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SUSTAINING SCIENCE

BY DAVID ADE, AIA

The Sustainable Urban Science Center at Germantown Friends School in Philadelphia advances science and sustainability through student conversation and exploration, supporting the school's mission of lifelong learning and stewardship of the natural environment. Designed as a building that teaches, the facility features demonstration of sustainable strategies such as photovoltaics and cisterns that collect rainwater for toilet flushing.

The private kindergarten through 12th-grade Quaker school, founded in 1845, is located in Philadelphia's historic Germantown neighborhood, where a Revolutionary War battle was waged. Approximately 855 students attend the school. The Sustainable Urban Science Center, which is used by the ninth through 12th grades, doubled the size of the previous chemistry, physics and biology labs.

In addition to regular classes, students can pursue advanced and independent work in most disciplines. The Science Center includes dedicated space for such independent study work.

Building Envelope

Building performance begins at the exterior envelope where façade construction consists of a pressure ventilated rainscreen system and a curtainwall glazing system. Although the tight urban site restricted building orientation to that achievable within the existing city grid, rainscreen cladding on the exteriors of the south-facing classrooms mitigates heat gain. The rainscreen system divorces the cladding from the exterior wall construction, allowing air to circulate behind the panels, and reducing heat transfer through the wall.

Opposite Throughout the interior, the structure and building systems are designed to be exposed to view, eliminating the need for additional interior finishes and providing for a visible demonstration of the system pathways.

Above The zinc-clad physics classroom is cantilevered over the first floor to shade the fully glazed meeting rooms.

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Sun studies were conducted to determine if sunshades were needed at the window openings in the south façade, but computer modeling indicated that the height and proximity of an existing building would provide adequate shading during most of the school year. Interior solar shades address the brief periods during which additional shading is needed.

The steel-framed metal stud system includes 6 in. of sprayed-in biobased insulation, exterior sheathing and a continuous fluid applied membrane air barrier that establishes the exterior weather membrane. This assembly is covered by the 2 in. vented rainscreen system. On the north façade that faces the interior courtyard, a floor-to-ceiling energy-efficient curtainwall (U-value of 0.29) allows daylight to flood the common circulation spaces and provides views to the rain garden.

The facility uses two roofing systems that work in tandem with the storm water management system. In both roof systems, rigid insulation is layered on top of metal deck and covered with white thermoplastic polyolefin (TPO) membrane roofing. In areas where it is exposed as the exterior surface, it provides low reflectivity rating.

In other areas, the TPO assembly is covered by a vegetated roof. In both cases, the roofing system reduces heat island effect, a critical consideration for this urban site. A small outdoor classroom was created at an accessible portion of the

BUILDING AT A GLANCE

Name Sustainable Urban Science Center

Location Philadelphia

Owner Germantown Friends School

Principal Use Upper school (ninth–12th grades) science laboratory classroom building

Includes State-of-the-art teaching labs for chemistry, biology, and physics plus independent study areas, shared faculty offices, and a landscaped courtyard classroom

Employees/Occupants Eight faculty, 200 students

Occupancy 68%

Gross Square Footage 16,420

Conditioned Space

11,607 ft^2 regularly occupied spaces conditioned (heated and cooled)

4,813 ft^2 lobby, vestibule, upper gallery circulation spaces (heated only; cooled through natural ventilation)

Distinctions/Awards

Award of Excellence, 2011 National AIA/CAE Education Facility Design Awards

Honorable Mention Educational Category, 2010 Excellence in Design, ED+C

LEED for Schools Gold, 2010

Cost $7.7 million

Cost Per Square Foot $468

Substantial Completion/Occupancy September 2009

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vegetated roof so that small groups of students may safely occupy the roof to observe this living system throughout seasonal changes.

System Strategies

The building team sought to maximize daylight and views by designing the lab classrooms to receive natural light from multiple orientations. These classrooms are daylit from at least three sides, using borrowed light when an exterior wall is not available.

The single-loaded common circulation areas, which are organized around a courtyard, are designed with full-height glazing, while a skylit two-story atrium provides daylighting for the interior areas. Artificial lighting operates in

Above The second level circulation gallery is organized around a central skylight. The exposed steel and concrete slab construction provides reflectivity to enhance the daylighting performance. This space provides access to the lower level vegetated roof.

Below, left Each lab classroom has extensive daylighting. Heating and cooling are via a dedicated heat pump that is coupled with the geoexchange well system.

