Urban Challenge

BY PERRY HAUSMAN P.E., MEMBER ASHRAE

HOME TO AMERICA'S first outdoor pedestrian shopping mall, Kalamazoo, Mich.'s downtown has persisted as a vital part of the city through three centuries. Now, the thriving district is home to shops, restaurants and urban residences. Its vibrancy made it the ideal location for a developer seeking to revitalize the neglected 137-year-old Corporation Hall by integrating technology with sustainable and energy-efficient design. Despite the challenges of a tight urban site and cold climate, the building team found innovative solutions to install a geothermal system, setting an example of energy efficiency in a historic and urban location.

Front façade facing the street in downtown Kalamazoo. This redevelopment of a neglected property now provides a pharmacy within walking distance to downtown residents.

Photos © Justin Maconochie

Corporation Hall has served several uses over its history, including a fire station, the city's first City Hall, a library and a department store. By the late 2000s, the building was nearing the end of its useful life and was in need of a complete transformation.

One of the primary challenges of the revitalization project was getting a historic building in a cold climate to perform with low and sustainable energy use. The solution involved installing a geothermal heating and cooling system beneath the building (as opposed to locating the system on adjacent property.) This design allows heating to flow in and out of the building as needed and mitigates the need to install loud equipment on the roof of the building.

Rooftop view featuring a vegetative roof and large sloped glass roof monitors to capture natural light and bring it deep into the public zones.

Seeking LEED Gold certification, the finished Corporation Hall building is mixed-use, housing a furniture and décor store, a financial advisory office, and a pharmacy on the lower levels, and two-story residential units on the second and third levels. Each apartment has access to a private rooftop terrace and a covered parking garage.

Energy Efficiency

Engineers on the project team developed an energy model for making informed design decisions, ultimately arriving at several strategies that contributed to optimal performance results. Sustainable features include a green roof, low-flow plumbing fixtures, high-efficiency mechanical units, low-consumption LED lighting, light tubes, solar thermal energy (*Figure 1*), silent heat through a radiant floor and a nonidling demand-response snowmelt system.

Energy efficiency for the project began with the rehabilitation of the original 1876 building envelope, which consisted of the interior structure, basement slab, and foundations (the roof was replaced). To face the challenge of producing an energy-efficient building in a cold climate, spray foam insulation was used as well as high-performance windows and responsible daylighting.

In-floor radiant heat is the primary heating delivery method for the entire building and is supplemented with the air system as a secondary heat source. This design was chosen because the low-temperature heat system maximizes the efficiency of the central station heat pump. The heat pump provides low-temperature heating water and chilled water using an earth-coupled heat exchanger. Paired together, the two systems complement each other.

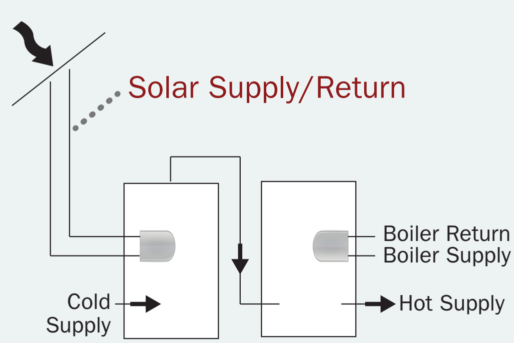
Along with these systems are the condensing boilers used for secondary domestic water heat, redundant building heat and snow melt. The boiler-generated heating water loop is maintained at a 160°F supply temperature to satisfy a 140°F domestic water storage setpoint.

Domestic hot water is preheated with return heating water to provide cold return water to the boiler. The water is stored at 140°F to eliminate the possibility of growing bacteria such as Legionella in the tank.

The condensing boiler's efficiency increases inversely with return water temperature: colder water means higher efficiency. Pressure-independent control (PIC) valves continuously match heating and chilled water flow to the building's demand. They perform real-time balancing to maintain system performance at changing building loads. As a result, the variable speed pumps run at lower

Figure 1 SOLAR THERMAL SYSTEM

Solar Thermal Panels: Domestic water is preheated with solar thermal panels piped to a tube bundle inside the storage tank. The 131 ft^2 collector is sized to provide an annual energy benefit of 34,600 kBtu.



