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Monday-Friday, 8am – 5pm
Physical Facilities Department
Cole Service Building
101 South Fisher Drive
Oxford, OH 45056-3609
(513) 529-7000
(513) 529-1732 fax
www.pfd.miamioh.edu

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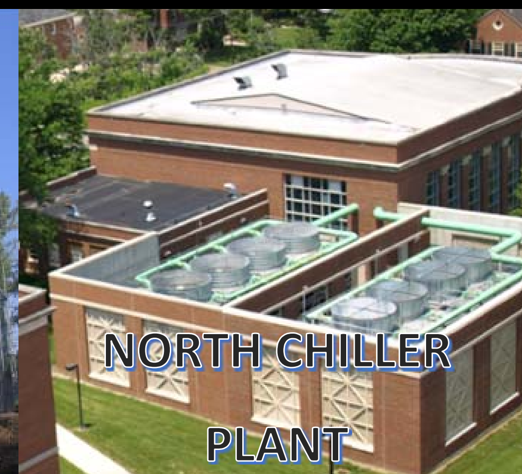
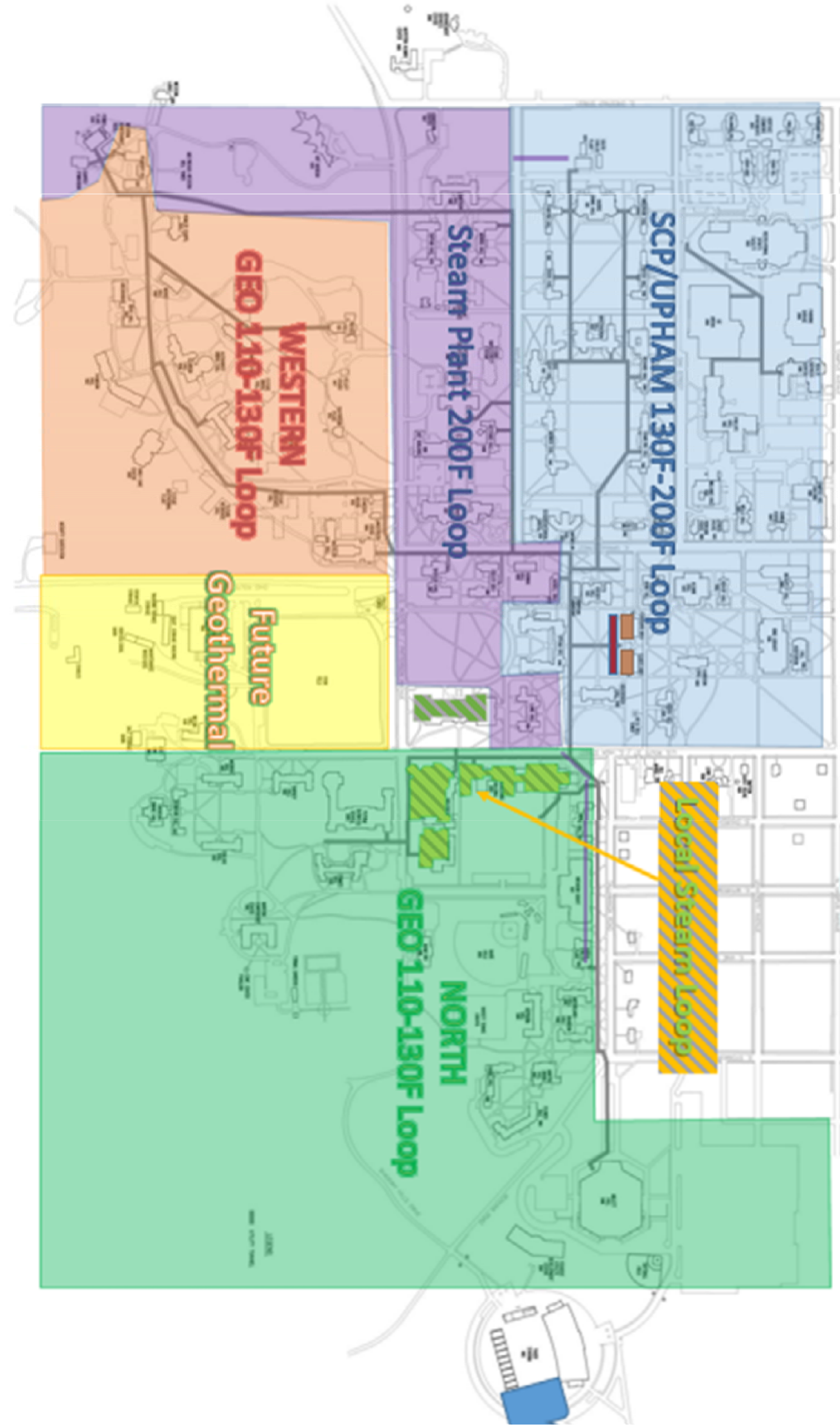
UTILITY SYSTEMS