Below, right The chemistry lab classroom includes a periodic table that is laser cut into the rubber flooring.

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The lower level of the vegetated roof is accessible to students and faculty and provides direct views to the cisterns and photovoltaic array.

tandem with the daylighting design through zoned switching, with linear orientation running parallel to the exterior window wall. This design also provides user flexibility within the classroom to separately light the lab and lecture areas.

Operable windows throughout the building provide fresh air ventilation during swing seasons when artificial cooling is not needed. The lobby and gallery circulation spaces (about one-third of the building floor plate) are naturally ventilated through two levels of operable windows. No artificial cooling is provided to these areas. Discussions with the school during the design phase considered an automated system for windows, but the school determined that too much automation would isolate the students from interacting with their "living" building.

The facility uses two sources of renewable energy: 24 geoexchange wells, which reduce the electrical load required to condition the building, and three photovoltaic arrays (10 kW).

The photovoltaic arrays are designed to offset about 6% of the project's total annual energy cost at maximum load conditions. Although the life-cycle analysis indicated an approximate 30-year payback for this system, the school included it as a demonstration of an alternative energy source.

Distributed heat pumps, located adjacent to the spaces they serve, reduce duct sizes and runs (and material costs) and provide efficient delivery of conditioned air. The tight exterior envelope at the classrooms eliminated the need for perimeter heating, freeing up floor area for casework and allowing for an overall smaller building footprint. Less square footage translated into lower initial construction costs, and a smaller building volume translated into lower operating costs.

In the fully glazed circulation areas, hot water from a water-to-water heat pump is distributed through radiant ceiling panels for heating, while cooling to these areas is provided through the natural ventilation that is supplemented with a rooftop exhaust fan on the hottest days. Because the circulation areas are only transient spaces, the school was open to higher

ENERGY AT A GLANCE

Annual Energy Use Intensity (Site) 43 kBtu/ft²
- Natural Gas* 5 kBtu/ft²
- Electricity 37 kBtu/ft²
- Renewable Energy 1 kBtu/ft²

Annual Source Energy 129 kBtu/ft²

Annual Energy Cost Index (ECI) $1.5/ft²

Annual Net Energy Use Intensity 42 kBtu/ft²

Annual Load Factor 15%

Savings vs. Standard 90.1-2004 Design Building 41%

ENERGY STAR Rating 64

Heating Degree Days 4,954

Cooling Degree Days 1,101

*Note: Natural gas used for domestic hot water only. Data based on model. Actual use not available because the building is not submetered.