Solar light tubes on the vegetative roof provide natural light deep into the building.

BUILDING AT A GLANCE

Name Corporation Hall

Location Kalamazoo, Mich.

Owner Catalyst Development

Principal Use Mixed Use: Apartment and retail
Includes Five residential tenant spaces, two retail tenant spaces (home furnishings and pharmacy), enclosed five-car garage

Expected (Design) Occupancy 112 people
Percent Occupied 100%

Gross Square Footage 33,000 ft^2
Conditioned Space 30,274 ft^2

Distinctions/Awards 2015 ASHRAE Technology Award, Second Place (Commercial Buildings—Existing)

Substantial Completion/Occupancy January 2013

When Built 1876
Major Renovations first a fire station, then City Hall, then a library, then a government building, then a department store that closed in 1965, then leases for several years before sitting vacant until this project (2013)
Renovation Scope Complete gut of interior walls and floors; only building shell and structure remained

Total Renovation Cost $6.6 million (includes site work and geothermal)
Cost per Square Foot $200

ENERGY AT A GLANCE

Annual Energy Use Intensity (EUI) (Site) 38.8 kBtu/ft^2
Natural Gas 15.2 kBtu/ft^2
Electricity (From Grid) 22.9 kBtu/ft^2
Renewable Energy (Solar Thermal) 0.7 kBtu/ft^2

Annual Net Energy Use Intensity 38.1 kBtu/ft^2

Annual Source (Primary) Energy 88 kBtu/ft^2

Annual Energy Cost Index (ECI) $1.11/$ft^2$

Savings vs. Standard 90.1-2004 Design Building 60%

Heating Degree Days (Base 65°F) 7,431

Cooling Degree Days (Base 65°F) 817

Annual Hours Occupied 8,760

WATER AT A GLANCE

Annual Water Use 14,529 gallons

KEY SUSTAINABLE FEATURES

Water Conservation Low-flow fixtures

Daylighting Light tubes

Individual Controls Occupants have access to energy dashboards and touch screen programmable temperature, fan and humidity controls.

Transportation Mitigation Strategies Located in walkable downtown Kalamazoo, Mich.

BUILDING ENVELOPE

Roof
Type Thermoplastic polyolefin (TPO)
Overall R-value R-28.5
Reflectivity Solar reflectance index is 98 initially and 81 after 3 years

Walls
Type Brick and block with cavity spray foam
Overall R-value R-18.2
Glazing Percentage 25.6%

Windows
Effective U-factor for Assembly U 0.35
Solar Heat Gain Coefficient (SHGC) 0.34
Visual Transmittance 0.359

Location
Latitude 42.29 N
Orientation Façade faces east

BUILDING TEAM

Developer Catalyst Development Co.; Patti Owens, Vice President & managing director

Owner Catalyst Development Co. #7

Architect/Designer TowerPinkster Architects | Engineers; Jason Novotny, Design Architect; Steve Loney, Project Manager

Construction Manager CSM Group; Todd McDonald, President

Structural Engineer Nehil • Sivak Consulting Structural Engineers; Tom Palarz, project manager/structural engineer

Environmental/Geotechnical Consultant Soils and Materials Engineers Inc.; Tim Mitchell, Vice President/civil and geotechnical engineer

Geothermal Consultant Midwest Geothermal; Bob Braam (retired); Scott Skoog, President

City of Kalamazoo Brownfield Redevelopment Authority Marc Hatton

Michigan Economic Development Corporation Katherine Czarnecki, director of Community Development; Stacy Esbrook, Brownfield Programs specialist; Sarah Latta Rainero, CATeam specialist; Karla Campbell, board and strategic relationship advisor

Rear entrance. The brick pavers and concrete driveway are each protected from snow and ice with a melting system using a weather predictive demand-control activation algorithm.

speeds, and return water arrives back at the heat pump at the design temperature, resulting in saved energy.

