EVALUATING A COMMUNITY GROUND SOURCE HEAT PUMP SYSTEM AT COLORADO MESA UNIVERSITY

COLORADO MESA UNIVERSITY

SUMMARY

Colorado Mesa University (CMU) is in Grand Junction, Colorado, serves approximately 11,000 students, and spans 141 acres. This campus consists of 37 buildings including admissions, dormitories, athletics, academics, and student centers.

Beginning in 2008, CMU began deploying a geothermal loop system to reduce the need for conventional cooling and natural gas heating and reduce overall campus water use. The system was designed to utilize water-source heat pumps to serve interior spaces with a closed geothermal loop that utilizes the thermal stability of the ground as a heat sink. The networked loop consists of five loop fields with 471 bore holes drilled to depths ranging from 375 to 600 feet. These loop fields can be utilized as a thermal energy source to mitigate on-peak demand by filling the bore holes with loop water during off-peak periods and discharging the bore holes during on-peak periods. In 2023 Xcel Energy commissioned Michael's Energy to analyze the performance of CMU's geothermal system.

Today, this system serves 1.2 million sq. ft. of building area across 16 facilities with a diversity of cooling and heating needs. The system is comprised of (7) 50-HP central loop pumps, 91 individual building pumps, 5 conventional cooling towers, 2 hydronic boilers, 21 water-to-water heat pumps, 962 water-to-air heat pumps, and a

sophisticated control system. This equipment is sized to meet a design cooling load of 3,113 tons and a design heating load of 2,728 tons.

It is important to note that the geothermal system wasn't designed to meet 100% of the load, 100% of the time. CMU strategically interconnected conventional assets that already existed as buildings were added to the network. These assets are intended to increase overall system efficiency. These sources include water-to-water heat pumps for domestic hot water needs and pool preheating, a heat exchanger that enables the facilities team to reject heat via irrigation water, and five conventional cooling towers to reduce loop temperatures. In the winter months when loop temperatures decline to less than 57°F, the hydronic boilers inject heat into the loop. There were no instances of boiler operation throughout the 2022/2023 heating season. Additional gas usage can be attributed to dormitory domestic hot water (DHW) heating because the water-to-water heat pumps aren't able to raise the temperature of the water high enough to meet designed supply temperatures (140 F). However, newer heat pump technology can potentially solve this problem.

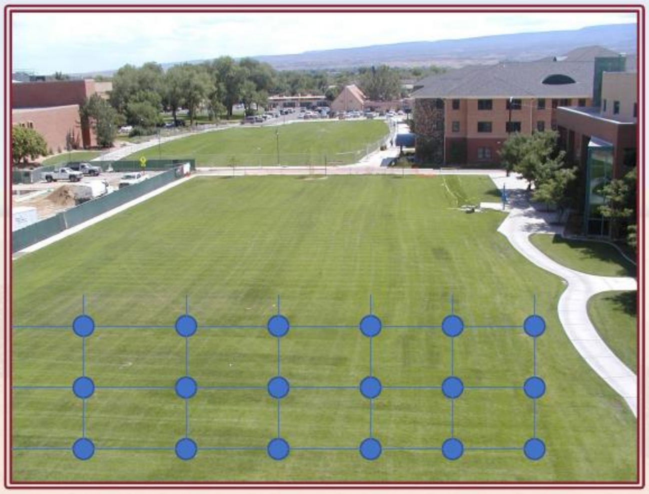
A key advantage of a network geothermal system is the system's ability to share heating and cooling loads. This load sharing can happen from room to room, floor to floor, and building to building. A water-to-air heat pump in heating mode removes heat from the building loop, cooling down the loop water. Another heat pump on the same loop in cooling mode expends less energy supplying space cooling than it would have otherwise. The same is true in reverse, where heat pumps in cooling mode reject excess heat into the building loop to be consumed by heat pumps in heating mode.

When comparing historical central campus loop temperatures versus outside air temperatures, it is apparent that this load sharing occurs when outdoor air temperatures are between 25°F and 55°F. This wide load-sharing operating band greatly increases the overall efficiency of the system as the need for heat pump compressor operation is greatly reduced.