WATER AT A GLANCE

Annual Water Use 3,291 gallons

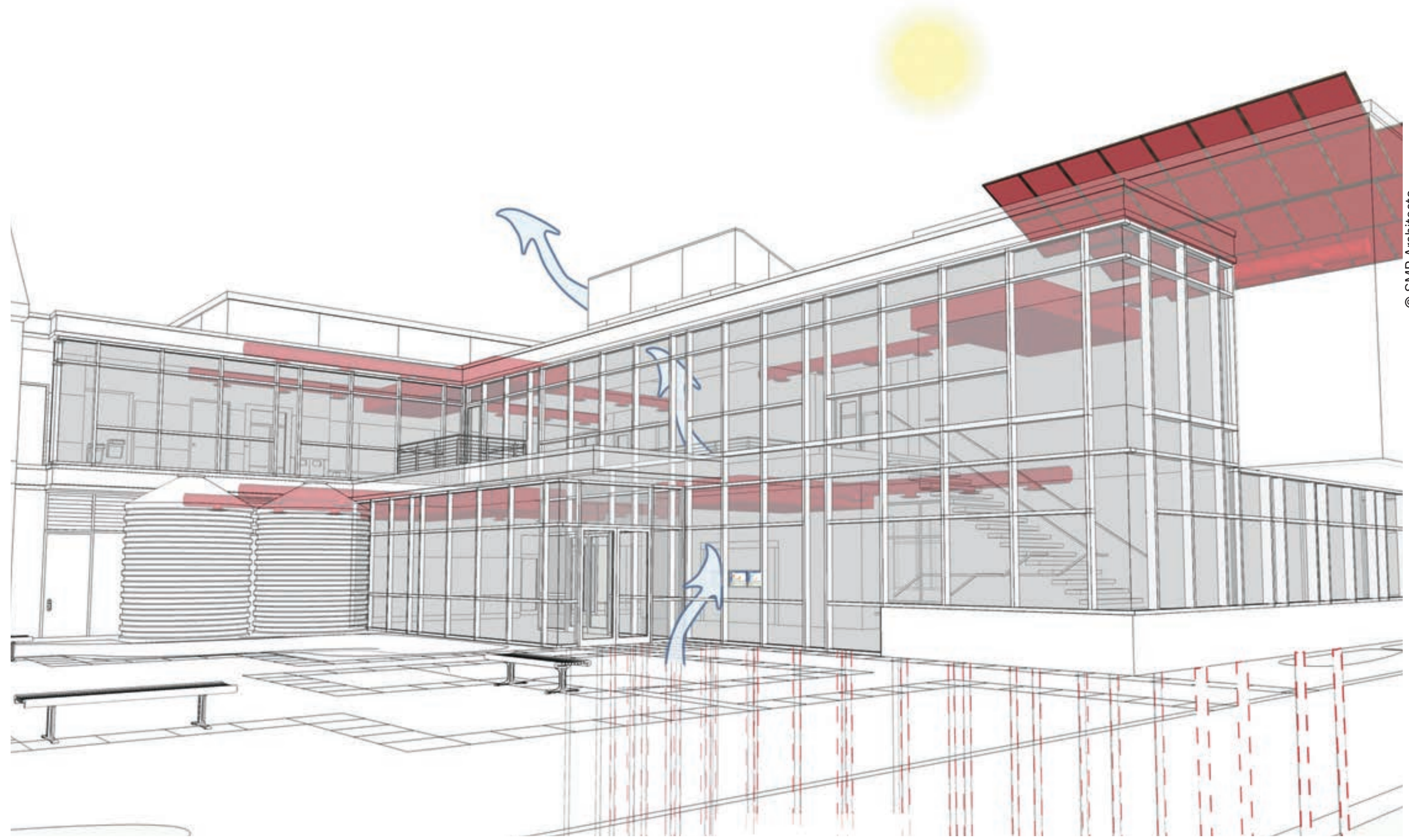
ELECTRICITY USE, 2010

	kWh
Jan	9,322
Feb	4,256
Mar	15,312
Apr	22,319
May	20,260
Jun	19,233
Jul	20,728
Aug	18,115
Sep	17,065
Oct	10,180
Nov	9,283
Dec	7,877

temperatures (82°F to 85°F) in these spaces to achieve greater efficiency in the building systems. The classrooms, office and meeting spaces where students and faculty require comfortable spaces in which to learn and teach are cooled by the ground-coupled heat pump system.

A gas-fired hot water heater provides domestic hot water for the restrooms and labs.

The building system runs are all exposed to view as teaching opportunities for the faculty to highlight the different systems and describe their functions. Driveway surface patterns indicate the buried geoexchange well field below, giving students a visual representation of the otherwise hidden building system.



The energy efficiency strategies in the building include naturally ventilated circulation spaces, three photovoltaic arrays and distributed heat pumps served by a ground-coupled geoexchange well system.

ENGAGING STUDENTS WITH SUSTAINABILITY

The Sustainable Urban Science Center design is based on the concept that buildings, through didactic example, can also serve to teach about environmental stewardship. From early planning workshops with the Germantown Friends School faculty and students, the design team focused on the concept of "Sustainability and Science in Sight."

The facility, which includes biology, chemistry and physics lab classrooms for ninth through 12th grades, engages students in a laboratory for learning on a variety of levels. On the surface, the visible integration of sustainable strategies sends a message that this building is different from any typical classroom facility.

Features such as the above-ground cisterns and the green roofs are intentionally featured in the design identity. By simply passing by, students understand that this building is different—it *looks* like a science building.

Exposed building technologies, passive systems and green materials spur daily conversation about what makes the building sustainable. The cisterns are located within direct view of the restrooms to prompt discussion about rainwater harvesting and responsible use of potable water.

At a deeper level of interaction, students connect with the facility as part of their study and research. Water level gauges on the exterior of the cisterns and pavement markings indicating the number and spacing of the geoexchange wells provide opportunities for field surveys involving measurements and calculations.

At the deepest level of interaction, students also use an integrated building monitoring system to understand how seasonal, weekly and diurnal cycles impact the efficiency and performance of the science building that they inhabit every day.

Building Materials

To reduce material use, the building structure is revealed as the interior finish wherever practical, reducing the need for another layer of interior material. The recycled-content structural steel and deck are exposed throughout the majority of spaces; they are painted white to increase surface reflectivity and daylighting effectiveness.

