**CONCEIVED** during the building slump of the Great Recession, this multi-tenant building in Madison, Wis., tells an important economic story: a developer-driven project can attain a high level of performance while remaining competitive and replicable in the market. Cited by local developers as a testament to the viability of sustainable spec office construction in the Madison market, the 85,000 ft$^2$ office building achieved LEED Platinum and operates at 35 kBTU/ft$^2$·yr.

The developer cites faster leasing as the primary business benefit of pursuing a highly sustainable project. Even in a slow market, 749 University Row was fully leased before construction was complete. The developer plans to build a third high-performance building if a suitable urban parcel becomes available.

A Welcoming Place for Tenants

In a competitive leasing market, a high performance building provides an advantage to tenants who want to reduce environmental impact and make sustainability part of their branding strategy. It also provides low energy and water costs, and a more comfortable and potentially productive environment for occupants.

To create a welcoming workspace, designers focused primarily on dynamic daylighting (Figure 1) using several integrated elements:

**Well-placed glazing.** The ratio of window to wall area is just 39%. Areas that are glazed are placed with high window head-heights to allow sunlight to penetrate as far...
as possible into the space. A frameless mounting system for this glazing reduces the casework costs. Specified glazing properties were for the highest possible visible transmittance (0.55) while maintaining a solar heat gain coefficient (SHGC) of 0.28.

Glare control. Exterior glare control is provided by 2.5 ft exterior solar shades set at the top of vision glazing, but below transom glazing. To control the increased amount of interior light, roller shades on the perimeter windows have a 5% open weave to allow exterior views even when the shades are down.

Skylighting. On third-floor spaces, tenants have taken advantage of the roof exposure to add tubular and standard domed skylights. This even daylighting allows tenants to feel the sun moving across the sky through the course of the day.

Tenants typically make the most of the glazing design and daylight by configuring their space to open up views using low partition heights, interior meeting rooms and glass partitions and doors.

In addition to daylighting and views, the building achieves excellent indoor air quality from its use of a 100% dedicated outdoor air system (DOAS) (see Practical Sustainability).

**Practical Sustainability**
Developing a high performance building for multiple tenants can pose additional challenges, especially when some of those tenants have yet to be identified as the building is designed and constructed.

The developer of this three-story, seven-tenant project overcame these challenges by taking a practical approach to building design and construction.

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**Figure 1 DAYLIGHT MODELING**

Horizontal and vertical plane illuminance maps helped the building team analyze penetration of daylight with a variety of different design considerations, especially toplighting.

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“We helped to mitigate risk by working with proven subcontractor-partners and consultant-partners to guide us all through the green aspects of the construction process from the beginning.”

— Paul Lenhart, president and CEO of Krupp General Contractors, the developer, builder, general contractor and owner of 749 University Row
### Building at a Glance

**Name** 749 University Row  
**Location** Madison, Wis.  
**Owner** University Crossing Investors and Krupp General Contractors  
**Principal Use** Office  
  Includes Dentist office, small enclosed parking  
**Employees/Occupants** 190  
**Expected (Design) Occupancy** 190  
**Percent Occupied** 100%  
**Gross Square Footage** 85,000  
**Conditioned Space** 70,000  
**Substantial Completion/Occupancy** 2013  

### Energy at a Glance

**Annual Energy Use Intensity (EUI) (Site)** 35 kBtu/ft²  
**Electricity (Grid Purchase)** 33.3 kBtu/ft²  
**Natural Gas** 1.8 kBtu/ft²  
**Annual Net Energy Use Intensity** 35 kBtu/ft²  
**Annual Source (Primary) Energy** 106.3 kBtu/ft²  
**Annual Energy Cost Index (ECI)** $1.1/ft²  
**ENERGY STAR Rating** 94  
**Carbon Footprint** 76.1 metric tons CO₂e  
**Percentage of Power Represented by Renewable Energy Certificates** 37%  
**Heating Degree Days (Base 65°F)** 7,300  
**Cooling Degree Days (Base 65°F)** 630  
**Annual Hours Occupied** 3,640  

### Water at a Glance

**Annual Water Use** 582,000 gallons  

### Key Sustainable Features

- **Water Conservation** Rainwater collection with 10,000 gallon tank and graywater system, low-flow fixtures, waterless urinals.  
- **Recycled Materials** Carpeting, concrete floors, structural steel, hollow metal doors, aluminum window system, glazing and ceiling tiles.  
- **Daylighting** Tall, optimally placed windows; sunscreens and open-weaved roller shades for glare control; fully dimming daylighting controls, top-lighting for interior zones on top floor; many tenants have low or no cubicle walls.  
- **Individual Controls** Tunable lighting, operable thermostats in each zone (except common areas).  
- **Transportation Mitigation Strategies** Indoor, heated bike parking; individual showers; locker rooms; adjacent to 12 bus routes; car parking is shared with apartments across the street to limit space.  
- **Other Major Sustainable Features** Re-use of an abandoned site, dedicated outdoor air system and CO₂ monitoring for higher indoor air quality, robust measurement and verification allowing for building research and dissemination.

