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John J. Sbrega Health and Science Building, Fall River, Mass.

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).

The John J. Sbrega Health and Science Building accommodates flexible instructional labs and support space for field biology, biotech, microbiology, and general chemistry.

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.

Instructional spaces are organized around a shared, light-filled learning commons and student "living room." The walls separating lab spaces from the atrium are glazed, allowing for views into the labs.

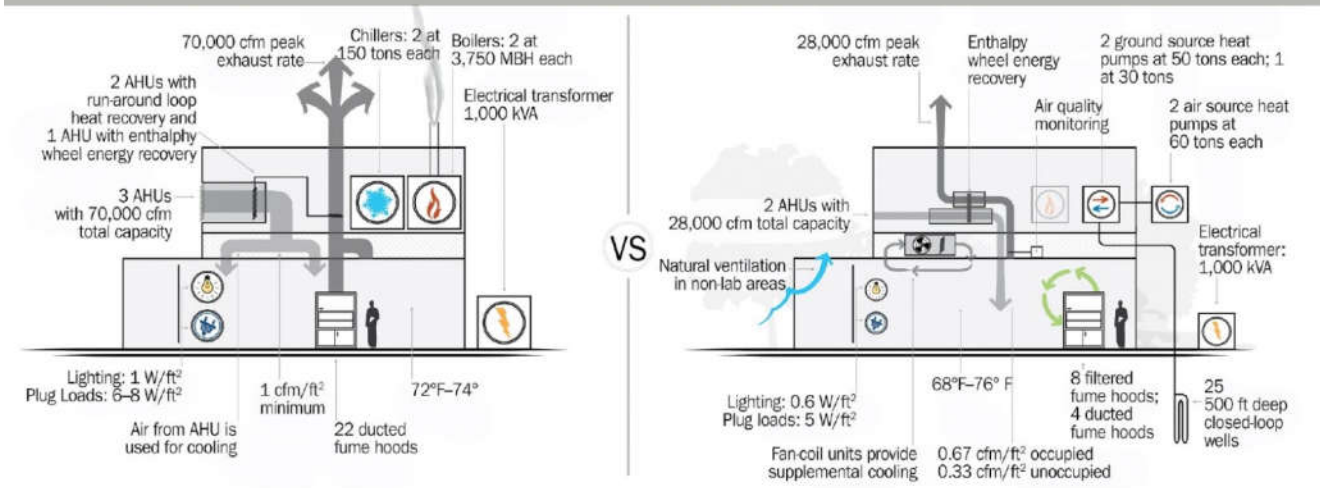
Sustainable Design Strategies

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.

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

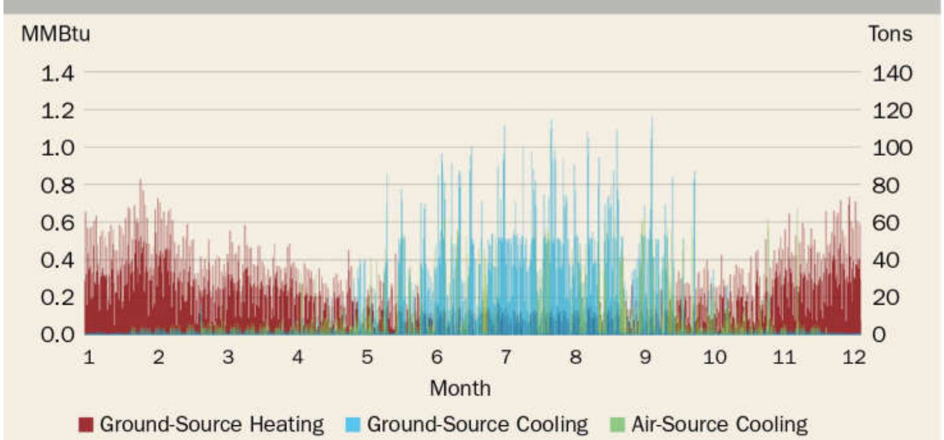


For every premium paid for a sustainable technology, a savings was found somewhere else, the result of an open and fruitful collaboration between the architect and engineer (*Figure 1*) illustrates these and other nuanced changes made between the two designs.