Miami University

Utility Enterprise

Fact Sheet



Miami University Energy Plan 2026

thermal storage capabilities thanks to the installation of a 1.6 million gallon thermal energy storage tank. This tank will decrease electricity costs by allowing electricity to be bought and used to chill water at night when prices are lower due to lower demand. This water chilled at night can then be stored and discharged through the day as needed, reducing the electricity use during peak hours.

In 2022, Central quad will follow suit with conversion to heating hot water with a new distribution plant planned for the southeast basement of Upham Hall. Finally, in 2026, the steam plant will be converted to a 100 MMBTU HHW distribution plant with waste heat recovery and no longer operate on steam. This transition from steam to HHW will offer greater reliability and efficiency while being easier to control.

Notes

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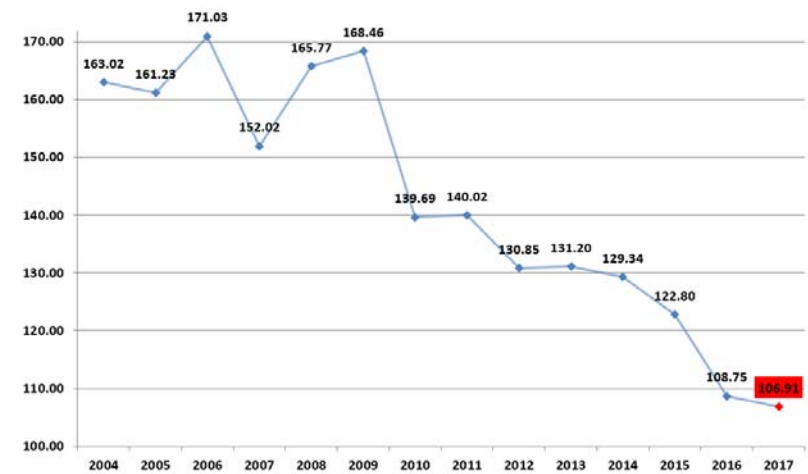
All Utility Systems are managed by the engineering group and maintenance staff, located in the Cole Service Building.

heating and cooling on 90% of the campus.

The objectives of the Utility Master Plan are to continue to reduce the amount of energy per square foot utilized by the university by making it more efficient and self-sufficient. In 2008, the energy usage was 165.77 KBTU/GSF. This number has already been reduced by 36.5% to 105.32 KBTU/GSF in 2017 and is projected to be at 75.59 KBTU/GSF by 2026. This change will also be accompanied by a 43% reduction in carbon footprint per square foot since 2008. Reducing the amount of natural gas and coal used and increasing the amount of energy produced by alternatives such as geothermal will not only reduce the energy footprint of the university but also make it less subject to the whims of the market.

Oxford KBTU/GSF PROGRESS CHART



(Note: Actual 2017 value was 105.32 KBTU/GSF, 1.59 below the goal of 106.91 KBTU/GSF.)

In order to meet Miami's sustainability commitments and goals by 2025, improvements and changes are continuously being made to the utility systems. Plans currently underway as part of the Utility Master Plan include expanding the Western Geothermal Plant's service to Bachelor Hall by 2020 and to Thomson, Boyd, McKee, and Peabody Halls as well as Kumler Chapel by 2025. A conversion of the North Chiller Plant to Geothermal is also planned, with a well field that will likely be placed in the current parking lot of Millett Hall. This geothermal plant will service many of the buildings on the North side of campus by 2025.