### Building Envelope

#### Roof
- **Type** Built-up roof on metal deck  
- **Overall R-value** R-30  
- **Reflectivity** Non-reflective (white roof not effective in this climate)  

#### Walls
- **Type** Metal panel and masonry over steel-frame backup; rigid insulation and liquid applied air barrier  
- **Overall R-value** R-18  
- **Glazing Percentage** 39%  

#### Basement/Foundation
- **Basement Wall Insulation R-value** R-15  

#### Windows
- **Effective U-factor for Assembly** 0.32  
- **Solar Heat Gain Coefficient (SHGC)** 0.28  
- **Visual Transmittance** 0.55  

#### Location
- **Latitude** 43° N  
- **Orientation** The long axis of the building is 38° east of north, due to the orientation of the adjacent major street  

### Building Team

- **Building Owner/Representative** University Crossing Investors  
- **Architect, LEED Consultant** Potter Lawson, Inc.  
- **General Contractor** Krupp General Contractors  
- **Mechanical Engineer** Potter Lawson, Inc.  
- **Electrical Engineer** Specialized Electric  
- **Energy Modeler** Seventhwave  
- **Structural Engineer** Pierce Engineering  
- **Civil Engineer** D’Onofrio Kottke and Associates, Inc.  
- **Landscape Architect** The Bruce Company  
- **Commissioning Agent** Sustainable Engineering Group  

All areas of the building are designed to receive ample natural light. Tenants designed interior spaces to use this daylight to varying extents.

Solar shades were added midway up each floor’s façade to shade the majority of the view glazing. The depth of the shades was optimized for the local climate.

An approach to sustainability, making sensible choices to keep costs low while maintaining functionality. The developer put high performing base systems in place to allow as much or as little performance as the tenants could implement.

For example, the façade was designed for maximum depth of daylight penetration, with strategic glare control. All tenants enjoy this natural light. Some tenants choose to go a step further and implement automatic daylighting controls to save more energy than manual controls.
In the same way, the central ventilation system (the DOAS) is designed to accommodate demand control. Some tenants use CO₂ sensors or occupancy sensors to take significant advantage of this; others have implemented CO₂ control only in spaces required by LEED or code. The system works well for both.

Finally, tenant utility use is submetered. This makes sense from a business perspective for the developer, but more importantly, it allows the tenants to have feedback and control over their own energy costs, which they could use to lower energy use further. Tenant submetering does need to be accounted for in the measurement and verification plan (see Initial Performance).

The Right Site
Finding a suitable site for a sustainable project is job one. The developer took one of Madison’s underused urban infill sites and turned it into a mixed-use development to the west of downtown. Demolition of the unusable buildings on the existing site went through a rigorous recycling plan, diverting over 1,700 tons of construction waste from landfills.

The development has begun to revitalize the neighborhood and increase urban density. The building is third in a master plan of seven buildings for the site. The development is currently home to a coffee shop, health club, clinic, and 118 apartments, in addition to the office tenants.

The parking below the apartments is shared with 749 University Row. When tenants of the apartment building leave for work or school in the morning, parking spots open up for University Row tenants. This reduced parking size, coupled with its underground location, substantially reduces surface parking and eases storm water runoff. A small surface parking lot serves the retail shops and dental clinic.

Many who live and work in the development are able to avoid driving altogether, an important factor considering that the energy footprint of high performance buildings is increasingly dominated by transportation to and from the building.

In addition to being located on a street with 12 bus lines, the building was designed for bicycle commuters. It has tempered underground bike parking, showers and lockers. A bike sharing station is located next door.
CASE STUDY 749 UNIVERSITY ROW

ABOVE LEFT Task tuning was implemented after furniture installation and occupancy to dim lights in a number of areas, including this conference room. This practice precisely matches light levels with lighting requirements at working areas. ABOVE RIGHT Tenants use a variety of daylighting control systems. Task tuning is possible with any system that has the capability of dimming lights.

