14.21 CASE STUDY 1—ACTIVE CLIMATE CONTROL SYSTEMS

Ball State University Ground Source Heat Pump System, Muncie, Indiana

PROJECT BASICS

- Location: Muncie, Indiana, USA
- Latitude: 40.21°N; longitude: 85.41°W; elevation: 967 ft (295 m)
- Heating degree days: 5642 base 65°F (3176 base 18.5°C); cooling degree days: 3666 base 50°F (2038 base 10°C) at Muncie airport; annual precipitation 40.1 in. (1019 mm)
- 731-acre university campus, 47 buildings
- Building area: 5.5 million ft^2 (510,967 m^2) of conditioned space
- Completed Spring 2015
- Client: Ball State University
- Design team: MEP Associates, Ball State Facilities Planning and Management

Background Ball State University's ground source heat pump system is the largest of its type in the United States. The $82.9 million, multi-phase project allowed the campus to replace aging heating and cooling infrastructure, reduce carbon emissions, save on annual energy costs, and meet the Presidents' Climate Commitment sustainability goals. The university saw the project as a way to advance its sustainability agenda by showing other institutions ways of overcoming barriers to ground source heat pump implementation. As an educational institution, Ball State also saw the project as a way to engage faculty, students, and staff in greening-the-campus efforts.

Context Ball State University began evaluating options for replacing its coal- and natural-gas-fired district energy system boilers in 2004. The four boilers, installed between 1941 and