In addition to the expansion of Miami's geothermal plants, there are also plans to convert all steam resources on campus to heating hot water. To do this, the south chiller plant is currently being converted to HHW. It will soon also have

Utility Master Plan

For most of its history, Miami's Oxford campus has been heated by burning coal, a process in which much energy is lost and a large carbon footprint is generated. Those days, however, are drawing to a close. With the signing of Miami's Sustainability Commitments and Goals in 2011, President Hodge assured that we will stop burning coal by 2025. This pledge was the force behind the heating and cooling master plan designed by the Physical Facilities Department. The campus Utility Master Plan is to have 40% of the campus' gross square footage heated and cooled by geothermal by 2025. By 2026, the campus plans to be moved completely off steam to heating hot water and to be utilizing simultaneous

STEAM PLANT HISTORY

The original heating plant, built in 1907, was far removed from the campus it serviced to the west. Located just off of Spring Street, the heating plant was 4,490 square feet and cost $31,200.00 to build. The Power Plant was remodeled and expanded several times during the twenties and thirties. Also during that time, buildings in the surrounding landscape began to appear. Gaskill Hall (then one-third its current size and known as the Shop Building) was built just north of the Power Plant in 1925. In 1949, both buildings underwent a large construction project in which they were expanded and conjoined. The Power Plant itself expanded to 7,500 square feet, but eventually became too small to meet the needs of the growing campus. It was demolished in 1981, and the location was turned into a parking lot to service Gaskill and Rowan Halls.

Furnace Room, Central Heating Plant 1907.

Steam Plant as part of Gaskill Hall (left) in 1964, and its demolition by wrecking ball in 1981 (right).

"When built in 1907, the Miami steam and power plant on Spring Street was comfortably distant from the Slant Walk campus dominated by Old Main Hall. Seventy years later its tall smokestack marked the very heart of the Miami campus."

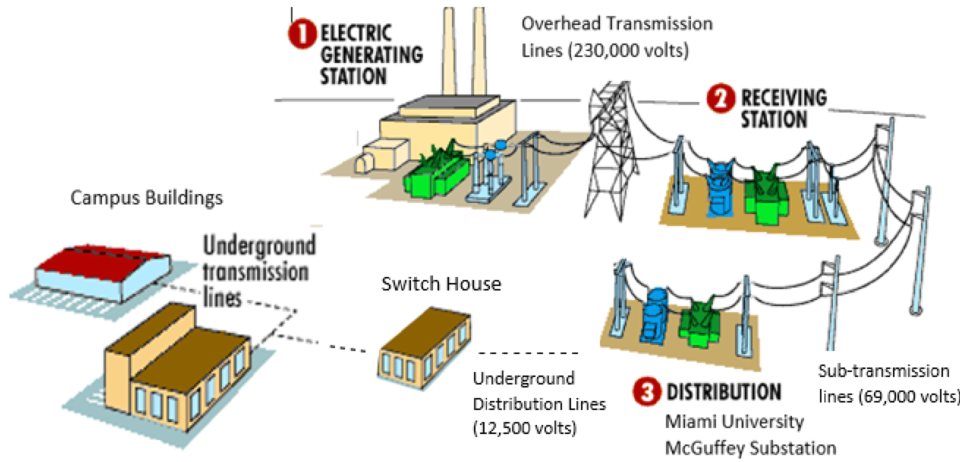
--From The Miami Years 1809-1984 by Walter Havighurst

THE STEAM PLANT

The current operating steam plant, originally built in 1979, added onto in 1995 with the addition of boiler #4, and again in 2004 with the installation of the two Wärtsilä natural gas engine Generators covers 37,177 square feet and is five stories tall. It resides on the southeastern most point of Western Campus, right behind Peabody Hall. This steam plant contains four boilers, which supply the heating needs for the University. The boilers are operated and maintained around the clock by a rotating staff of 16 employees. The plant has flexibility of fuel choices including coal, natural gas and a limited ability for fuel oil. In the past, the steam plant used to run predominately on coal. However, since February of 2016 the steam plant has run 100% on natural gas due to favorable pricing. In the event that natural gas service is temporarily lost or prices skyrocket, 5,000 tons of coal are still kept on hand to keep the plant running. It should be noted, however, that by 2025 the campus will be entirely coal free in compliance with the Miami's sustainability commitments.

The steam plant produces steam year round for heating buildings, cooking in the dining halls, driving steam turbines that turn fans and pumps, humidification, processes in the chiller plants, and heating domestic water.

208/120 volt systems.