Living Lab

Seventhwave is the energy analyst for 749 University Row and a tenant in the building. As a nonprofit firm specializing in energy consulting, research, and education, Seventhwave’s mission is a good fit for the sustainability goals of the building. Being a tenant allows the firm to actively add to the body of knowledge for the broader community of building professionals. The building has been measured extensively (see seventhwave.org/building-dashboard for an online dashboard).

Measurements are used for a traditional M&V plan that was set up and conducted as part of the design and construction process. Measurement is also used to create a living lab that furthers internal knowledge of cutting edge performance measures.

The first foray into research came when the HVAC system was selected, and the team recognized that it was designing and installing one of just a few water-source VRF systems in the entire Midwest. Funding from local utilities allowed the system to be studied in depth, including flow rates, temperatures, and power consumption at many points.

Though results aren’t final, initial measurements show that the system performs within 8% of rated efficiency, but is underperforming at part load. Ongoing research will investigate what is causing the system to perform or underperform in various scenarios.

The advanced lighting controls in the building are also the subject of significant study and learning. So far, the primary area of research has been demonstrating task tuning. Task tuning is the practice of using dimmable lighting to adjust light levels so that illumination is appropriate for the activity in the space. Savings from tuning were greater than 20% in two spaces studied in the building, with very little additional effort or cost. (See seventhwave.org/tasktuning for a full report.)

The performance of demand controlled ventilation in a VRF DOAS is also being studied. Tenants use occupancy sensors and CO₂ sensors to modulate flow from the DOAS. Research has shown this to be a highly effective practice in buildings where the designer specifies a detailed control sequence, and commissioning includes CO₂ sensors and that sequence. (See seventhwave.org/dcv for a full report.)

A few other measurements of interest include:

- Though the VRF units are not performing quite to their ratings (see Lessons Learned), the DOAS is over-performing. Ongoing measurement of its heat recovery effectiveness shows an improvement from a design rating of 67% effectiveness to an actual effectiveness of 74% based on real-time measurement of temperature at multiple locations in the unit. This is likely due to decreased airflows from the demand controlled ventilation system; design airflow through the DOAS is 8,800 cfm but DCV allows this value to be 6,950 cfm on average.
- Though the building was expected to be cooling dominated, the geothermal system has maintained temperatures below 75°F even in the hottest summer months.
- The lower level parking lighting includes occupancy sensors that dim the LED lighting by 60% when nobody is present. Occupancy sensors alone save 53% of the lighting energy in the garage.

Envelope and HVAC

Wisconsin’s climate requires heating and cooling even in the highest performing buildings. However, it is still worthwhile to design the envelope to provide as much comfort as possible before applying mechanical systems.

749 University Row uses rigid insulation on the exterior of the structure only, with a liquid-applied air barrier. To avoid potentially harmful chemicals in some insulation products, mineral wool insulation is used. The material is recycled from industrial waste and achieves an R-18 wall.

The building is then heated and cooled using a ground-source variable refrigerant flow (VRF) system (Figure 2). This HVAC option was selected by using an energy model that was completed in conceptual design based on basic massing, orientation, and anticipated high-performance envelope properties. The model was used to analyze various approaches, from standard variable air volume, to different heat pump options, to different VRF options.

Ground-source VRF was the best fit for a variety of reasons, with the two

An inviting entry stairwell encourages occupants and visitors to use the stairs instead of the elevators, which are located behind a row of doors.
Lessons Learned

- **Variable Refrigerant Flow.** Tuning immediately following start-up required a bit more time and more parties than planned. The thermostat is deceptively simple, but actually can require significant tuning.

  Due to the newness of the system type, the contractor had to rely on the vendor for the trickier tuning exercises. Finally, after design was essentially complete, it was learned that a bank of condensing units serving a single tenant was not capable of modulating the water valves to allow for variable flow based on load.

  As a result, energy used for pumping power for the building was significantly higher than predicted. This lack of modulation needs to be addressed by the manufacturer.

- **Stairwell and Elevator Design.** An inviting entry stairwell encourages the majority of occupants and visitors to use the stairs instead of the elevators, which are located behind a row of doors. As a result, elevator motive energy use is low. However, unfortunately the elevators were not selected with occupancy controls, so lights and fans still use energy when the elevator is not in use.

- **Dealing with Orientation.** The building is located on a street that runs approximately 38° off of east-west—not the ideal east-west orientation that usually drives high performance. With the building forced into this position by its context to the street, the team paid careful attention to solar control via overhangs and solar shades on the outside, and diffuse daylight-emitting roller shades on the inside. Significant effort can be avoided with a better orientation, but when forced, solutions are available.