When compared to a conventional cooling and heating system consisting of water-cooled chillers and natural gas hot water boilers, this system has a demand reduction of ~650 kW (13%), an energy savings of ~1.3 GWh (10%), a natural gas savings of ~58,000 Dth (55%), and a water savings of ~10 million gallons, annually. Water savings were provided by the Grey Edge Group and were not part of this analysis. Seasonal coefficient of performance (COP) values are displayed in Table 1, below. Note that a typical boiler operates with a COP of 0.8, a typical chilled water system at 3.4, and electric resistance heating at 1.0. A larger number indicates increased system efficiency and lower energy consumption per unit heating or cooling.

Table 1 CMU networked geothermal efficiency vs a standard system

	Networked Geo COP	Conventional COP
Spring	7.0	1.9
Summer	3.6	3.4
Fall	5.8	2.0
Winter	8.9	1.2
Overall	**5.7**	**1.9**



Drill field east and south of Dominguez Hall

Pipes connecting bore holes

8" dia. Pipes between Central Loop And H.H

Top: The drill field in front of Grand Mesa Hall

Right: A drill rig

18” diameter HDPE Central Loop

METHODOLOGY

Due to the large number of input assets that make up the Colorado Mesa University (CMU) Geothermal network, monitoring the system in empirical fashion would have proven cost and time prohibitive. Statistical regression analysis was used to discern power requirements and equipment performance in lieu of establishing automation system trend logs or taking onsite power measurements. The results are not an investment-grade analysis but provide a realistic understanding of overall and seasonal system performance, when compared to conventional cooling and heating equipment.

DEFINITIONS

HX	Heat exchanger
AHU	Air handling unit
CFM	Cubic feet per minute
HP	Horsepower
EER	Energy Efficiency Ratio
WSHP	Water source heat pump
kW	Kilowatt
GPM	Gallons per minute
COP	Coefficient of Performance

DATA GATHERING

- Historical hourly data from April 2022 to April 2023 was collected for weather, central loop temperature, and available loop assets.
- Loop assets include central loop water pumps, building pumps, bore field pumps, cooling towers, cooling tower pumps, irrigation heat exchanger (HX) pumps, water-to-water heat pumps, and water-to-air heat pumps.

- Additional data was collected on known asset values and building settings, such as heating capacity, cooling capacity, heating design temperature, and cooling design temperature.

ASSUMPTIONS

- Conventional cooling and heating equipment power and efficiencies were estimated based on ASHRAE 90.1 documentation.
- Assumptions include chillers (0.61 kW/ton), primary pumps (0.018 kW/ton), secondary pumps (0.026 kW/ton), cooling towers (0.059 kW/ton), condenser pumps (0.057 kW/ton), and AHU fan kW (812 kW).
- AHU fan kW was derived using the following methodology and conversion factors: 400 CFM/ton, 0.75 HP/1000 CFM, Supply Fan HP (0.3*Max loop load), Return Fan HP (0.12*Max Loop Load).
- The water source heat pump (WSHP) efficiency disaggregation was built based on conversations with campus staff and is as follows: 60% - 13 Energy Efficiency Ratio (EER), 10% - 13.5 EER, 10% - 15 EER, 10% - 16 EER, 10% - 18 EER.

EMPIRICAL DATA

- Empirical data, consisting of average loop temperature and outside air temperature, was utilized to determine the load sharing temperature range. This is the temperate range where different buildings connected to the central loop are sharing energy between themselves, and little additional source and sink energy is required from the bore fields or conventional equipment.
- Data revealed a load sharing range when outside air temperatures are between 25°F and 55°F.

CALCULATION METHODOLOGY

- Loop cooling loads were derived from the relationship between outside air temperature, system balance point, and the design cooling temperature.
- Loop heating loads were derived from the relationship between outside air temperature, system balance point, and the design heating temperature.

- Input asset power (kW) was calculated using regression analysis for the equipment that didn’t have historical trend data configured. These assets are outlined below.
    - Heat pump cooling kW was calculated through regression analysis. This regression was built based on a load curve from a WSHP.
    - Heat pump heating coefficient of performance (COP) was calculated through regression analysis. This regression was built based on a load curve from a WSHP.
    - Cooling tower kW was determined through use of a second order polynomial regression, to model fan power between 85°F and the cooling design temperature.
    - Loop and building pump kW were determined through use of a third order polynomial regression, to model pump power based on a dual temperature loop load profile, assumed flowrate (GPM), assumed pump head, and pump horsepower.
- COP was calculated as a function of total loop load and input power.
- Total input power was determined by summing all input assets.
- Seasonal and overall system COP was evaluated for the geothermal system compared to a conventional water-cooled chiller system.