The Peaking Engine Facility is composed of two 5,732 kilowatt (kW) Wärtsilä engine generators. They produce a voltage of 12,470 volts, and have a total combined power output of 11,464 kW. The engines are 18 cylinder, reciprocating at 720RPM and produce 7,919 hp each. They run off of natural gas at a pressure of 80 pounds per square-inch (psi), and are considered to be "lean burn, low NOx (Nitrogen Oxide) emission". Each engine-generator weighs 106 tons and sets on an isolated concrete foundation that is 4 ft. thick. Pollution control equipment consists of a catalytic oxidizer that is designed to reduce Carbon Monoxide (CO) emissions by 95%. The engines run primarily in the middle of the day during the summer season to reduce the campus peak load contribution on the transmission grid.

Peaking Engine Details

Generator Number	Manufacturer	Fuel Type	Natural Gas Pressure (psi)	Generator Voltage (V)	Power Output (kW)	Year Installed
1	*Wärtsilä*	*Natural Gas*	*80*	*12,470*	*5,732*	*2005*
2	*Wärtsilä*	*Natural Gas*	*80*	*12,470*	*5,732*	*2005*
Total Output	-	-	-	-	11,464	-

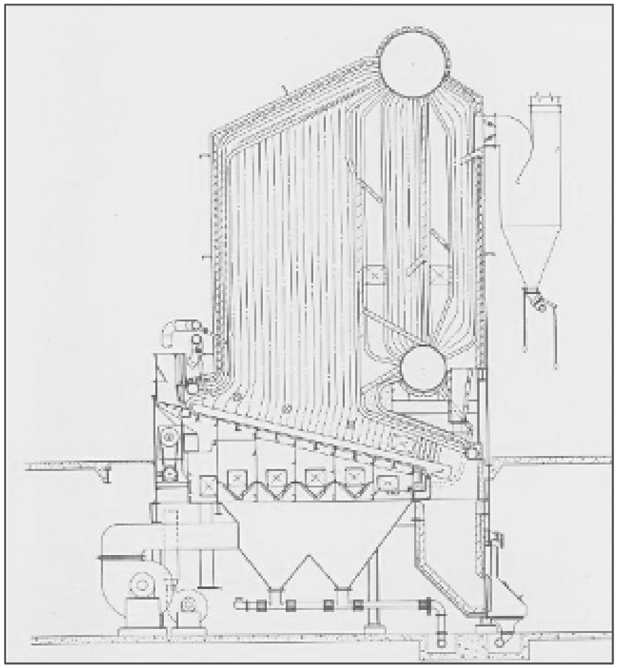
The Peaking Engines were manufactured by the Finish Company Wärtsilä. They were built in Finland and shipped to the United States by boat.

BOILERS

The steam plant consists of seven boilers. Three of the boilers are stoker coal boilers installed in 1979 that have been retrofitted with gas burners. All three coal boilers have the capability of burning either coal or natural gas, with the exception of one that can burn fuel oil as well. A fourth boiler installed in 1995 is a package boiler that strictly burns natural gas or fuel oil. The boilers are capable of producing 80,000 pounds of steam per hour, except for the package natural gas boiler, which can produce 100,000 pounds of steam per hour. By April of 2019, three additional 12.5MMBTU steam boilers will be installed in the Western Maintenance Building. Each of these three boilers has the ability to output 9,918lb/hr of steam and are fueled using natural gas.

Boiler Details

Boiler Number	Manufacturer	Fuel Type	Boiler Capacity (lb./hr)	Steam Pressure (psi)	Steam Temperature (°F)	Year Installed
1	*Keeler*	*Coal, Natural Gas, or Fuel Oil*	*80,000*	*115*	*348*	*1979*
2	*Keeler*	*Coal or Natural Gas*	*80,000*	*115*	*348*	*1979*
3	*Keller*	*Coal or Natural Gas*	*80,000*	*115*	*348*	*1979*
4	*Nebraska*	*Natural Gas or Fuel Oil*	*100,000*	*115*	*348*	*1995*
5	*Unilux*	*Natural Gas*	*9,918*	*115*	*348*	*2018*
6	*Unilux*	*Natural Gas*	*9,918*	*115*	*348*	*2018*
7	*Unilux*	*Natural Gas*	*9,918*	*115*	*348*	*2018*
Total	-	-	369,754	-	-	-

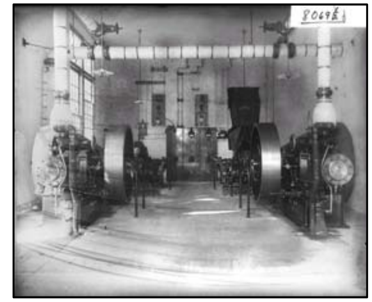


A cross section of the stoker coal boilers installed in the late 1970's. The boiler is over three stories tall.

