nuclear and hydro plants could produce power for a fraction of that number. The University of Rochester steam load was attractive as a host site, and several proposals were received for plants with electric capacities ranging upwards of 200 MW.

After the '6-cent law' was repealed, and it became clear that a third-party developer would be unable to deliver a viable project, the university developed a plan to install a 23 MW simple-cycle gas turbine to cogenerate heat and power. The local utility thought the plan was premature in the New York market, and in 1993 it offered a seven-year rate incentive that matched the financial benefits of the cogeneration project. The university accepted. In the final years of this contract, natural gas-fired merchant plants appeared, and the university and several nearby institutions joined together to invite proposals for a merchant plant that could deliver steam to all. The market in western New York was not conducive to merchant plants, however, and this effort failed.

Shortly thereafter, the university received a proposal to install a 13 MW gas turbine at the plant, and although it offered minimal financial benefit, this proposal triggered an internal evaluation of the university's cogeneration potential that led to the project that was eventually approved and implemented.



Courtesy University of Rochester. Photo Richard Baker.

The Rush Rhees Library, the most well-known building on campus, is named after university president and district heating proponent Rush Rhees, who served in the early 1900s. The building is connected to the district heating and cooling systems and will soon be connected to the new hot water system.

that would generally operate below 200 degrees F. (Supply temperature is generally 165 F in summer and 188 F in winter.)

Subsequently the university engaged the energy markets and economics consulting firm Levitan and Associates Inc. to forecast 25-year gas and electric prices for western New York and prepare a detailed financial analysis of the internally identified options. Levitan recommended proceeding with two separate elements: the high-pressure boiler and steam turbine, and the low-pressure steam turbine and hot water district heating. A gas turbine of any size did not meet the financial hurdle that had been established due to the region's high natural gas market prices and relatively low electric prices. This recommendation essentially validated the university's own internal study, and the university's board of trustees approved the recommended project in 2004.

Efficiency Drives Design

FVB Energy was hired in 2004 to design the new hot water district heating system, including the pipelines and building connections, and supervise its installation. FVB Energy carefully integrated the hot water system with the university's cogeneration plant that generates hot water using exhaust steam from 7.2 MW and 18 MW condensing steam turbines. To minimize installation costs and ensure a long service life with minimal maintenance, the system was designed to meet European piping standards EN-253 and EN-448. The new hot water system was planned to serve the entire heating load for the River and Medical Center campuses as well as accommodate 20 years of projected growth.

The University of Rochester's steam distribution system was in fairly good condition and about 90 percent of the condensate was returned to the plant.

During the system design process, university facilities personnel visited hot water district heating systems in St. Paul, Minn.; Jamestown, N.Y.; and Canada to familiarize themselves with preinsulated piping system and installation techniques. The staff learned that low-temperature hot water can be run several miles with minimal losses and that many European systems distribute hot water over distances of 30 miles or more between large power plants and urban areas. University staff discovered that many European district heating companies are replacing

The University of Rochester's new cogeneration facility can produce up to 250 MMbtu/hr of hot water for the hot water district heating system and 25 MW of electricity. Although cogeneration had been a topic of discussion at the University of Rochester since institution's early days, the technology was finally implemented with the startup of this new plant in 2005.

20-year-old preinsulated pipe still in good condition with new pipe that has much lower thermal losses with a good economic payback.

Although the University of Rochester's steam distribution system was more than 30 years old, it was in fairly good condition, and about 90 percent of the condensate was returned to the plant. A detailed heat balance analysis, however, revealed that nearly 25 percent of the energy value in the steam at the boiler header was lost in the distribution system. While this was not a major concern when the plant was burning inexpensive coal, the higher cost of natural gas combined with greater environmental awareness made this level of inefficiency unacceptable. As a result, hot water was deemed a more efficient medium for this application.

Construction Begins

The hot water system construction started in late 2004 and was completed in fall 2005. The project connected the River and Medical Center campus buildings with existing hydronic heating systems to the new hot water system. They previously used steam-to-hot-water heat exchangers to accommodate space heating, domestic hot water and snow melting needs and accounted for roughly half the total heating load from the central plant.

The original intent was to install a directly connected system, in which the district hot water also circulates in the building heating systems, which is how the university's large chilled-water system works. The district heating system design operating pressure of 230 psig made this difficult, however, since many of the older hydronic systems were designed for lower pressures. In the end, the pressure concerns and uncertain condition of many of the older hydronic systems led to using an indirect system, with heat exchangers to physically separate the district heating and secondary systems. A total of 118 heat exchangers were installed in the project (table 1).

Dual-wall plate-and-frame exchangers were used for domestic water heating to meet requirements of the New York state plumbing code. AIC shell-and-coil exchangers were utilized when the secondary systems were used for both heating and cooling to avoid fouling from the chilled water. These included some older two-pipe fan coil systems plus some new dual-temperature coils in which chilled-water coils are used in winter for heating with low-temperature water. Compact brazed-plate exchangers were used for most heating applications. Since the initial installation was completed in late 2005, another 30 exchangers have been installed in new buildings and renovated areas; another 150 are being evaluated for connection.

