The 35-acre Evie Garrett Dennis campus serves nearly 1,300 K–12 students. It houses multiple schools and shares facilities and site amenities.

Phase One, which opened in 2010, consists of four buildings: a student union, a primary charter school (grades K–2) and a science and technology charter school (grades 6–12) that is housed in two buildings. The student union includes gymnasiums and cafeteria, and the athletic fields comprise a nine-lane track, synthetic turf competition field and a multi-purpose field for physical education.

Phase Two (which is not discussed in this article) is Vista Academy, a district-run high school that opened in Fall 2011. Phase Three calls for the construction of a building to house community programs such as preschool education, youth athletics and mental health services.

Sustainable features include energy-efficient designs and technologies, resulting in an energy use intensity of 33.4 kBtu/ft². Major contributors to the buildings’ energy performance include high efficiency heat pumps and geos Exchange fields (eliminating the need for boilers and chillers), a tight building envelope and daylighting. Photovoltaic panels cover the roof of the student union, producing enough energy to power two of the campus buildings.

**DENVER’S EVIE GARRETT DENNIS CAMPUS IS THE DISTRICT’S FIRST MULTIBUILDING CAMPUS AND THE FIRST TO TAKE STEPS TOWARDS ACHIEVING NET ZERO ENERGY.**

**NZEB IN PROGRESS**

**CASE STUDY**

**EVIE GARRETT DENNIS CAMPUS**

**BUILDING AT A GLANCE**

<table>
<thead>
<tr>
<th>Name</th>
<th>Evie Garrett Dennis Campus Phase One</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Green Valley Ranch, Denver</td>
</tr>
<tr>
<td>Owner</td>
<td>Denver Public Schools</td>
</tr>
<tr>
<td>Principal Use</td>
<td>Elementary through high school campus</td>
</tr>
<tr>
<td>Employees/Occupants</td>
<td>90 full-time employees/1,278 students and visitors</td>
</tr>
<tr>
<td>Occupancy</td>
<td>100%</td>
</tr>
<tr>
<td>Gross Square Footage</td>
<td>186,468</td>
</tr>
<tr>
<td>Conditioned Space</td>
<td>100%</td>
</tr>
<tr>
<td>Site Size</td>
<td>35 acres</td>
</tr>
<tr>
<td>Distinctions/Awards</td>
<td>2009 LEED Gold (LEED for Schools), 2010 Excellence in Achievement Award, Tilt-Up Concrete Association Participant in 2030 Challenge</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$36 million</td>
</tr>
<tr>
<td>Cost Per Square Foot</td>
<td>$189/ft²</td>
</tr>
<tr>
<td>Substantial Completion/Occupancy</td>
<td>August 2010</td>
</tr>
</tbody>
</table>

**ENERGY AT A GLANCE**

| Energy Use Intensity (Site) | 33.4 kBtu/ft² |
| Natural Gas | 2 kBtu/ft² |
| Electricity (from grid) | 26.3 kBtu/ft² |
| Renewable Energy (PV) | 5.1 kBtu/ft² |
| Annual Source Energy | 95 kBtu/ft² |
| Annual Energy Cost Index (ECI) | $0.89/ft² |
| Annual Net Energy Use Intensity | 28.2 kBtu/ft² |
| Cooling Savings vs. Standard 90.1-2007 Design Building | 38.3% |
| Heating Degree Days | 6,020 |
| Cooling Degree Days | 2,732 |

**BY LAURA BARRETT AND PETE JEFFERSON, ASSOCIATE MEMBER ASHRAE**

© Mike Rogers/M.E. GROUP

This article was published in High Performing Buildings, Spring 2012. Copyright 2012 American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. Posted at www.hpbmagazine.org. This article may not be copied and/or distributed electronically or in paper form without permission of ASHRAE. For more information about High Performing Buildings, visit www.hpbmagazine.org.
Design Process
The campus was designed and documented using 3-D building modeling software for all disciplines (architecture, structural, MEP) to expedite design and improve coordination. The additional effort required to create a 3-D model proved worthwhile. Members of the building team submitted fewer requests for information than what is typical for a conventional fast-tracked design process using 2-D CAD.