The control room where all boilers are monitored.

PEAKING ENGINES

As part of the original Steam Plant in 1907, there were engine-generators in what was known as the Dynamo Room. This supplied the electricity for the campus, which at the time, only consisted of 10 buildings.



The Dynamo Room, Central Heating Plant, 1907.

Until recently, all of the electricity that the campus consumed was produced by and bought from the regional supplier, Duke Energy. In 2005, an addition to the Steam Plant was made to house two new engine-generators. These engine-generators have been termed "peaking engines," due to their function, which is to operate when the demand for electric power is at its peak or if a regional power outage interrupts power to the campus. Functionally, the engine-generators can supply enough power to keep the campus operational during a power outage, although some campus services would need to be suspended. The peaking engines have five operating modes, Peak Shaving, Peak Load Contribution, Emergency Demand Response, Generate for Profit and an Island mode. The University buys power by the hour at Day-Ahead pricing and the engine-generators are used in the various modes to control the cost of electric. If Utility power is lost the commitment made to the University is that these peaking engines will restore power within 2 hours to the Oxford Campus.

Bank of nine cylinders of the 18 cylinder engine.

Steam Plant building addition that houses the Peaking Engines.

HIGH VOLTAGE ELECTRICAL SUBSTATION

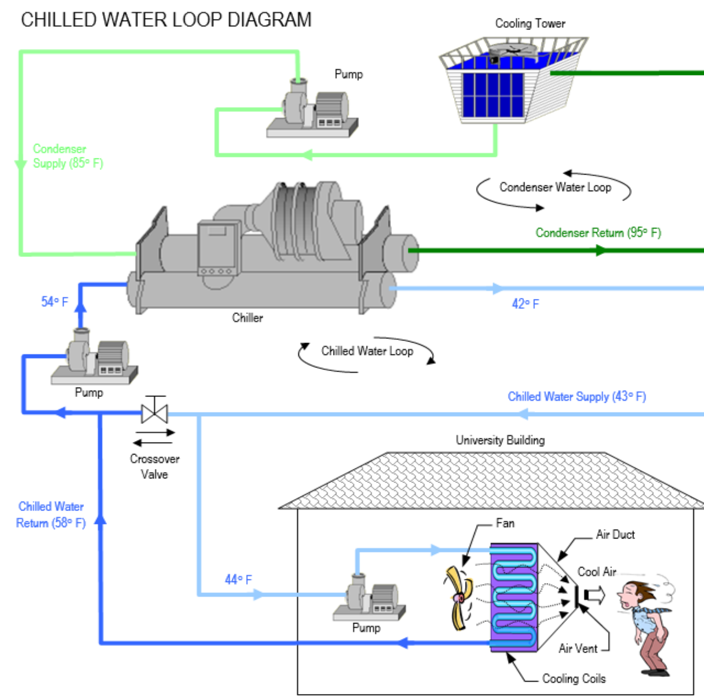
The electrical utility which services Miami University is Duke Energy. The power comes to campus through the Duke 69,000 volt transmission lines and is delivered to Miami's own McGuffey Substation where it is stepped down to 12,470 volts. McGuffey Substation came on line in July 2004 and replaced the old McGuffey Substation which was built in the 1956 and stepped down to 4,160 volts. Owning its own substation allows the University to purchase electricity at lower transmission rates and upgrade the station as needed. The station contains two identical 20 MVA transformers either of which is capable of carrying the entire University load. There is room to add a third 20 MVA transformer in the event load on campus increases. The station also includes power factor correction capacitor banks, voltage regulators, and Switch House #7 for regulated electrical distribution to the campus.

McGuffey Substation is located off of Rt. 73 by the Police Services Center.

CHILLERS

The campus consists of centralized chilled water plants that serve the cooling needs of seventy-nine campus buildings which grows every year. In each plant, pumps circulate water through the chillers where the water is cooled by a refrigerant. The refrigerant cools the water by taking on heat from the water. The chilled water is then sent out to campus while the refrigerant recirculates within the chiller. While the chilled water passes through the cooling coils of the buildings' air-handling units, it picks up heat, cools the air, and is sent back to the chillers to be re-cooled. In the chilled water loop, the water leaves the chiller plant at 43° F and returns at a temperature of 58° F.