Leveraging lessons learned from other systems, the district heating pipes were run through existing building spaces or tunnels wherever feasible, using standard Schedule 40 steel pipe. The system construction project included 9,526 trench ft of preinsulated pipe manufactured by Logstor (1,261 on the Medical Center campus; 8,265 on the River Campus) and 7,425 paired ft of interior piping (5,395, Medical Center; 2,030, River Campus). A combination of direct-buried preinsulated piping and internal pipe of standard construction was used for the new hot water system, which extends more than 3 miles.

Seventy Kamstrup hot water meters conforming to European thermal energy metering standard EN-1434 were also installed for system monitoring and troubleshooting as well as cost allocation. Flow, temperature, energy and volume readings for each meter are read every five seconds by the university's real-time metering system using the meter's M-Bus output connected via Ethernet gateways. All metering data are accessible through a public Web interface, which has been a useful tool. The meters have proved extremely valuable for monitoring and managing the system, and all new heat exchangers added to the system are equipped with individual heat meters.

Hot Water Begins to Flow

The University of Rochester's new hot water system came on line in October 2005. From June 2006 to May 2007, 320,000 MMBtu of hot water were used in connected buildings, while 440,000

Table 1. Heat Exchangers Installed in University of Rochester's District Heating Construction Project, 2004-2005.

Area	Brazed-Plate	Dual-Wall Plate-and-Frame	Shell-and-Coil	Total
River Campus	36	25	3	64
Medical Center	11	15	28	54
Total	**47**	**40**	**31**	**118**

Source: University of Rochester.

Courtesy University of Rochester.

Most of the heat exchangers installed during the university's hot water system construction are brazed-plate-type units (foreground), shown here along with the older steam models, which were abandoned in place.

Mlb of steam were used by remaining steam loads served by the central plant. The hot water system now accounts for about 42 percent of the central plant's total heating load. Although the initial project connected hydronic systems that were previously served by steam-to-hot-water exchangers, the university hopes to retrofit its remaining steam buildings, convert many steam preheat coils to hot water and connect 1.7 million sq ft in 69 additional buildings not currently served by the central heating plant. The university is currently exploring options to finance and implement these additional hot water opportunities.

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Meters installed at the plant and each connected building show that thermal losses on the new distribution piping have been less than 1 percent – a dramatic improvement over the steam system's 25 percent losses. Mechanical spaces that were formerly hot and noisy in the winter because of steam pipes are now quiet and cool. Steam lines to 16 buildings have been abandoned in place, and the remaining direct-buried steam lines will be abandoned as additional hot water loads are connected, further reducing maintenance costs and thermal losses. On the River Campus, for instance, only 56 percent of the steam leaving the plant over the past 12 months made it to individual building meters, resulting in $750,000 of energy wasted in the remaining steam distribution network.

Linking Hot and Cold

In addition to its district heating system, the university currently has a 22,000-ton steam turbine chiller plant and is constructing a new 4,000-ton electric satellite chiller plant. District cooling is provided to 42 buildings on the River and Medical Center campuses. Meeting continuously rising chilled-water demand has proved very challenging, particularly due to space constraints that make construction of new chiller capacity difficult. As an alternative, the university is currently evaluating liquid desiccant dehumidification to minimize chilled-water growth and potentially decrease it substantially.

Liquid desiccants absorb humidity directly from outside air entering air-handling systems, avoiding the need to subcool outside air down to 55 F for humidity control and then reheating it for delivery to conditioned spaces. These systems are widely used in industrial applications, but their use in commercial and institutional settings has been limited by the large amount of low-temperature heat required to regenerate the desiccant.

Hot water district heating provides an excellent source for this service, and during the summer it appears possible to reduce the university's existing chilled-water demand by more than 75 percent by using 165 F hot water as a regeneration heat source. This, in turn, significantly increases the amount of electricity cogenerated during the summer when market prices are generally higher.

Converting from steam to hot water has given the University of Rochester a new and efficient heating infrastructure, with minimal losses and maintenance expenses and an opportunity to address increasing demands for cooling. The extensive effort that went into planning and executing the project – in the quest to become 'ever better' – clearly paid off with the delivery of a quality installation that can best serve the needs of this growing campus.

Morris A. Pierce is energy manager and adjunct assistant professor of history at the University of Rochester in Rochester, N.Y. He has been with the University of Rochester since 1988 when he wrote his doctoral dissertation on the history of cogeneration and district heating while managing the university's energy needs. He has written numerous articles on district energy and local heat supply planning, as well as the history of these subjects, and also teaches courses on the history of technology, environment and energy at the university. Pierce holds a bachelor of science from the U.S. Military Academy at West Point, a master's degree from the University of Northern Colorado and a doctorate degree from the University of Rochester. His email address is mapi@mail.rochester.edu.