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.

Figure 2 HEATING AND COOLING SYSTEMS OPERATION

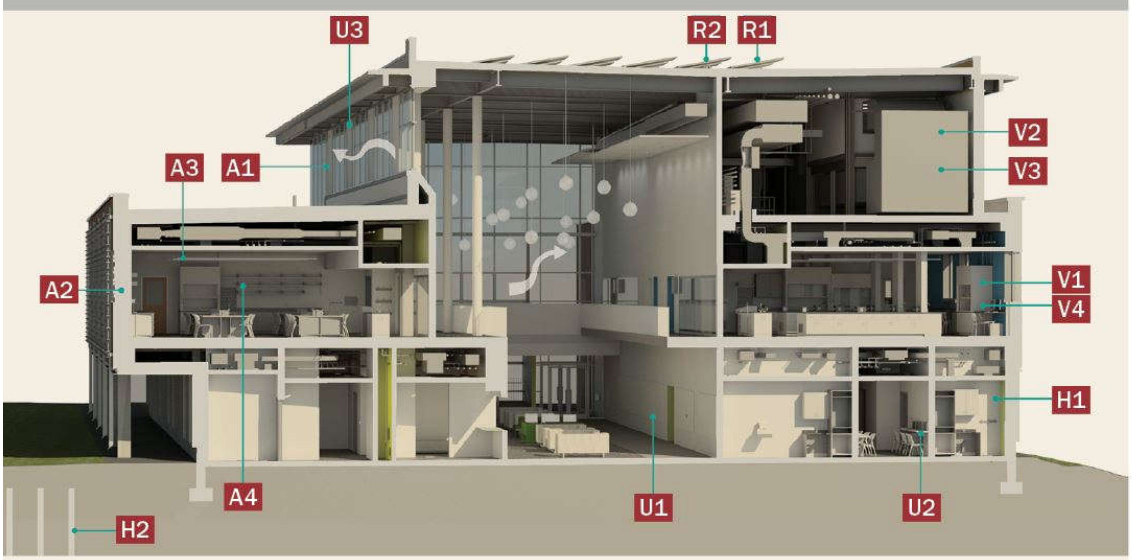


The amount of heat energy extracted from or rejected to a thermal mass is a product of the thermal mass and the change in temperature. To reduce the amount of thermal mass (well-field size), the seasonal temperature swing in the ground of 45°F to 60°F was expanded. Therefore, after a summer of rejecting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

Figure 3 ZERO NET ENERGY DESIGN



VENTILATION

- **V1** Ductless/filtration fume hoods
- **V2** Dedicated outdoor air systems
- **V3** Enthalpy wheel energy recovery
- **V4** Air quality monitoring

ARCHITECTURAL/LIGHTING

- **A1** Optimized glazing
- **A2** Envelope commissioning
- **A3** LED lighting
- **A4** Daylight/Occupancy sensors

HEATING AND COOLING

- **H1** Localized cooling
- **H2** Ground source/Air source heat pumps

USERS

- **U1** Expanded temperature setpoints
- **U2** Laptops
- **U3** Natural ventilation

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:

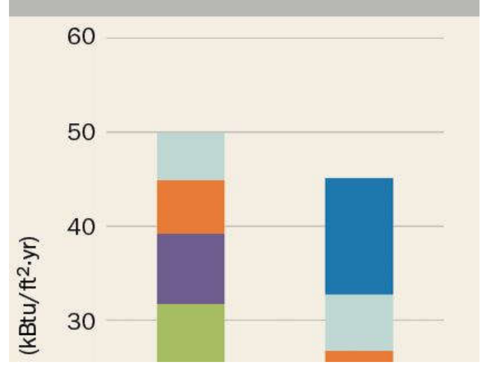
- Daylight: sizing/locating windows so daylight enters where needed; light-colored ceilings reflect daylight into rooms; walls abutting the atrium are glazed, allowing daylight into labs; in the atrium, daylight enters the south and north ends through a two-story tall curtainwall and on the east side 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.
- 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 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.