Since heat is constantly being removed from the chilled water to the refrigerant, the refrigerant needs to get rid of the excess heat. A separate loop of water called *condenser water* is used to take away the heat. The condenser water circulates through the chillers, removes heat from the refrigerant, and then is sent to the cooling towers. The cooling towers reduce the temperature of the condenser water through an evaporation process and then pump it back into the chillers to complete the loop.



South Chiller Plant

The South Chiller Plant is the original chilled water plant, which was built in 1969. An addition was put on the plant in 1997 to allow space for two more chillers. The South Chiller Plant is located on the south end of campus across from Harris Dining Hall. The plant currently houses a total of four chillers and in 2018 will have three Heat Pump Chillers and three steam to heating hot water heat exchangers installed. The three heat pump chillers have simultaneous heating and cooling capabilities meaning they can get useful work out of both sides of the refrigeration cycle. The heat pump chillers can produce chilled water on the evaporator side and heating hot water on the condenser side of the system allowing them to contribute to the required heating and cooling loads at the same time. Utilizing both sides of the system simultaneously results in an increase in its efficiency.

The South Chiller Plant.

Centrifugal Chiller in South Chiller Plant.

MECHANICAL DISTRIBUTION SYSTEMS

STEAM

Steam at a pressure of 115 pounds per square inch is routed through campus by a network of underground tunnels and direct buried pipes. There are currently 5.4 miles of utility tunnels that run under the sidewalks of the campus. In addition, there are about two miles of direct buried steam pipe running just a few feet underground throughout campus.

Heating Hot Water

Steps are currently being made to phase out the use of steam on campus completely in favor of heating hot water by 2026. The transition to HHW will offer advantages in efficiency and reliability over steam while being safer and easier to control due to lower operating temperatures between 110° F and 130° F. As conversions are made, existing steam lines will be reused for HHW while condensate lines will be replaced with appropriately sized HHW line.

CHILLED WATER

Chilled water is distributed to campus at 44° F and returns at 58° F. The chilled water lines share the tunnel space with the steam lines or heating hot water. There are also several miles of direct buried chilled water pipes sprawling about the campus grounds.

There are 5.4 miles of underground tunnels containing steam (lower right), chilled water (lower left), and communication lines (upper right) run throughout campus.

Western Geothermal Pant Chiller Details

Chiller Number	Manufacturer	Chiller Type	Refrigerant	Chiller Capacity (tons)	Heating Capacity (MBH)	Year Installed
1	*Chillit*	*Variable Speed Screw*	*R-134A*	*300*	*3,970*	*2017*
2	*Chillit*	*Electrical Screw*	*R-134A*	*250*	*1,952*	*2013*
3	*Chillit*	*Electrical Screw*	*R-134A*	*250*	*1,952*	*2013*
4	*Chillit*	*Electrical Screw*	*R-134A*	*250*	*1,952*	*2013*
5	*Chillit*	*Variable Speed Screw*	*R-134A*	*300*	*3,970*	*2017*
6	*Chillit*	*Variable Speed Screw*	*R-134A*	*300*	*3,970*	*2017*
7	*York*	*Variable Speed Magnetic Bearing Centrifugal*	*R-134A*	*700*	*N/A*	*2017*
Total Capacity	-	-	-	2,350	17,766	-

Western Geothermal Plant Boiler Details

Boiler Number	Manufacturer	Fuel Type	Boiler Output Capacity (MBH)	Entering Water Temperature (°F)	Leaving Water Temperature (°F)	Year Installed
1	*Fulton*	*Natural Gas*	*3,876*	*120*	*140*	*2013*
2	*Fulton*	*Natural Gas*	*3,876*	*120*	*140*	*2013*
Total Capacity	-	-	7,752	-	-	-

South Chiller Plant Details

Chiller Number	Manufacturer	Chiller Type	Refrigerant	Chiller Capacity (tons)	Heating Capacity (MBH)	Year Installed
1	*Trane*	*Electrical Centrifugal*	*R-123*	*1,480*	*N/A*	*2003*
2R	*Trane*	*Electrical Centrifugal*	*R-123*	*1,500*	*N/A*	*2013*
4	*York*	*Electrical Centrifugal VFD*	*R-134A*	*1,730*	*N/A*	*2012*
5	*York*	*Electrical Centrifugal VFD*	*R-134A*	*1,375*	*N/A*	*2006*
6	*Chillit*	*Electrical Screw*	*R-134A*	*250*	*4,019*	*2018*
7	*Trane*	*Electrical Screw*	*R-134A*	*200*	*2,367*	*2018*
8	*Trane*	*Electrical Screw*	*R-134A*	*200*	*2,367*	*2018*
Total	-	-	-	6,735	8,753	-

