IN NEED OF a new facility to educate future chemists, doctors and dentists on their campus in southern Massachusetts, Bristol Community College tasked the design team with creating a cutting-edge teaching laboratory. However, while the project was paused due to funding questions, the design team seized the opportunity to reassess their initial approach. The revamped design resulted in the first zero net energy lab in the Northeastern United States with a 70% reduction in energy use at no added construction cost.
The 50,000 square foot John J. Sbrega Health and Science Building at Bristol Community College (BCC) in Fall River, Mass., provides a means for science education in a wide variety of disciplines.

Located at the edge of the college’s main lawn with close proximity to the entrance, the project site provided a unique opportunity to showcase a commitment to environmental sensitivity and a sustainable design approach to the built environment of the campus.

An initial basis of design called for a high performance building with numerous energy-conservation measures (ECMs) to meet the statutory requirement of Massachusetts LEED Silver Plus, including a minimum of 20% energy-cost reduction (compared to ASHRAE/IESNA Standard 90.1-2007).

While the project paused for funding, the college intensified its American College & University Presidents’ Climate Commitment (ACUPCC) to carbon neutrality by 2050 and initiated plans to develop a site-based solar array. The site solar array would be funded through a power purchase agreement (PPA) in which a third-party finances and installs the array. Over the term of the 20-year contract, the college can then purchase the renewable energy at a reduced rate with no annual rate escalation over the duration of the term.

Pausing the project for funding presented the design team with the opportunity to reassess the original high performance design, which, according to preliminary energy analysis, would not have kept pace with the college’s 2050 commitment. The design team made a strategic investment to develop a zero net energy (ZNE) design.

LEFT Achieving zero net energy means the amount of energy required annually to operate the building is offset by an equal amount of energy generated on site, a difficult feat for an energy-intensive building type in a cold climate like New England’s.

BELOW The John J. Sbrega Health and Science Building accommodates flexible instructional labs and support space for field biology, biotech, microbiology, and general chemistry.
CASE STUDY  JOHN J. SBREGA HEALTH AND SCIENCE BUILDING

BUILDING AT A GLANCE

Name  John J. Sbrega Health and Science Building  
Location  Fall River, Mass.  
Owner  Bristol Community College  
Principal Use  Teaching Laboratory  
Includes  Wet labs, dental/radiography area, computer labs  
Employees/Occupants  28 full-time; 250 transient  
Gross Square Footage  50,600  
Distinctions/Awards  NBI Verified Zero Net Energy (2017); AIA COTE Top Ten Award (2017); USGBC Energy Efficiency Award (2017); I2SL Go Beyond Project Award (2016); Candidate for LEED Platinum

ENERGY AT A GLANCE

Annual Energy Use Intensity (EUI) (Site)  45 kBtu/ft²  
Electricity (Grid Purchase)  –33.1 kBtu/ft²  
Electricity (On-Site Solar)  65.7 kBtu/ft²  
Roof Solar Array (60 kW)  4.8 kBtu/ft²  
Site Solar Array (3.2 MW)  60.9 kBtu/ft²  
Natural Gas  12.4 kBtu/ft²  
Annual On-Site Renewable Energy Exported  15.9 kBtu/ft²  
Annual Net Energy Use Intensity  –15.9 kBtu/ft²  
Annual Load Factor  47.5%  
Savings vs. Standard 90.1-2007 Design Building  76% (this reduction represents site EUI before accounting for renewables)  
Percentage of Power Represented by Renewable Energy Certificates  100% (contracted to purchase RECs for 20 years)  
Percentage of Carbon Deferred by Purchasing Offsets  N/A  
Heating Degree Days (Base 65°F)  5,207  
Cooling Degree Days (Base 65°F)  1,086  
Annual Hours Occupied  4,800  
Annual Water Use  50,430 gallons  

KEY SUSTAINABLE FEATURES

Water Conservation  Low-flow lavatories, kitchenette and laboratory sinks.  
Daylighting  The main atrium features daylight-dimming controls.  
Individual Controls  LED indicators interface with weather station to notify occupants of proper ambient conditions to manually open windows and enable natural ventilation in labs.  
Carbon Reduction Strategies  Reduced overall building loads, PV arrays on roof and across campus driveway, solar hot water system.  
Other Major Sustainable Features  Ground-source and air-source heat pumps, LED lighting design (0.58 W/ft²), automated natural ventilation in atrium, DOAS with energy recovery wheels, filtered fume hoods.  