SIMPLE PAYBACK ANALYSIS FOR ENERGY CONSERVATION INVESTMENTS

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Incremental Construction Cost</td>
<td>$688,042</td>
</tr>
<tr>
<td>Xcel Energy Incentive</td>
<td>$51,363</td>
</tr>
<tr>
<td>Project Adjusted Incremental Cost</td>
<td>$636,679</td>
</tr>
<tr>
<td>Annual Energy Cost Savings</td>
<td>$158,000</td>
</tr>
<tr>
<td>Payback (Years)</td>
<td>4</td>
</tr>
</tbody>
</table>

Courtesy of the Weidt Group, 2010

Creating a carbon neutral campus.

That’s what the George Washington University pledged to do under the American College & University Presidents’ Climate Commitment.

Johnson Controls’ equipment has kept GW’s buildings operating efficiently and comfortably for nearly four decades. Now GW is partnering with Johnson Controls to help achieve its carbon neutral goal by 2020.

Johnson Controls’ high-efficiency HVAC equipment is cutting GW’s energy use and reducing greenhouse gas emissions. Its Metasys® building management system monitors and controls the performance of nearly four million square feet of campus buildings. What’s more, Johnson Controls’ service team ensures this equipment operates at peak efficiency, GW is cutting energy use and reducing carbon emissions, and three LEED® GOLD buildings have been built on the campus.

From educational institutions and hospitals, to government and commercial buildings, Johnson Controls can make your building work for you more efficiently, sustainably and profitably. To find out how Johnson Controls can help you, visit MakeYourBuildingsWork.com or call 888-195-0707 today.
SCHOOLS ON EGD CAMPUS

The Evie Garrett Dennis Campus houses three schools: Denver School of Science and Technology (DSST), SOAR Charter School and the Vista Academy. DSST is considered to be one of the leading open-enrollment STEM school networks in the U.S. and has become a destination for educators nationwide. SOAR Charter School serves Kindergarten through second grade. SOAR schools offer an innovative, holistic approach to education that includes an academically rigorous curriculum, a mandatory extended school day, and daily enrichment opportunities.

The Vista Academy provides high school students with a strong college preparatory program in addition to several vocational focus areas. Students can attend this non-traditional program during non-traditional hours such as evenings and weekends in order to fit their needs.

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Net Zero and Photovoltaics

A major goal identified during the eco-charrette for the project was to design the EGD Campus to be “net zero ready.” After exploring alternate definitions of what “net zero” might mean, the team decided that the ASHRAE definition was the most appropriate. Essentially, the team felt that a net zero building should be designed such that the energy produced by on-site renewable energy would exceed the energy consumed by the building (including both gas and electric use) over the course of a calendar year. The original project budget did not include sufficient funds to purchase a renewable energy system, so the team designed the buildings and site so that a renewable energy system (including both gas and electric use) over the course of a calendar year.

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Above: Exterior view looking north at DSST Charter School Intermediate Academy on left, and Student Union (Building 1) in distance to right. Below, left: The Student Union (Building 1) cafeteria serving area incorporates bright colors and playful architectural elements. Lighting and HVAC equipment are integrated with the flowing design concept. Below, right: Each building has its own color palette and design concept. Upper image is DSST Charter School Intermediate Academy lobby with ‘Purple Mountain Majesty’ scheme. Lower image is SOAR Charter School Primary Academy lobby with ‘Green Fields’ scheme. These spaces are enhanced with an abundance of daylight and complementary electrical lighting where needed. HVAC equipment is integrated into the side wall design to ventilate and condition the space without detracting from the architectural experience.

Only Schneider Electric EcoBreeze maximizes year-round economization.

Data centers face unprecedented cooling challenges brought on by high-density computing, dynamic temperature profiles, regulatory requirements related to efficiency, and uncertain long-term plans for capacity or density. Today, Schneider Electric has the innovative answer to meeting these and other cooling challenges.