South Chiller Plant Heat Exchanger Details

Heat Exchanger Number	Manufacturer	Service	Capacity (MBH)	Year Installed
1	*Bell and Gossett*	*Steam/HW*	*16,500*	*2018*
2	*Bell and Gossett*	*Steam/HW*	*33,000*	*2018*
3	*Bell and Gossett*	*Steam/HW*	*33,000*	*2018*
Total	-	-	82,500	-

North Chiller Plant

The North Chiller Plant is located on the north side of campus on Tallawanda Road next to Withrow Court. The North Chiller Plant was formally known as Billings Hall. Billings Hall was built in 1952 as a natatorium, and in 2000, was converted for use as a chiller plant. The plant currently houses four chillers and two heat pump chillers. The heat pump chillers allow for simultaneous heating and cooling by producing chilled water on the evaporator side while at the same time producing heating hot water on the condenser side of the system. By utilizing both sides of the refrigeration cycle, their useful work output is increased, which increases their coefficient of performance.

The North Chiller Plant (Billings Hall).

Billings Hall Natatorium (left, 1952) was remodeled for use as a chiller plant in 2000 (right).

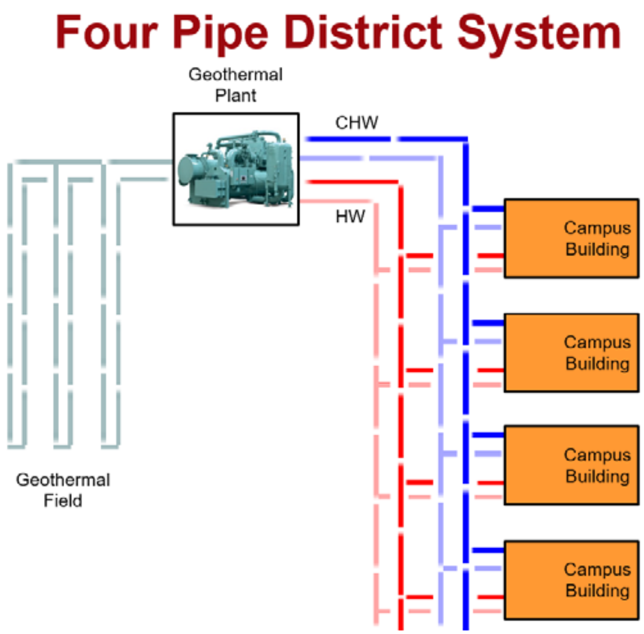
The well field for the Western Geothermal Energy Plant currently contains 690 wells drilled 600 feet deep 20 feet on center in the well field. Each well has 2 - 1 ¼” High Density Polyethylene (HDPE) pipes connected at the bottom by a HDPE U-bend. Additional coiled tubing is also located at the bottom of the ponds and provides the heat exchange capacity of 30 geothermal wells by taking advantage of the efficient water to water heat exchange. All combined, there is a total of over 150 miles of HDPE piping installed.

The Western Geothermal Plant Well Field and Pond.

York Variable speed Magnetic Bearing Chiller (green) and Chillit Heat Pump Chillers (red).

Pumps in basement of Western Geothermal Plant.

Geothermal Heat Pumps are a highly efficient method of heating and cooling that uses the natural energy of the earth. Heat pump chillers operate between 3 closed water loops. One loop exchanges heat with the constant earth temperature (55°F) through vertical well pipes. During the summer, when the temperature of the earth is relatively cool compared to the air temperature, the system takes the heat from inside, and stores it in the ground, cooling the building. Conversely, when the air temperature in the winter becomes relatively cold compared to the ground, this heat is then removed from the ground and added back to the system to heat the buildings. The other loops move the heated and cooled water to the buildings being serviced.



The system in place also allows for simultaneous heating and cooling. On days when heating and cooling loads are balanced, this allows for useful work out of both sides of the refrigerant cycle to be utilized by producing chilled water on the evaporator side and heating hot water on the condenser side of the system. These days are common during the spring and the fall and require no well field water to be pumped, resulting in a period of greatest efficiency with a coefficient of performance in the range of 6-10.