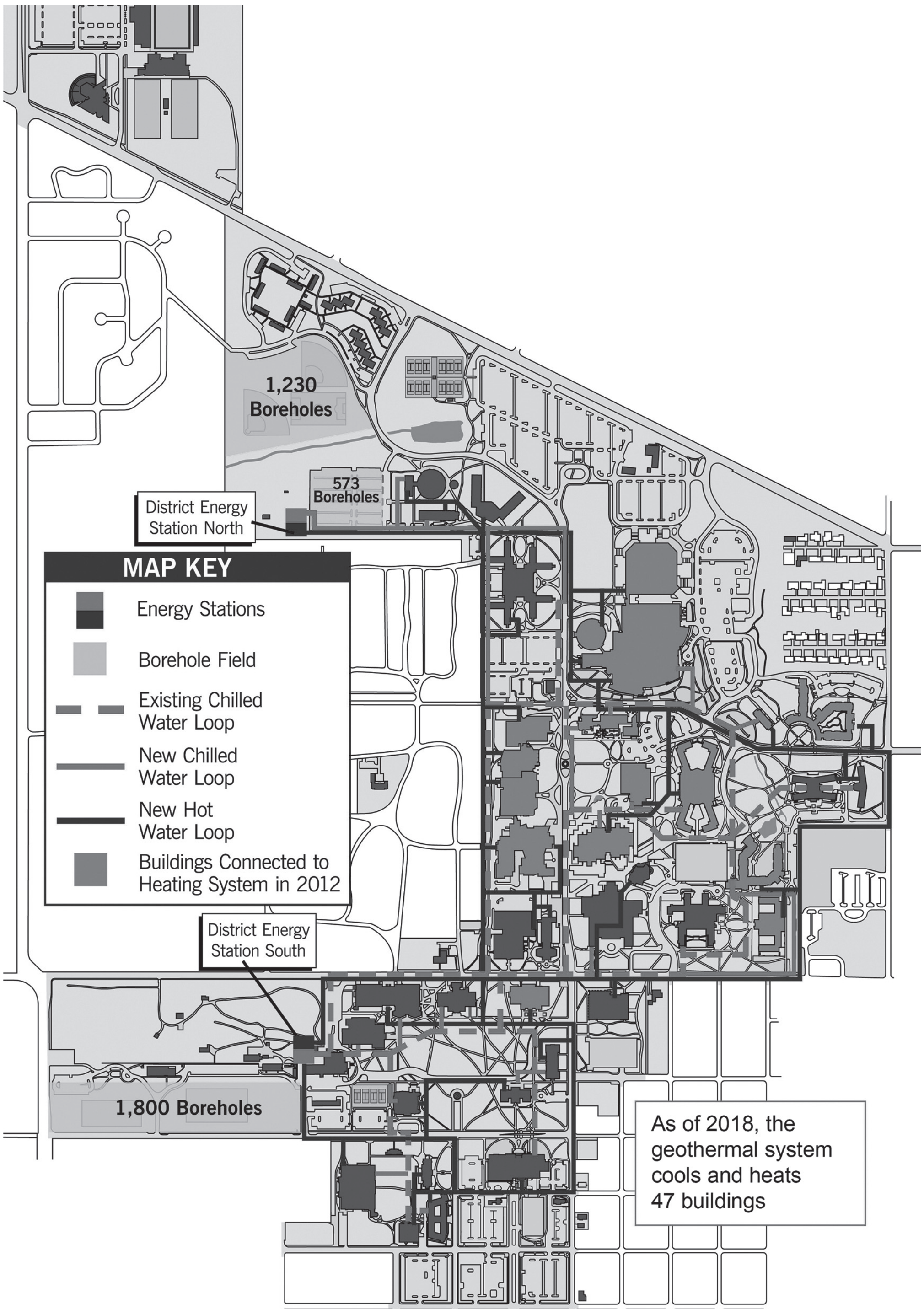

Fig. 14.135 *Campus map illustrating the two construction phases, connected buildings, district energy stations, and well fields. (© Ball State University; Reproduced and reprinted under license from Ball State University. All rights reserved.)*

1955, were at the end of their rated lifetimes and would soon require additional pollution controls for emissions compliance. Dissatisfied with the idea of replacing the equipment with new fossil-fuel-burning equipment, the university began looking at cost-effective ways to heat and cool the campus while achieving carbon neutrality goals set by the administration. Intrigued by US Department of Energy research on ground source heat pump systems, facilities planners began evaluating the viability of using the technology for the university's district heating and cooling needs. District heating/cooling systems are fairly common, as are ground source heat pump installations. The combination of these technologies is not so common. Thus, Ball State took an informed risk when it constructed the nation's largest ground source district heating and cooling system.

Design Intent Ball State's GSHP district heating and cooling system solved practical infrastructure replacement needs and is a direct reflection of the university's commitment to carbon emissions reductions, sustainability, and reduced environmental impact. The design intent included:

- Cutting carbon emissions by half (by 80,000 tons [72,575,000 kg] CO_2 per year)
- Servicing the same campus buildings as before with the new system
- Using the ground surface above the wells for parking and athletics
- Reducing campus operations/energy costs
- Improving regional air quality by eliminating the release of particulate matter from coal boilers
- Minimizing system construction impacts to ongoing campus operations
- Minimizing the area of ground required for the well fields
- Minimizing environmental impact to underground aquifers

Construction

- The project was completed in two phases. Phase 1 began in 2009 and was completed in 2012. This phase included the construction of two well fields, a north energy station, and connecting campus buildings on the north side of campus to the new system. Phase 2 began in 2011 and was completed in 2015. The coal boilers were disconnected in 2014. The total project cost was \$83 million with \$5 million coming from a U.S. Department of Energy grant. Several campus buildings were not connected to the system because they are slated for demolition, and their replacements will be connected to the system at a later date.

Key Design Features

The Ball State GSHP system has four main components: boreholes, energy stations, hot and cold water distribution loops, and campus building interfaces.

Boreholes Sometimes called geothermal wells, boreholes are a defining feature of a large-scale GSHP system. To access stable ground temperatures that are unaffected by seasonal weather patterns, ground-source systems must go deep into the earth. Ball State has more than 3600 boreholes located in three separate well fields spread across campus. Each borehole is 6 in. (152 mm) in diameter and approximately 400 feet (122 m) deep on the north side of campus and 500 feet (152 m) deep on the south side of campus. A closed

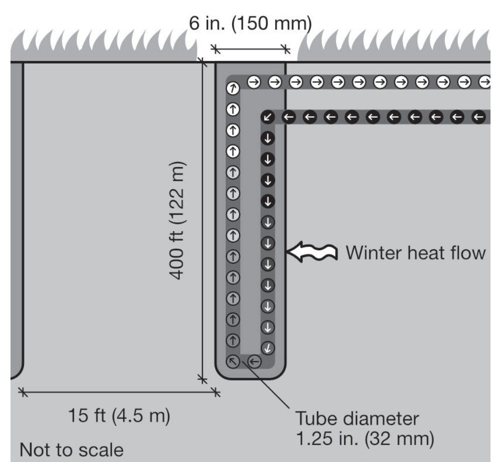

Fig. 14.136 *Diagram illustrating the heat exchange process when water from the heat pump chillers is pumped through the closed-loop boreholes. (Drawing by Alisa Kwok after information provided by Ball State University.)*

Fig. 14.137 *Borehole construction photo at the south well field. (© Ball State University; Reproduced and reprinted under license from Ball State University. All rights reserved.)*

loop of 1.25 in. (32 mm) diameter high-density polyethylene (HDPE) tubing is inserted into each hole. Over 1000 miles (1609 km) of tubing were used in total. The holes are then filled with a grout to promote improved thermal conduction between the ground and the tubing. Boreholes are spaced 15 feet (4.6 m) apart, and the tubing from each hole is connected to a main manifold connected to a heat exchanger at the energy station. Fresh water (no antifreeze is necessary) from the energy station is run through the tubes where it sheds heat to the ground in summer (cooling season) and absorbs heat from the ground in the winter (heating season). The tubing is closed loop, so there is no direct contact between the water and the ground. At the ground surface, the borehole well heads are covered and the wellfields returned to other campus uses.