The geothermal system is one of the biggest contributors to the project's energy efficiency, but installing it beneath an existing building in an urban location posed significant challenges. To accomplish this, the drill rig was driven down a temporary ramp leading into the existing basement where boreholes were drilled through the existing slab, extending an average of 400 ft into the ground.

Designing an earth-coupled heating and cooling system for an existing building that occupies 89% of a 10,614 ft^2 site was no small task, since the system was installed beneath the existing building to prevent equipment being placed on the roof. Engineers and the construction team worked together in the design phase to precisely plan each specific bore location while carefully coordinating with both existing and new footings.

A radio frequency identification tag (RFID) was placed at the top of each

LEFT Fire protection (foreground) geothermal manifold (midground), and geothermal pump and heat pump (background). Each geothermal bore is piped as a "home run" to the geothermal manifold shown here. Each bore can be individually isolated in case of a catastrophic failure. This is a critical design since the geothermal field is located below the building.

BELOW The first floor retail space is in the heart of the Kalamazoo Mall in Downtown Kalamazoo. The renovated space fills a void that had been vacant for several years and provides pharmacy and other retail services to the community.

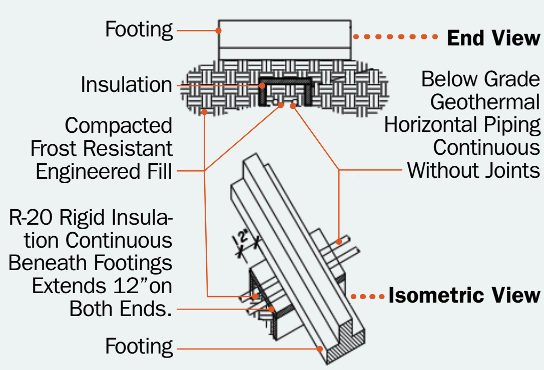
bore to enable building operators to easily locate the below slab piping during any future renovations. In the unlikely event of the earth-coupled heat exchanger freezing the earth, unique insulated coffers were designed beneath the building to prevent frost from heaving the existing facility (*Figure 2*).

To track energy use and efficiency, energy dashboards are installed throughout the building. Data can be viewed at the occupant level with additional detail provided to building operators.

As the building's face of energy efficiency, the dashboard measures, calculates, records and reports energy use for each tenant. Real-time energy data is also reported for heating, cooling, lighting, plug loads, domestic hot water and renewables. Condensed information is also displayed for public viewing to show how the building's energy savings relates to everyday environments.

Figure 2 GEOTHERMAL TRENCH DETAIL

The geothermal glycol solution has the ability to operate at below-freezing temperatures and can actually freeze the ground. This figure illustrates the insulation design used to protect the ground near the footings from being affected by freezing temperatures.



Maneuvering the drill rig into place for the first bore holes to be drilled.

The energy dashboard also provides continuous system monitoring, offering immediate feedback via e-mail on energy output and zone-specific temperature changes. Energy competitions between tenants encourage smart energy consumption choices.

All of these measures contributed to the energy model showing a 60% energy dollar savings over ASHRAE/IESNA Standard 90.1-2007, Energy Standard for Buildings Except Low-Rise Residential Buildings, using Appendix G modeling guidelines. The building's total energy consumption, as reported by the utility company, is tracking within 10% of the energy model; actual annual energy consumption is 38.1 $kBtu/ft^2 \cdot yr$ (not including 0.7 $kBtu/ft^2 \cdot yr$ from solar

CLOCKWISE FROM TOP A skylight improves the daylighting of this residential stairway with an exit to the outdoor patio. Materials from the existing structure were repurposed, including extensive reuse of timbers for stair treads, wall accents and decorative ceilings.

The building features a green roof as a part of a private rooftop terrace for the five residences in the building. The terrace features a cedar pergola and a modular roof paver system, encouraging outdoor activity and social connection to downtown.

The central public zone on the first floor is carried to the upper floors and differentiates the common floor plan of the residential units into more introverted or extroverted offerings.

Residential units occupy the second and third floors of Corporation Hall. Large windows provide increased daylighting to this kitchen, and repurposed timber from the existing building is used as a decorative ceiling feature.

thermal), compared to the predicted 34.6 $kBtu/ft^2 \cdot yr$ (*Figure 3*).