The concrete slabs (25% slag) are polished for a low maintenance finish and also provide good surface reflectivity. In areas such as lab casework where fit-out materials are needed, the core structures are composed of renewable wheatboard agrifiber.

KEY SUSTAINABLE FEATURES

Water Conservation
Collected storm water used to flush toilets; low-flow fixtures, dual-flush toilets; native plantings require no irrigation

Storm Water Management
Cisterns, vegetated roofs, rain gardens, underground holding tank

Recycled Materials
Concrete includes 25% percent slag, recycled content carpet and rubber tile flooring, recycled glass content tile and countertops, and toilet partitions that are comprised of recycled plastic

Daylighting
Individual controls: zoned lighting, dual lamping (for 50% or 100% light levels), solar shades, occupancy sensors, task lights at faculty desks, distributed heat pumps with dedicated spaces allowing for independent temperature control zones

Renewable Energy
Ground-coupled heat pump/geoexchange system, photovoltaics

Building Dashboard
Interactive building monitoring system

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Above The central courtyard features outdoor classroom space with access to the rainwater harvesting cisterns and storm water management rain gardens.

Below Storm water management strategies include rainwater harvesting, vegetated roofs and rain gardens.

For built-in millwork and areas of wall paneling, wheatboard and sunflower seed board are featured as examples of sustainable alternatives to traditional wood. Recycled glass-content ceramic tile and countertops are used as well, as are recycled plastic content toilet partitions.

Exterior finishes are extremely durable and low maintenance. Zinc cladding at the rainscreen is a self-healing metal that will naturally age over time. Fiber cement panels, also part of the rainscreen system, require no painting or sealing, and the panel sizing was based on standard dimensions to reduce waste. Anodized aluminum at the

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BUILDING ENVELOPE

Roof
Type 1 Metal deck with insulation entirely above roof with white thermoplastic polyolefin (TPO) membrane roofing
Overall R-value R-30
Reflectivity 0.87 (ENERGY STAR, Initial Solar Reflectance)
Type 2 Metal deck with insulation entirely above roof with white TPO membrane roofing, vegetated roof
Overall R-value R-30

Walls
Type Pressure ventilated rain screen with steel framed metal studs at 16 in. on center, 6 in. sprayed-in biobased insulation between studs, exterior plywood sheathing, fluid applied membrane air barrier, 2 in. continuously vented air gap, exterior siding in fiber cement or zinc
Overall R-value R-44
Glazing Percentage 40

Basement/Foundation
Slab Edge Insulation R-value R-8
Perimeter Insulation Under Slab on Grade R-value R-8

Windows
U-value 0.29
Solar Heat Gain Coefficient (SHGC) 0.38
Visual Transmittance 70%

Location
Latitude 39° N
Orientation Linear east-west orientation with the majority of classrooms having southern exposure

Top Lab classrooms are paired around a shared lab prep room. Heating and cooling are provided by ground-coupled heat pumps that are located above each prep room ceiling.

Above The main lobby and event space is flooded with daylight. The space is naturally ventilated and is heated through hot water radiant ceiling panels that are suspended at the perimeter glazed walls.

window systems likewise requires no finish upkeep for the life of the installation.

During construction, more than 91% of construction waste was diverted from landfills. The building design includes built-in stations to support the school's recycling program.

Storm Water Management

Storm water management is a critical consideration for urban sites, particularly in older cities like Philadelphia, where the combined storm and waste water system overflows into the local river during heavy periods of rain.

Storm water is managed through rain gardens, vegetated roofs and rainwater harvesting. Careful study was required to balance the loads/needs of these systems as they must perform in tandem as an integrated system.

Storm water that falls on the outdoor classroom plaza, as well as portions of the parking lot, is directed as sheet flow into the central rain garden courtyard, where water flow is highlighted at stone

An aerial view of the project provides an overview of the storm water management strategies: vegetated roofs, rainwater harvesting cisterns and an ecological rain garden landscape at the central courtyard and entry streetscape.

outfalls and at a decorative grate crossing in the pavement.

The natively-planted rain gardens include a variety of ground covers, shrubs and canopy trees that create an urban oasis for insects and birds. After only 24 months of growth, the landscape is reestablishing the type of regional woodland that existed on this site prior to urban development.

Two levels of vegetated roof, one of them accommodating outdoor student seminar space, manage storm water for the lower portions of the roof area. Storm water from the non-vegetated upper roofs fills two 4,800 gallon aboveground cisterns and feeds a linear rain garden along the driveway and sidewalk.