- **Building Automation System.** The VRF uses proprietary controls, requiring a second, higher-level BACnet compatible building automation system (BAS). As a final layer, the BAS also feeds a building dashboard where performance can be seen by the public via the internet.

  Not all buildings should pursue this depth of control capability due to its associated costs and complexity. But when this level of functionality is needed, this type of control system hierarchy will often result with VRF systems. If it is done this way, the structure—including naming—requires significant forethought and the controls contractors will not have time to give it that forethought or come up with a robust naming hierarchy in the field.

- **High Performance with Multiple Tenants.** Having multiple tenants in the building does add additional complexity to ensure the building will perform, beyond the basic fact that each tenant has widely varying needs and operations. M&V was made more complex with multiple meters. The M&V consultant set up points of contact with each tenant through the owner at the time of move-in, and explained the high performance goals of the building and the need for utility billing information.

  Balancing and commissioning agents found the staggered move-in dates over a nine-month period to be challenging. Each time a new tenant moved in, system balancing and control tuning devolved. These agents initially tried to conduct significant operations after the first couple of tenants, but ultimately saved the most thorough activities for after the final tenant was in place.

- **Common Area Thermostats.** Occupants were locally changing the setpoint on common area thermostats. These thermostats had to be locked out.

- **Costs and Benefits of High Performance Building.** Building owner Paul Lenhart summed up the business impact of sustainable building, “I’m an advocate for the construction of high performance buildings,” he said. “I feel they are one more positive legacy we can leave and they point to good stewardship of limited resources.

  High performance buildings are also good for business and offer competitive advantages in the marketplace [due to faster leasing]. “As a bonus, as high performance building materials and technologies are used more frequently, costs will inevitably go down, making sustainable buildings more affordable and widespread,” he said.

The building has attracted a variety of tenants, from a dental office, to an architect, to nonprofit organizations.

most critical being performance and form. The performance of the system in this climate is substantially better than air-source VRF or any of the more traditional HVAC choices (Figure 3).

A unitary ground-source heat pump system showed slightly better performance than the VRF system, but it would require heat pumps to be distributed throughout the building. This was highly undesirable for the owner, especially with some tenant spaces not yet taken or designed.

A necessary complement to the VRF system is a DOAS, bringing in 100% fresh air for occupants, and modulating based on CO2 and occupancy sensors. The DOAS is made up of a ground source heat pump with a total energy recovery wheel.

The decision to serve the VRF system via the ground was almost lost to site constraints. The boreholes, which typically go to 400 ft in the region, were constrained to just 250 ft to avoid a city water aquifer. As a result of the constraints, nearly 50% more wells were required. Since the site offered little green space or surface parking, the geothermal borefield was ultimately placed in a ring around the building roughly 15 ft off the foundation.
Tenants typically make the most of the ample daylight by configuring their space to open up views.

**Interior**

The primary focus of interior design was to create a welcoming environment. Some tenants also made sustainable elements a key focus of their build-outs.

After HVAC, efficient lighting represented the next most significant area of energy savings. Interior build-out designs averaged 0.67 W/ft² (compared to code lighting power of 1 W/ft²) through use of LED and traditional fixtures with good design.

Seeking to minimize use of materials, the design team limited interior walls. Carpeting is used minimally throughout the facility and never in high traffic areas.

Concrete was left exposed in many places. An acoustic roof deck was used, eliminating the need for some acoustic ceilings and increasing ceiling heights.

**Initial Performance**

A comprehensive M&V plan was included in the design and executed following occupancy to ensure performance for tenants. Tracking energy use at 749 University Row is complex, with multiple submetered tenants and staggered occupancy dates. Figure 4 summarizes energy use for a 12-month period following full occupancy.

Nearly all space heating is accomplished with electrically-driven VRF and heat pump equipment, which is possible with the use of the ground loop. Natural gas is used as a cost-effective source for heating-only uses such as domestic hot water, garage heating and a final stage of DOAS heat.

Based on the data during that period, the building is performing with an energy use intensity (EUI) of 35 kBtu/ft²·yr (equating to a source EUI of 106 kBtu/ft²·yr) and an ENERGY STAR score of 94. While this energy use results in a step below predicted energy cost (Figure 5), some causes have already been identified (Lessons Learned).

**Conclusion**

Though developers continue to perceive risk in constructing high performance buildings for multiple tenants, some are finding that they can mitigate risk and deliver added value to the market by involving experts to focus on performance throughout the design and construction process. University Row has proven that this process works.

**ABOUT THE AUTHOR**

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