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EcoBreeze™ is the industry’s only economizer with two economization modes in one footprint. Specifically, it automatically can switch back and forth between air-to-air heat exchange and indirect evaporative cooling to maximize local climate conditions at all times. As a result, it uniquely ensures the most efficient and effective form of cooling year round.

In addition, the innovative cooling solution boasts a modular design for capacity, redundancy and service flexibility. What’s more, scalable SWM modules make right-sized cooling possible, allowing data center operators to match cooling capacity to actual cooling needs. And EcoBreeze is much faster and easier to deploy than traditional data center cooling infrastructure.

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+ Flexible

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+ Scalable

The pre-engineered modules can be sized to capacity and redundancy requirements as needed, lowering both CapEx and OpEx.

+ Easy

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Business-wise, Future-driven.

- Faster and easier: Flexible, quick, and cost-effective deployment since it uses zero white space with the data center.
- Right-sized: The pre-engineered SWM modules that fit into two frame sizes can be sized to 5kW - 100kW, increments of capacity and redundancy requirements as needed, lowering both CapEx and OpEx.
- Energy efficient: Automatically switches between air-to-air and indirect evaporative heat exchange for the most efficient cooling. A supplemental 3kW circuit on board gives additional peace-of-mind reliability.
- Two economizer modes: Indirect evaporative cooling and air-to-air heat exchange in the same module enables more economization opportunities.

Make the most of your energy™

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HPHotims.com/37998-4
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Energy
Building Envelope. Many options were studied using energy modeling to find a solution that minimized thermal bridging and air infiltration while meeting the budget and schedule demands of the project. The design team originally focused on solutions that used closed-cell spray foam in most areas. However, a tilt-up concrete structure with 2 in. of continuous insulation between the studs and concrete, and 6 in. of batt insulation in the stud cavity ultimately was chosen for most of the buildings. This yields an R-20 assembly when

- Water Conservation
  - Low-flow restroom fixtures, dual-flush toilets
  - Fixtures save 34.67% over LEED baseline
  - Drought-tolerant landscaping
- Recycled Content Materials
  - Concrete, masonry, metal framing, steel structural members, glazing, gypsum board, and a majority of interior finishes, such as ceiling tiles, carpet, ceramic tile, cork, fabrics, furniture, etc.
- Daylighting
  - Light tube system, fenestration pattern and east-west building orientation designed optimum daylight harvesting, glazed designed for light quality and glare control
- Controls
  - Daylighting sensors and occupancy sensors
- Materials
  - 92% of construction waste diverted, regional materials, spray foam insulation, low-VOC products
- Other Major Sustainable Features
  - Geoochange system for heating/cooling, storm water management, 30,000 ft² of photovoltaic panels

**Key Sustainable Features**

**Monthly Energy Use, Generation**

**Annual Energy Consumption by Building**

**Note:** Time period for data is August 2010–July 2011.

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the derating of the batt insulation is factored.

Closed-cell spray foam insulation blocks air and seals all joints, seams and window openings. Larger volume areas such as the gymnasium use a precast concrete system that includes continuous insulation (R-25) sandwiched between panels. The roof consists of a steel deck, white thermoplastic polyolefin (TPO) membrane and has a minimum R-value of 30. Higher levels of roof insulation were modeled, but had poorer returns on investment compared to other strategies.

<table>
<thead>
<tr>
<th>BUILDING ENVELOPE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Roof</strong></td>
</tr>
<tr>
<td><strong>Type:</strong> Steel deck, insulation, white thermoplastic polyolefin (TPO) membrane</td>
</tr>
<tr>
<td><strong>Overall R-value:</strong> R-30</td>
</tr>
<tr>
<td><strong>Walls</strong></td>
</tr>
<tr>
<td><strong>Type:</strong> Stucco/insulated concrete sandwich wall system/tilt-up concrete</td>
</tr>
<tr>
<td><strong>Overall R-value:</strong> R-22–25 in all areas</td>
</tr>
<tr>
<td><strong>Basement/Foundation</strong></td>
</tr>
<tr>
<td><strong>Basement walls:</strong> 8 in. concrete, no insulation below ground; 2 in. rigid insulation on exterior basement walls from 4 ft down</td>
</tr>
<tr>
<td><strong>Windows</strong></td>
</tr>
<tr>
<td><strong>Type:</strong> Aluminum windows with double panel low-e glass</td>
</tr>
<tr>
<td><strong>U-value:</strong> 0.36</td>
</tr>
<tr>
<td><strong>Solar Heat Gain Coefficient (SHGC):</strong> 0.31</td>
</tr>
<tr>
<td><strong>Location</strong></td>
</tr>
<tr>
<td><strong>Latitude:</strong> 39˚</td>
</tr>
<tr>
<td><strong>Orientation:</strong> East/west axis</td>
</tr>
</tbody>
</table>