The cistern water is UV treated for use in the building to flush toilets. When the cisterns reach capacity during heavy rainfall periods, they overflow into the rain gardens, rather than into the municipal storm sewer.

The landscape requires no irrigation as the native plants are accustomed to the seasonal changes in local climate. Together with low-flow plumbing fixtures, the potable water use is less than half when compared to a LEED defined base case design.

In addition to functioning as a series of educational demonstrations for the school, the landscape and site design also serve as a best management practices example of ecological storm water design and have been used as a case study by the municipal water department.

Performance

After two years of occupancy, the building is using about 15% less energy than design modeling predicted and 41% over the base case design. Rainwater harvesting and plumbing design have reduced water use by 54% over the baseline design.

BUILDING TEAM

Building Owner/Representative
Germantown Friends School

Architect, LEED Consultant
SMP Architects

General Contractor
Wolfe Scott Associates

Mechanical, Electrical Engineer
Vanderweil Engineers

Energy Modeler EMO Energy Solutions

Structural Engineer CVM Engineers

Civil Engineer F.X. Brown

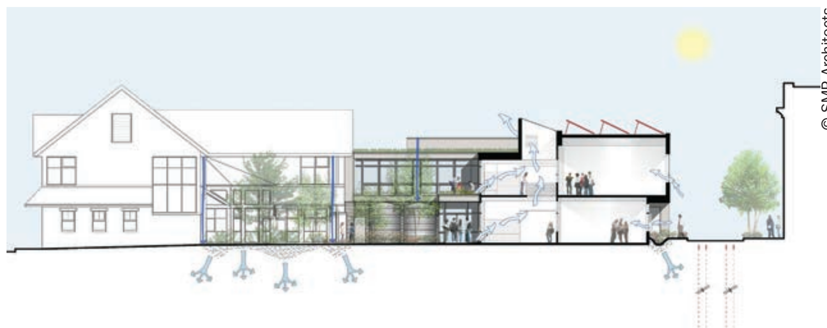
Landscape Architect
Viridian Landscape Studio

Lighting Design
Lighting Design Collaborative

Lab Planner HE+RA, Health Education + Research Associates

Building Monitoring System
Lucid Design Group

At the ground floor level the faculty offices, meeting rooms and biology lab classrooms are organized around the central entry lobby that faces the outdoor classroom courtyard with a rain garden ecological landscape.



Daylighting is a key design strategy for the project with a skylit atrium enhancing classroom daylighting through borrowed light at the center of the building. Circulation spaces are naturally ventilated while mechanically cooled lab classrooms and offices have operable windows for swing seasons.

The building monitoring system plays an important part in the facility's performance because it allows students and faculty to understand in real time the impact of their daily actions. Interactive flat screens for the monitoring system are prominently located in the entry lobby, and as reported by the science faculty, interacting with them has become a daily practice for many students.

The system is available through the school's website, so the school community may access it for information about sustainability, or those with specific research interests may compare and contrast performance to other nongreen buildings on campus.

The project team worked with the school to establish single-stream recycling. The system documents recycled versus debris weights, allowing students to quantify over time the success of their recycling efforts.

Conclusion

True to the Society of Friends' mission of decision making through group consensus, goals for collaboration among owner, design team and contractor were established from the early stages of design. This partnership significantly contributed to the overall success of the project. ●

LESSONS LEARNED

Heat Pump Access. To reduce the length of duct runs, heat pumps are distributed throughout the building, located in support space ceilings adjacent to the areas served. Due to low floor-to-floor constraints defined by an existing building, the heat pumps serving two of the labs are challenging for the owner to access for maintenance. In retrospect, the owner would have preferred giving up floor space to a mechanical closet.

Cistern Pump. Although the pumps serving the cistern were designed and commissioned to meet acoustic requirements, they developed noise issues not long after the building was turned over to the client. Extensive research by the design team, subcontractor, and facilities staff eventually led to discovery that the wrong type of small rubber drain plug had been installed at the base of each pump. Once corrected, the noise issue was resolved.

Cistern Roof. The profile of the roofs on the aboveground cisterns is an inverted cone. This cone sheds rainwater by gravity, but this water is not captured and flows off to the adjacent surfaces. During intense storms, the cisterns' location near the building façade was generating heavy deluges toward the face of the building, resulting in intermittent leaks in the façade. A diverter shield now redirects the cistern roof runoff away from the building façade.

ABOUT THE AUTHOR

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