Fig. 14.138 *Borehole wellhead showing the 6 in. (152 mm) diameter HDPE closed-loop tubing. (© Ball State University; Reproduced and reprinted under license from Ball State University. All rights reserved.)*

Fig. 14.139 *Supply and return well field water headers at the energy stations. (© Ball State University; Reproduced and reprinted under license from Ball State University. All rights reserved.)*

Energy Stations In a district energy system, heat and coolth are generated at one or more central energy stations and distributed to individual buildings. Ball State has two energy stations, one at the south end and one at the north end of campus. Each station employs two heat pump chillers that use a vapor compression refrigeration cycle and circulate R134A refrigerant. Heat is exchanged with the closed loop wells to pull heat from the ground or to shed heat into the ground. This heat exchange (in conjunction with heat pumps) allows for simultaneous production of cold water (42°F [6°C]) and hot water (150°F [66°C]) for heating and cooling buildings. Each unit can produce 38,000,000 Btu/hr (11,137 kW) of heating and 2500 tons (8790 kW) of cooling.

District Loops Hot and cold water generated by the heat pump chillers are sent to campus buildings via hot and cold water supply and return loops in existing tunnels supplemented by new direct-burial piping runs. The original heat distribution to buildings at Ball State was via steam, but this piping network had to be replaced with hot water piping to work with the new GSHP system.

Building Interfaces Heat and coolth from the district loops are exchanged with mechanical equipment at each campus building, which includes air handling, hydronic heating, and domestic hot water equipment. Pumps, variable frequency drives, and heat exchange coils at buildings were replaced or installed as necessary.

Fig. 14.140 *One of four 2500-ton (8790 kW) heat pump chillers used at the district energy stations on campus. (© Ball State University; Reproduced and reprinted under license from Ball State University. All rights reserved.)*

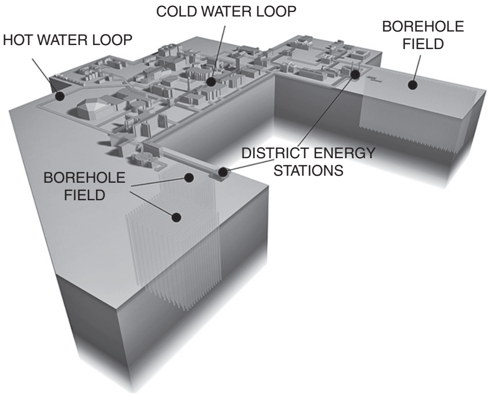

Fig. 14.141 *District hot and cold water loops connecting buildings to the central district energy stations. (© Ball State University; Reproduced and reprinted under license from Ball State University. All rights reserved.)*

Each building is connected to a building management system (BMS) that is monitored at the central energy stations.

Performance Data

Information available to date suggests that the Ball State GSHP system is performing well and meeting the original design intents:

- Energy use intensity (EUI) reduction from 175 kBtu/ft^2/yr (552 kWh/m^2/yr) to an estimated 105 kBtu/ft^2/yr (331kWh/m^2/yr) for the campus as a whole
- Substantially increased coefficient of performance (COP): an improvement for heating from 0.62 (old coal and natural gas system) to roughly 7.0 (combined heating and cooling with GSHP system); less radical improvement in cooling system COP was also seen (in change from cooling tower heat rejection to ground-based heat rejection)
- Elimination of 36,000 tons (32,600,000 kg) of coal burned annually with associated greenhouse gas reductions and air quality improvements
- Average $2 million per year saved in energy costs

Fig. 14.142 *One of two district energy stations constructed for the project. (© Ball State University; Reproduced and reprinted under license from Ball State University. All rights reserved.)*

Fig. 14.143 *The south well field is a soccer field and is located next to one of the campus energy stations. (© Walter Grondzik; used with permission.)*

Fig. 14.144 *Additional well field, adjacent to the soccer field. (© Walter Grondzik; used with permission.)*

FOR FURTHER INFORMATION

Ball State University Facilities. cms.bsu.edu/about/geothermal

New York Times. archive.nytimes.com/www.nytimes.com/cwire/2009/05/29/29climatewire-how-a-pioneering-university-hopes-to-cut-its-96239.html

Chronicle of Higher Education. https://www.chronicle.com/blogs/buildings/ball-state-u-to-install-nations-largest-geothermal-system/5497