BUILDING TEAM

Building Owner/Representative  Bristol Community College  
Architect/Landscape Architect  Sasaki  
General Contractor  Bond Brothers  
Mechanical/Electrical Engineer, Energy Modeler  BR+A Consulting Engineers  
Civil Engineer  Nitsch Engineering  
Commissioning Agent  Synergy Engineers  
Geothermal Consultant  Haley & Aldrich, Inc.*

*The site array installed in the PPA was sized to generate enough electricity to offset the consumption of the entire campus. Preliminary energy analysis showed the Health and Science Building required only a 22% allocation of the total generation to achieve net zero in conjunction with the smaller roof-mounted array.

Figure 1  THE ORIGINAL HIGH PERFORMANCE DESIGN (LEFT) AND THE NEW ZERO NET ENERGY DESIGN (RIGHT)
Sustainable Design Strategies

Drawing upon extensive industry experience and benchmarking analysis of lab teaching facilities around the world, the architects and engineers of the design team chose to attack the most critical energy driver associated with the space type by minimizing the building’s loads and optimizing the systems designed to serve them. This involved focusing the early efforts of the design on understanding plug loads, passive solutions, and occupant behavior.

The design team accomplished this by taking a holistic approach to the design, as opposed to a “bells and whistles” approach. The team vetted various different combinations of design options using exhaustive building simulation, calculations, and research and discussions with manufacturers of advanced building technologies. The team performed a comprehensive plug load study, plugging in every piece of equipment to be installed in the new building to correctly size the cooling and electrical systems.

Follow-up interviews with educational staff and faculty provided valuable insight to equipment use patterns, which the team then developed into energy use profiles, maximizing the accuracy of the energy analysis. The team also performed extensive computational fluid dynamics (CFD) analysis to optimize the building’s orientation and window operation to provide the opportunity to naturally ventilate the space when the ambient conditions allowed.

For every premium paid for a sustainable technology, a savings was found somewhere else, the result of an open and fruitful collaboration between the architect and engineer (Figure 1) illustrates these and other nuanced changes made between the two designs.

ZNE buildings typically rely on renewable electricity for heating and
cooling by using a heat-pump system. This heat-pump approach often includes a large ground-source well-field, designed to handle the peak heating and cooling loads and annual demand for the building.

For the Sbrega building, this system would have required about 80 closed-loop wells, each 500 ft deep. At approximately $15,000 per well, plus the cost of high-capacity ground-source heat pumps, this was an expensive proposition. A more cost-effective approach was required.

The amount of heat energy extracted from or rejected to a thermal mass is a product of the thermal mass and the change in temperature. To reduce the amount of thermal mass (well-field size), the seasonal temperature swing in the ground of 45°F to 60°F was expanded. Therefore, after a summer of rejecting heat from the building, the ground temperature may approach 90°F maximum, while after a winter of extracting heat from the ground, the ground temperature may approach 30°F minimum.

In addition to expanding this range, the ground-source heat pump system capacity was further reduced by designing it for the heating demand, but not the full cooling demand. Instead, supplemental air-source heat pumps were incorporated into the system. On peak cooling days, running air-cooled heat pumps in lieu of a larger ground-source heat pump system results in an energy penalty. But in September, with the ground at maximum temperature, the air is often cooler: At this point, air-source can outperform ground-source.

Figure 2 shows how the ground-source and air-source heat pumps handle the heating and cooling loads of the building throughout the year.

EC-motor fan coil units were selected as the primary source for heating and cooling in most spaces, especially the labs, to further reduce both the main air-handling unit system size and the heating and cooling energy required to precondition the outdoor air. Completely decoupling the primary heating and cooling from the ventilation allowed the systems to more quickly recover from aggressive night-setback temperatures. A total energy heat recovery wheel was installed in the main air-handling units to precondition the outdoor air. Completely decoupling the primary heating and cooling from the ventilation allowed the systems to more quickly recover from aggressive night-setback temperatures. A total energy heat recovery wheel was installed in the main air-handling units to precondition the outdoor air.

In the “high performance” design, energy demand was driven largely by 18 fume hoods that exhaust 100% outdoor air. After a period of vetting the technology involving, among other things, visiting similar installations and speaking with users, the college agreed to switch to filtration fume hoods and air-quality monitoring.

Filtered fume hoods reduce the main air-handling unit size, which reduces the construction cost, and also reduces the heating and cooling energy required to precondition
the outdoor air. The system allows the labs to safely operate at four air changes per hour when occupied and two air changes per hour when unoccupied, with an emergency purge mode as necessary. Reduced minimum airflow significantly reduces the annual reheat energy.