Top left: The gymnasium in the Student Union is visible from many different areas, including the Hall of Champions. Downlighting in Hall of Champions area uses low energy LED fixtures.

Below, lighting and ventilation components are integrated with architectural ceilings in multiple layers to create a vibrant and engaging space for learning in the Learning Resource Center in the Student Union.

Below, bottom: Each of the two gymnasiums features large tubular daylight devices (TDDs), seen as round cylinders on the left side in this image. Lighting in gymnasiums includes high efficiency multi-lamp fluorescent fixtures with three steps of lighting control. A daylight harvesting lighting control system is designed to step-dim the gymnasium luminaires in response to available daylight. Often the daylight contribution from the TDDs is significant enough that the occupants switch off the electric lighting entirely.
contains 365 individual 1,000 ft slinky coils. Pumping systems are centralized in the student union, and two-pipe heat pump water distribution piping is provided to each building. This approach allows the facilities team to perform maintenance in a centralized location that doesn’t disrupt academic functions. Energy recovery ventilators (ERVs) save energy by providing fresh air to spaces based on feedback from carbon dioxide and occupancy sensors. High efficiency two-stage water-to-water heat pumps provide space heating and cooling. The ERVs use direct/indirect evaporative cooling to precool outside air. This design reduces the cooling load on the heat pumps and geoexchange field when in cooling mode.

Penthouses on each building contain most of the heat pumps and ERVs. The school district strongly preferred the penthouse location over solutions that located heat pumps above ceilings or throughout the building in mechanical closets. The school district sent representatives on tours of existing buildings that use different strategies and systems. Feedback from the hosting schools helped the district.

Daylight analysis led to a fairly modest window-to-wall ratio of 21.3%. The windows are “tuned,” meaning the performance characteristics of the glazing vary based on orientation (north windows are treated differently than east/south/west) and function (daylight versus vision).

Mechanical Elements. Strategies were selected to reduce energy consumption and minimize the cost of heating and cooling the campus. The EGD campus uses a multitude of energy-efficient HVAC strategies, including geoexchange heating and cooling, which uses the relatively constant temperature of the earth to heat and cool the building.

The geoexchange heat pump system uses miles of sealed coiled piping (referred to as slinky loop) buried 12 ft under the EGD athletic fields. This horizontal loop field
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Airtightness testing of homes has been around for more than 20 years. Various energy programs and fluctuating energy bills have provided homeowners an incentive to improve the airtightness of their homes. Energy tax credits can also be received by the homeowner but only if the house air tightness has been verified that it is less leaky after remodeling than before.

Efforts to make commercial buildings more energy efficient in the US has only recently been incorporated into various “green” initiatives. Tests of commercial buildings show that they tend to be more leaky than the average house, based on air leakage per square foot of surface area. That means that commercial buildings are less energy efficient than the average house.

To measure the actual air tightness of a large building means more air is needed to maintain a reasonable test pressure. The Energy Conservatory, a leader in air tightness testing, has kits available to directly measure more than 18,000 cubic feet per minute of air leakage. Multiple kits and fans can be used simultaneously to generate more air for accurate and reliable measurements of air leakage for testing before and after retrofitting.

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Diagnostic Tools to Measure Building Performance

The Energy Conservatory

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HIGH PERFORMING BUILDINGS
Spring 2012
Materials
The project uses many locally sourced, recycled content and low-emitting materials. A few of the major examples include concrete, masonry, metal framing, steel, structural members, glazing, gypsum board, and a majority of interior finishes, such as ceiling tiles, carpet, ceramic tile, cork, fabrics and furniture.

