

# Underneath the ivy

**Early adopters of district energy, Ivy League schools continue expanding and improving their underground distribution networks.**

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The Ivy League colleges and universities are some of the oldest and most renowned in the United States. The term “Ivy League” has become synonymous with academic excellence, with each school consistently ranked among the best in the world. With this history comes some of the oldest infrastructure and utility distribution systems in the country.

Most of the Ivy League district energy systems date back over a century and have been modernized from single coal-burning heating plants to multipurpose, multiplant energy systems. But what happens below the surface at these elite schools? How do the networks deliver district energy when they are invisible to thousands of students, faculty, staff and visitors? RMF Engineering Inc. has had the opportunity to be a part of many exciting recent developments to the district energy systems at these prestigious schools.

## **BROWN UNIVERSITY**

At Brown University in Providence, R.I., the campus heating system primarily consists of a high-temperature hot water (350 degrees F) distribution supply and return loop from the Central Heat Plant. This hot water loop is operated under high pressure (250 psig). Brown maintains and operates some steam and medium-temperature hot water distribution piping as well. The majority of the heating net-

work piping is a direct-buried, prefabricated, double-walled, drainable, dryable system. A few sections of this system are installed within underground tunnels or routed through buildings.

There are six main steam hubs on campus, which utilize the high-temperature hot water to generate steam for building use in older terminal devices. In some cases, the steam is then used to generate medium-temperature hot water. The steam hubs are reaching the end of their respective service lives, are a source of energy loss and require more maintenance than hot water systems. To simplify the heating system, reduce energy loss and decrease costs, Brown recently decided to convert the campus to a medium-temperature distribution system (in the 200-275 F range). This will include eliminating the steam hubs and converting campus buildings as required to utilize hot water.

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**AT BROWN, IT'S NOT UNCOMMON DURING CONSTRUCTION PROJECTS TO ENCOUNTER ABANDONED PIPING FROM DECADES EARLIER.**  
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One of the greatest challenges in installing new distribution piping on Brown's campus has been the space beneath the streets, which have been in

use since the 1700s. It's not uncommon during construction projects to encounter abandoned piping from decades earlier. RMF Engineering recommended that Brown use aerogel-type thermal insulation on distribution piping in situations with space constraints to minimize thickness while retaining high-value insulating properties. This allowed for a smaller pipe envelope and enabled installation in tight spaces.



Courtesy RMF Engineering Inc.  
New high-temperature hot water piping in a prefabricated conduit system in a narrow window at Brown University.

## COLUMBIA UNIVERSITY

In New York City, Columbia University's district energy system dates back to 1896 when the original steam plant and distribution piping system were built. Chilled-water distribution began in the 1960s, with the addition of a central chiller plant in the 1980s. The generating plants have been significantly upgraded in recent years with the addition of four 2,800-ton chillers and the refurbishment of three steam boilers. Through the new equipment and energy optimization software, Columbia has been able to improve its chilled-water system operational and cost efficiency and reduce its greenhouse gas emissions.

Most of Columbia's heating and cooling distribution piping is welded steel and is accessible in walkable tunnels or basement-level building corridors that connect most of the buildings. The tunnels and corridors afford access to the utilities for the operation and maintenance staff at all times. Minimal amounts of the distribution piping are direct-buried, mostly to cross city streets. During renovation and improvement projects, Columbia has upgraded older sections of steam piping, which in some cases was constructed of riveted fittings. The campus is situated in an area with shallow bedrock, making excavation for new utility installation expensive and impractical. Columbia utilizes existing available pathways when system replacement or upsizing is required.



Columbia University primarily utilizes walkable tunnels and basement-level corridors for distribution of heating and cooling piping.



Cornell has been employing high-density polyethylene pipe successfully for its chilled-water distribution projects.

## CORNELL UNIVERSITY

Cornell University in Ithaca, N.Y., is at the forefront of materials technology. Cornell started sliplining sewers with high-density polyethylene 30 years ago and in the '90s studied lake source cooling, which featured 63-inch-diameter HDPE supply and return lines in Cayuga Lake. Since then, the campus has adopted HDPE for all of its chilled- and domestic water distribution, and lake source cooling has become a hallmark of Cornell's sustainability mission. The university has saved 25 million kWh annually using the system – over 10 percent of the campus's electric consumption today.

Most recently, Cornell employed HDPE to extend the district cooling system to two campus buildings, totaling 1,000 linear ft. The buildings' individual HVAC systems had reached the end of their useful lives, and connection to the district cooling loop was determined to be more cost-effective than replacement of individual building systems. Construction was originally scheduled in 2016 between the June commencement and August student arrival, however the contractor was able to mobilize, excavate and complete one of the chilled-water connections before commencement, thanks to the speed of fusing the HDPE joints.