This and several other decisions unlocked a series of strategies (Figure 3) that reduced the energy use intensity of the building by roughly 80%, including:
• Thirty-three percent to 67% reduction in air changes (occupied/unoccupied);
• Enthalpy wheel heat recovery;
• Decoupling cooling/heating from ventilation, using fan coil units for local control;
• Sixty-seven percent reduction in air handler capacity;
• High performance envelope to minimize heat loss by air leakage and thermal bridging;
• Expansion of interior temperature range to 70°F to 76°F degrees;
• Natural ventilation: operable windows, automatic in the “living room” and manual in labs;
• Twenty-two percent window-to-wall ratio;
• Self-shading: deep roof overhangs; fritted glass; shading devices; and
• LED lighting design using half the number of fixtures typically found in laboratories (0.58 W/ft²—a 50% reduction from baseline).

The design team also prioritized the comfort, health and wellness of the occupants. These factors work hand-in-glove with efficient operations. The following are a number of areas of special interest:
• Daylight: sizing/locating windows so daylight enters where needed; light-colored ceilings reflect daylight into rooms; walls abutting the atrium are glazed, allowing daylight into labs;
• Connection to the outdoors: natural ventilation; views; access to inviting roof terraces; building and landscape connected with indoor/outdoor “living rooms,” comfortable outdoor seating spaces.
• Thermal: achieved by decoupling heating and cooling from ventilation and allowing local control of

in the atrium, daylight enters the south and north ends through a two-story tall curtainwall and on the east side through a clerestory.
• IAQ: active air quality monitoring; increased outdoor air; use of low VOC materials, coatings, and adhesives; flush-out period for the HVAC system; natural ventilation.

A ground-source heat pump system heats and cools the building by using the geothermal ground loop as a heat source in the winter and heat sink in the summer.
temperature; high performance envelope; natural ventilation.

- Visual: Glare is controlled with both fritted glass and window treatments.
- Acoustical: Use of filtration fume hoods allows labs to be much quieter than labs fitted with standard fume hoods; ventilation air is delivered at a relatively low velocity; absorptive materials are placed appropriately; mechanical equipment is located either inside or behind screens, dampening noise.

- Activity and exercise: Monumental open stairs; elevator is downplayed; 1.5 acre lawn for recreation and on-campus wellness activities, promoting the physical health of the student body.

**Zoom Out**

Overall, the ZNE design reduced energy consumption by a predicted 70% compared to the original high performance design, saving over $100,000 in operational energy cost per year. Figure 4 shows that the first year of operation resulted in 10% less energy consumption than predicted by the energy model. Because the building requires a smaller portion of electricity generated by the PPA-funded site array than was initially anticipated, the building is operating net energy positive.

This achievement is in spite of unanticipated natural gas use associated with domestic hot water heating, which is largely due to the continuous operation of circulating pumps as well as the losses through the uninsulated copper tubing of the laboratory eyewash system. A valuable lesson learned by the design team for future projects is to avoid using dual-fuel domestic hot water heaters and
storage tanks, which contributed to the discrepancy observed in the case of this building.

While the dramatic energy use reduction of the ZNE design is a remarkable achievement for the team, the investment made by Bristol Community College to pursue such a groundbreaking target had to be justified fiscally as well. The brief project hiatus presented the rare opportunity to have two different designs cost estimated independently, so individual equipment additions and deletions and their associated impacts could be evaluated side-by-side.

When reconciled with the up-front cost savings over the original high performance design (equipment downsizing, program space, etc.), the cost of the additional features in the ZNE design resulted in an overall project construction cost increase of less than 1%. However, the design team sought utility incentives and applied for a Pathways to Zero Grant from the Massachusetts Department of Energy and Resources, which more than covered the slight construction cost increase.

The ZNE design had truly beaten the original high performance design, consuming 70% less energy and costing $200,000 less in up-front construction cost. Furthermore, the net life-cycle cost savings of the building and power purchase agreement are estimated to be over $4 million.

Conclusion

Located near the main campus entrance (Figure 5) and featuring an open breezeway effect, the “gateway” impact of the Sbrega Health and Science Building cannot go unnoticed. Organized around light-filled central atrium space, primary instructional and study spaces invite a broader constituency to collaborate and learn in more informal ways that jibe with the unique design features used in its conception. The first laboratory building to be zero net energy verified in the northeastern United States, this building has pioneered the concept of pushing the limits of sustainable design while maintaining an occupant-friendly teaching environment.

ABOUT THE AUTHORS

Chris Widzinski, P.E., LEED AP BD+C, is a sustainable design engineer at BR+A Consulting Engineers in Boston. S. Fiske Crowell, FAIA., LEED AP, is a principal at Sasaki in Watertown, Mass.