Financial Benefits

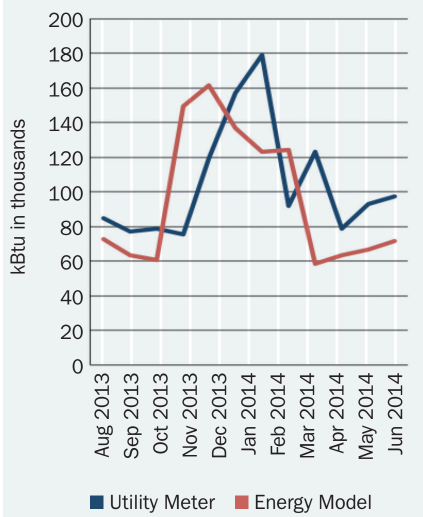
The project's energy-efficient features also bring financial benefits. For example, LED lighting alone offers an annual savings of 68,446 kWh, or $7,811.

Another large savings comes from the demand-response snowmelt system, which is designed to prevent idling. The building automation system (BAS) initiates a query to the local weather forecast. When snow is predicted, a learning algorithm determines when the system should begin heating the thermally massive snowmelt area so that the snow melts upon contact. Because the system detects when it needs to turn on and off, it provides savings of more than $3,000 annually, with a payback time of 2.3 years.

The geothermal system also provides a large benefit in efficiency and savings. While a traditional boiler chiller uses 498.6 MBtu/yr per ASHRAE Standard 90.1-2007 Appendix G, the geothermal uses only 342.9 MBtu/yr. This results in 31% energy savings as well as 57,000 lb of CO_2 savings.

Overall, Corporation Hall is operating at an annual utility cost of $36,495, or $\$1.11/ft^2$. An average similar building would typically operate at a utility cost of $62,906 (per

Figure 3 ENERGY USE DATA



Lessons Learned

The renovation of Corporation Hall brought with it many challenges and successes. Members of the building team generated innovative ways to deal with these challenges, and realized different processes that could have benefited the project. The lessons garnered from this experience could be used in future endeavors.

View looking into the existing basement with a rubble ramp (left), which was made for the drill rig. This allowed the equipment to get down to the basement to drill the 400 ft deep bore holes for the **geothermal system**.

☐ **Value of Building Envelope Commissioning.** Although this project did not employ building envelope commissioning, doing so may have saved the need for expensive post-construction efforts. During the first winter's operation at Corporation Hall, one bedroom had significant trouble maintaining its heating setpoint with the combination of radiant floor heating and the unit's air system.

After verifying design calculations and determining the space had been receiving adequate heat, thermal imaging and construction photos revealed significant thermal bridging and missing insulation. Upon this discovery, the problems were corrected, bringing the building's energy performance back to the level at which it was designed.

☐ **Importance of Advance Coordination of Geothermal Bores on Urban Site.** Originally, the geothermal bores were going to be installed at the back of the site; however, this was problematic because it was the job site's access point. This meant that trucks and equipment would be in the way of installation and vice versa.

It was then decided to move the geothermal bores to the front of the site, but the challenge of getting the installation equipment down into the basement still existed. The team created a ramp to get the machine down, but due to the limited space in the urban setting, the ramp had to be taken apart after the equipment was in place so it could move around for installation. Then the ramp was reassembled to get the equipment back out. Had there been more coordination during design, a more efficient process may have been possible to save time and energy on the assembly and disassembly of the ramp.

RIGHT Originally constructed as a fire station in 1876, Corporation Hall was converted into Kalamazoo's first City Hall, then into a library, a government building, and a department store, which closed in 1956. The building was then leased for several years and sat vacant in the middle of the Kalamazoo Mall, a street filled with shops, restaurants and condos.

the energy model), which equates to $26,411 in annual utility savings.

Conclusion

This new addition to downtown Kalamazoo uses integrated technology and sustainable design to save operating costs and reduce environmental impact. The building has been consistently at full occupancy from its opening, bringing new life to the area and providing an example of sustainable, energy-conscious living. ●

ABOUT THE AUTHOR

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