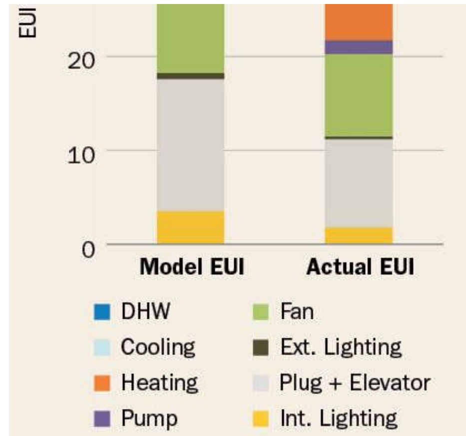
Figure 4 ENERGY USE



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.

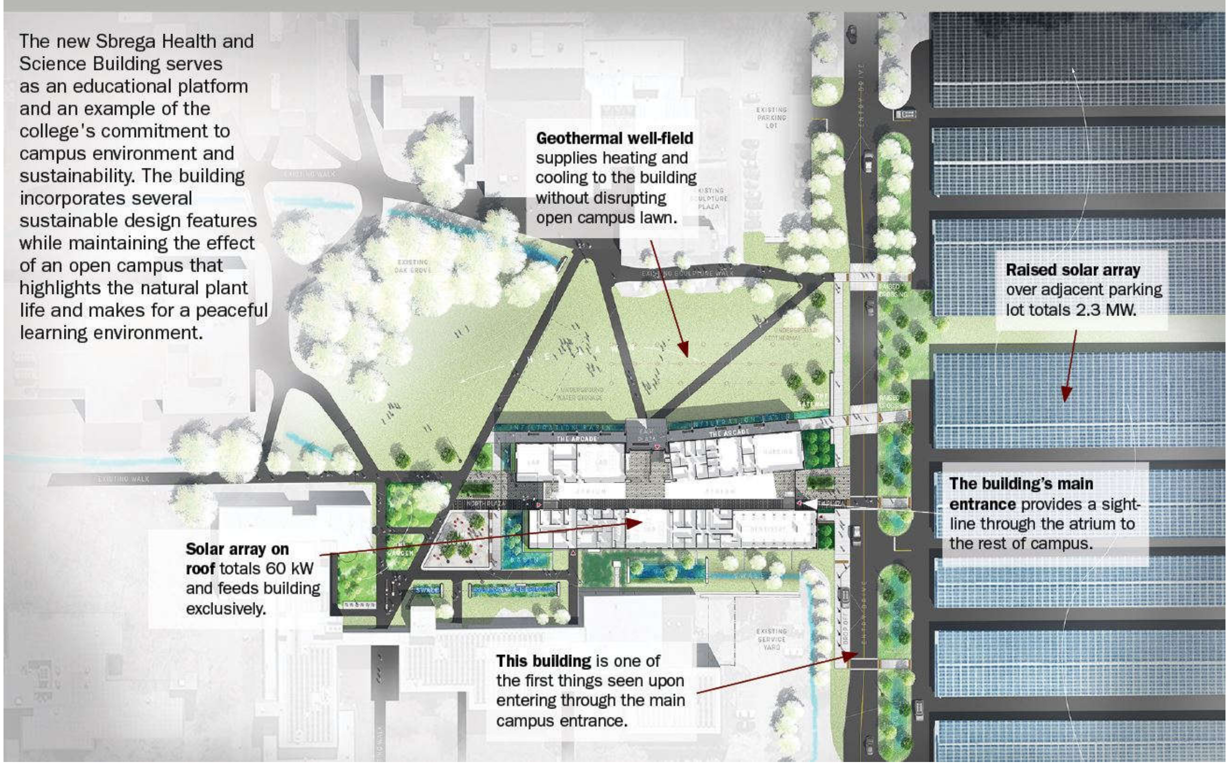
When reconciled with the up-front cost savings over the original high performance design (equipment downsizing, program space, etc.), the cost of the additional features in the ZNE design resulted in an overall project construction cost increase of less than 1%. However, the design team sought utility 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.



Metered energy use of the Sbrega building compared to anticipated use predicted by energy modeling.

Figure 5 SITE MAP



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. •

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