Recyclables are collected and stored throughout the campus, reducing the waste stream. During construction, waste that could be reused was diverted for use in future projects.

Measurement and Verification
Representatives of the local gas and electric utility, Xcel Energy, completed measurement and verification.

LESSONS LEARNED

Specify performance values for daylighting systems and carefully commission them. In this project, lighting controls required more substantial commissioning efforts post-occupancy than any other system. While specifications for lighting controls in traditional control systems designate function, performance values must also be specified for daylight harvesting control systems.

Specific, targeted foot-candle levels, turn-on, turn-off points, and measurement reference locations must all be communicated to the contractor and/or commissioning agent. However, because different lighting control products have different capabilities, it can be difficult to write an open specification for a lighting control system that functions in a particular way but does not exclude too many products.

At the EGD campus, building commons were designed with a tri-level lighting system (six lamp, fluorescent high bay that steps dims depending on the daylight level measured by a daylight sensor. However, the originally installed hardware did not have the capability to stop dim the lights back up as the sun went down.

The lighting control manufacturer, electrical contractor and architectural/engineering team spent extra hours during commissioning to develop a work-around involving a custom logic board for the lighting control system. Had the expectations of the lighting control system been more explicitly defined, this may have been avoided.

Build in some safety factor with ventilation requirements. In this case, the normally accepted tolerance for testing and balancing meant some areas were originally balanced below the requirements of ASHRAE Standard 62.1-2007. Rebalancing was required to bring all areas into compliance. Ventilation schedules need to include a safety factor if the specifications allow the contractor a range of acceptable balance amounts.

Networked lighting systems offer advantages. Traditional relay panel-based lighting control systems can be somewhat difficult to configure as performance characteristics become more and more complex (daylight harvesting, occupancy sensor controls, manual overrides, multi-level switching, scheduled operation, etc). Networked lighting control systems seem to offer greater flexibility in the face of these new performance expectations.

LESSONS LEARNED FROM DENVER PUBLIC SCHOOLS

Bring the building engineer on staff before mechanicals are complete so the engineer can learn how to operate the system.

Bring the campus manager on staff at least six months before the grand opening.

The low-VOC sealant on the gym floor is flaking. The gym floor will have to be sanded down and refinished with a better product this summer. While this product did not perform well, low-VOC sealants offer benefits to building users. Careful research and consideration is needed to select the best product for a specific application.

Lamps for interactive whiteboards should be selected based on potential natural light levels. In this project, the light gathering classroom windows and design can make it difficult to view the interactive whiteboards. During specific times of the year, the natural light washes out the boards. A brighter lamp should have been selected to prevent this from happening.

This process identified several items that had not been functioning as efficiently as intended, even after building commissioning was completed.

Some of the corrective measures taken include rebalancing several heat pumps to resolve ventilation issues and recalibrating occupancy sensors. The design and M&V team have found some issues with lighting controls, which are being adjusted to reduce energy use further.

This measurement and verification process was provided as part of an Xcel Energy rebate program that ultimately resulted in a $51,363 payment to the school district for the implementation of 55 noted and verified energy conservation strategies.

Conclusion
The Evie Garrett Dennis Campus is the first project built by Denver Public Schools that takes measures toward achieving net zero energy. It is somewhat unusual that the solar-ready infrastructure was actually used in the first year of building operation.

This concept requires more planning during the design process, but can significantly increase the feasibility of installing renewable energy at a later date. This will allow building owners to more affordably install renewable energy technologies as funds become available.

ABOUT THE AUTHORS
Laura Barnett, LEED AP, is a sustainable analyst for M.E. GROUP in Denver. Pete Jefferson, Associate Member ASHRAE, High-Performance Design Professional (HPDP), is a mechanical engineer and the managing principal of M.E. GROUP’s Denver office.

Mariano’s Fresh Market is committed to bringing its customers the freshest, high-quality foods. It’s also committed to sustainability and proudly displays its list of green accomplishments for its customers.

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