## DARTMOUTH COLLEGE

Dartmouth College in Hanover, N.H., has operated a district heating system since 1899 and uses it to warm the ma-

jority of its 5 million sq ft of facilities. In April 2017, Dartmouth announced new sustainability goals including deriving 50 percent of its energy from renewable sources by 2025 and 100 percent by 2050; achieving a 50 percent greenhouse gas reduction by 2025, with an 80 percent reduction by 2050; and improving the efficiency of the energy distribution system by 20 percent by 2030. To meet these goals, Dartmouth is developing an integrated plan incorporating demand-side energy efficiency programs and supply-side strategies to convert renewable thermal and electric energy supply sources. Part of this plan may be to replace the existing fuel oil-fired heating plant with a new woodchip-burning biomass plant. This should make it possible to achieve the 2025 goals.

In addition to changing the fuel used for heating, Dartmouth is developing plans to change the heating medium that is distributed throughout the Hanover campus from steam to more energy-efficient low-temperature hot water (less than 185 F). The college has approximately 19,700 linear ft of 20-psi steam distribution. The low-pressure steam has some superheat qualities because it's the exhaust product of steam turbine generators, which receive 450-psig, 650 F superheated steam from the main boilers.

The existing system is costly to operate and maintain, with portions nearing the end of their lifecycle. Avoiding the replacement and maintenance costs of the steam system would help to offset the upfront costs of a new biomass plant, hot water distribution and building conversions. The conversion to hot water would be incremental – prioritizing pieces of the existing steam system that will require replacement soon and taking the need to replace the piping sections as an opportunity to convert a portion of the system to hot water. The hot water piping will be a preinsulated, bonded pipe system with thin-walled steel service pipe, polyurethane foam insulation and HDPE outer casing. Dartmouth is developing detailed plans for the replacement of the steam system and design and construction of the new heating plant to help meet the campus's sustainability goals.

## HARVARD UNIVERSITY

It isn't often that America's oldest university – founded in 1636 in Cambridge, Mass. – plans a new district energy plant and distribution network from scratch. That is, however, exactly what RMF Engineering and Harvard University's Engineering & Utilities department are doing as the school plans for expansion of the campus into the Boston neighborhood of Allston. The plant will supply the Allston campus with hot and chilled water for heating and cooling, as well as cogenerated electricity.

### HARVARD IS PLANNING A NEW DISTRICT ENERGY PLANT AND DISTRIBUTION NETWORK IN BOSTON.

The Allston Landing North development presents challenges to installation of a traditional district energy system. The site began as reclaimed marshland on the Charles River. Years of use buried the marshland into a layer of organic soils. These soils act like a sponge, compressing when loaded and rebounding when unloaded. The groundwater table is also high due to close proximity to the river. An even bigger challenge facing the system design has been accommodating development that the Allston campus may undergo over the next 15 to 20 years, approaching the lifespan of some district energy distribution systems.

To mitigate these risks, RMF and Harvard E&U explored materials outside

those commonly used for district energy piping. HDPE is known as a material that's well-adapted to the underground environment. Recent advances have led to the creation of HDPE for raised temperature resistance (HDPE-RT), a version of the material capable of operating under temperatures of up to 180 F. The use of direct-buried ball and butterfly valves further reduces the risk of groundwater by eliminating underground valve structures. HDPE and HDPE-RT are flexible, corrosion-resistant materials and can withstand ground settlement and the high groundwater table. The longevity of the material will ensure it remains in peak operating condition when campus development is completed in the future.

In Cambridge, Harvard has been systematically extending its chilled-water distribution network to feed new parts of campus, including dorms located along the Charles River. Notable projects have included installation of 800 ft of 14-inch-diameter, direct-buried chilled-water lines through the Main Yard and the Widener-to-Cowperthwaite extension project, which installed 2,000 ft of 14-inch chilled-water lines to two of the dorms. About 1,100 ft were added to Harvard's existing walkable utility tunnel, and the remaining 900 ft were direct-buried. More dorms will receive cooling in the future with additional lines extending from the new 14-inch-diameter chilled-water mains.

## UNIVERSITY OF PENNSYLVANIA

A grid of city streets runs through the campus of the University of Pennsylvania

(Penn) in Philadelphia, Pa. Penn owns a direct-buried steam distribution system that runs primarily in those city streets and is leased to its district heating energy provider, Veolia Philadelphia. Veolia delivers high-pressure steam at 200 psig to two entry/metering locations in the Penn distribution system. The university is the single-largest customer of the Veolia plant.

On the coldest days of the year, as much as 400,000 lb/hr of steam is delivered to more than 180 buildings on the campus through more than 9 miles of steam piping. Because the distribution system has been in service for many years, there's a variety of piping and insulation types in operation; but the current standard for underground steam distribution on the campus is a direct-buried, pre-insulated, Class A, drainable, dryable, testable system. Penn recently added a new high-pressure steam connection to its Mod 7 Chilled Water Plant to provide an alternative source of energy for chilled-water generation. The steam used during cooling season is purchased at a summer rate and affords Penn the ability to manage peak electric demand. Two 5,000-ton steam turbine-driven chillers offset 6 MW of electric demand when in operation. The strategy to operate the "steamers" is particularly effective on PJM Interconnection's "red days," when electric demand savings results in substantial energy cost avoidance.