North Chiller Plant Details

Chiller Number	Manufacturer	Chiller Type	Refrigerant	Chiller Capacity (tons)	Heating Capacity (MBH)	Year Installed
1	*Chillit*	*Electrical Screw*	*R-134A*	*300*	*3,500*	*2015*
1A	*Chillit*	*Electrical Screw*	*R-134A*	*300*	*3,500*	*2015*
2	*Trane*	*Electrical Centrifugal*	*R-123*	*1,000*	*N/A*	*2000*
3	*Trane*	*Electrical Centrifugal*	*R-123*	*1,000*	*N/A*	*2002*
4	*Trane*	*Electrical Centrifugal VFD*	*R-123*	*1,000*	*N/A*	*2005*
5	*York*	*Electrical Centrifugal*	*R-134A*	*2,200*	*N/A*	*2007*
Total Capacity	-	-	-	5,800	7,000	-

North Chiller Plant Shell & Tube Heat Exchanger Details

Heat Exchanger Number	Manufacturer	Service	Capacity (MBH)	Flow Rate (GPM)	Ent. Water Temp. (°F)	Leaving Water Temp. (°F)	Install Year
1	*Armstrong*	*Primary Hot Water*	*14,700*	*1630*	*122*	*140*	*2015*
2	*Armstrong*	*Primary Hot Water*	*14,700*	*1630*	*122*	*140*	*2015*
Total	-	-	29,400				-

COOLING TOWERS

The heat that is removed from the refrigerant in the chiller ends up in the condenser water. At the cooling tower, fans pull air across the warm condenser water, cooling the water through evaporation. The fans then discharge warm, damp air into the atmosphere.

SOUTH CHILLER PLANT COOLING TOWER

The cooling tower at the South Chiller Plant was installed in 1995. It is a field-erected, fiberglass, Marley counter flow tower with four cells. The tower can provide water to the chiller plant at a rate of 18,000 gallons per minute. The water comes to the tower at 95° F and is cooled by the tower fans. After it is cooled, the water leaves the tower at 85° F.

South Chiller Plant Cooling Tower cools water from 95°F to 85°F.

NORTH CHILLER PLANT COOLING TOWER

The North Chiller Plant's cooling towers are stainless steel, crossflow Baltimore Air Coil. Three of the four cooling tower cells for the West Towers were installed in 2000, while the fourth was installed in 2002. The four cooling tower cells for the East cooling tower were installed in 2007. Each of the eight cooling cells provides water to the chillers at a rate of 3,000 gallons per minute.

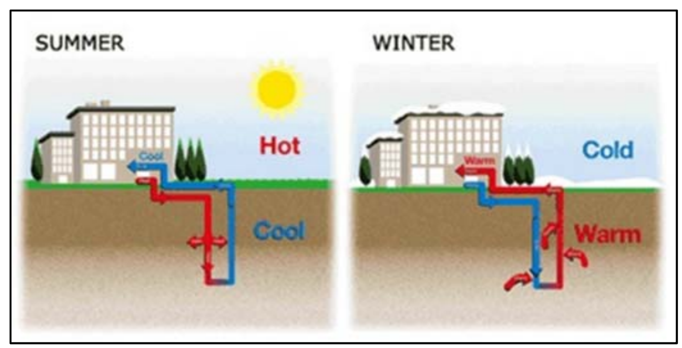
The North Chiller Plant.

Geothermal

Geothermal heat pumps have been operational on Miami's campus since 2011 in the school's oldest residence halls (Stoddard and Elliott). The Western Geothermal Plant was built in 2014 and expanded in 2017. Its 690 wells provide heating and cooling to 10 buildings with over ½ million sq. ft. including Western Dining, Havinghurst, Beechwood, Clawson, CDC, Hillcrest, Hoyt, Presser, and Stonebridge Halls, along with the Geothermal plant itself.

Geothermal systems are 400% more energy efficient in heating mode than conventional systems and can have a Coefficient of Performance (COP) as high as 20 in cooling mode. This means that for every Btu of energy put into the system, 20 Btu's of useful work output can be obtained. Miami's carbon footprint will be reduced not only by the efficiencies of the mechanical system, lighting design and thermal envelope, but also by mandated carbon reductions in purchased electricity used to "fuel" the system.

The Western Geothermal Plant.



Ohio's climate has seasons that allow heat to be put into the well fields in the summer and heat to be pulled out in the winter.