The plant addition was built to accommodate as many as four steam- or electric-driven 5,000-ton machines. A second district cooling plant known as Mod 6 uses all electric cooling and thermal storage for demand management. The two plants operate in conjunction with each other to feed 16 miles of underground ductile-iron chilled-water piping. Penn is considering plans for additional distribution of both steam and chilled water to enhance system reliability and operating efficiency.

## PRINCETON UNIVERSITY

At Princeton University in Princeton, N.J., there's a focus on reducing carbon dioxide emissions from the central plant and improving energy efficiency. Princeton's district thermal energy systems comprise over 13 miles of steam and chilled-water



Renewal of Harvard University distribution systems typically requires keeping multiple services active during construction.

pipings that run under the campus. In the past, efforts toward CO<sub>2</sub> reduction have included simple solutions, like upgrading insulation in buildings and distribution piping, as well as complex ones. These include economically dispatching the plant's eight chillers based on PJM independent system operator price signals, adding variable-frequency drives to the boiler feed pumps and adding an exhaust heat recovery system to the cogeneration system. Moving forward, Princeton's facilities team is looking for innovative solutions to improve its systems.



Courtesy RMF Engineering Inc.

Princeton has been successfully improving its chilled-water system through the installation of air separators.

One area for improvement is in the removal of trapped air from the chilled-water system. When chilled water is lost from the system through leaks or during maintenance activities, it is replaced with fresh city water. The addition of city water also introduces oxygen to the system, both as dissolved oxygen and entrained microbubbles of air. The oxygen creates an opportunity for bacteria to facilitate corrosion or rust and cause heat transfer loss. Princeton installed coalescing air and dirt separators with the hope of purging the entrained air. However, a method of measuring the air in the system and quantifying the results was needed to verify that the separators were effective. Princeton worked with chemists to develop test strips that change color to indicate the concentration of dissolved oxygen in the water. The university has been able to document reduced oxygen concentration since the air separators were installed. Now Princeton is working on the last piece of the puzzle: how the decreased oxygen content in the water impacts the efficiency of the whole chilled-water system.

**OPTIMIZING, IMPROVING, GROWING**

There are common characteristics among the Ivy League schools beyond

their reputations as academic leaders. They were early adopters of campus district energy, today promoting sustainable systems that demonstrate reliability and position the institutions as experts in best practices. All are implementing technologies to optimize operations and improve efficiency as their respective student bodies, and the district energy networks supporting them, continue to grow.



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engineers at RMF Engineering Inc. on the design of utility networks. They have worked together on projects for dozens of different campuses, including Brown University, Harvard University and Yale University. They attended and jointly presented on utility distribution best practices at IDEA's Annual Conference and Trade Show ("Inspiring the Next Generation") in Boston in 2015. They can be contacted at [Elizabeth.nolder@rmf.com](mailto:Elizabeth.nolder@rmf.com) and [Stephen.pollard@rmf.com](mailto:Stephen.pollard@rmf.com).

**OVERVIEW: IVY LEAGUE DISTRIBUTION NETWORKS**

CAMPUS	ENROLLMENT	DATE FOUNDED	HEATING MEDIUM	DISTRIBUTION PIPING		DISTRIBUTION TYPE	PIPING MATERIALS	
				HEATING	COOLING		HEATING	COOLING
Brown University	9,380	1764	High-temperature hot water (350 F)	14,400 linear ft	9,500 linear ft	Tunnel, direct-buried	Steel	Steel
Columbia University	22,920	1754	Steam (15/50/120 psi)	8 city blocks	5 city blocks	Tunnel, corridors	Steel	Steel
Cornell University	20,633	1865	Steam (75 psi)	60,000 linear ft	50,000 trench ft	Tunnel, direct-buried	Steam - steel Condensate - steel, fiberglass, HDPE-RT	Steel, ductile iron, transite, HDPE
Dartmouth College	6,141	1769	Steam (20 psi)	19,700 linear ft	5,000 linear ft	Tunnel, direct-buried, trench	Steel	HDPE
Harvard University	21,225	1636	Steam (150 psi) Low-temperature hot water (180 F)	60,000 linear ft	54,000 linear ft	Tunnel, direct-buried, trench	Steam - steel Low-temperature hot water - HDPE-RT	Steel, ductile iron, transite, HDPE
University of Pennsylvania	20,643	1746	Steam (200 psi)	9 miles	16 miles	Direct-buried	Steel	Ductile iron
Princeton University	7,592	1740	Steam (200 psi)	13 miles	13 miles	Tunnel	Steel	Steel

Source: RMF Engineering Inc.