Ultra Low Energy Campus Case Study

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OVERVIEW

Predicted EUI: 25 kBtu/sf/yr

Renewable Energy Use Production: 15 kBtu/sf/yr

Net EUI: 10 kBtu/sf/yr

Building Size: 273,000 sf

Location: City of Cambridge

Construction Type: New Construction

Construction Year: 2019

Occupation date: August 2019

KING OPEN/CAMBRIDGE STREET UPPER SCHOOLS AND COMMUNITY COMPLEX

In 2015 the Cambridge city council voted to adopt a Net Zero Action Plan, requiring all city buildings to target net zero energy design by 2020. When the City issued the request for proposals for the new King Open/Cambridge Street Upper Schools and Community Complex, it explicitly stated the project goal of net zero emissions, knowing that the project would open just ahead of 2020. Arrowstreet Architecture and Design, in association with William Rawn Associates, won the award and stepped up to the challenge to build the city's first all-electric, net zero emissions project. With thoughtful consideration for the occupants, the team designed a complex that maximized efficiency through the building configuration and integrated energy reduction strategies that are expected to result in 43% less energy than the average regional school.

Lessons Learned:

- Take advantage of the site's resources by capturing daylighting, shading, and on-site energy optimization, and other passive design strategies.
- Conduct feasibility studies and interviews to gain insight into occupant needs and unique needs. Carefully investigate daily and seasonal use patterns, and ask about equipment needs in case they can be combined and shared.
- Allowing future occupants to be part of the design process created ownership of the building, encouraging them to participate in maintaining the building during occupancy.
- Occupant engagement post-construction is essential for the complex to operate as designed. Engagement teaches students, staff, and visitors how the building operates best. For students, engagement translates into focused learning opportunities for students to become future environmental leaders.

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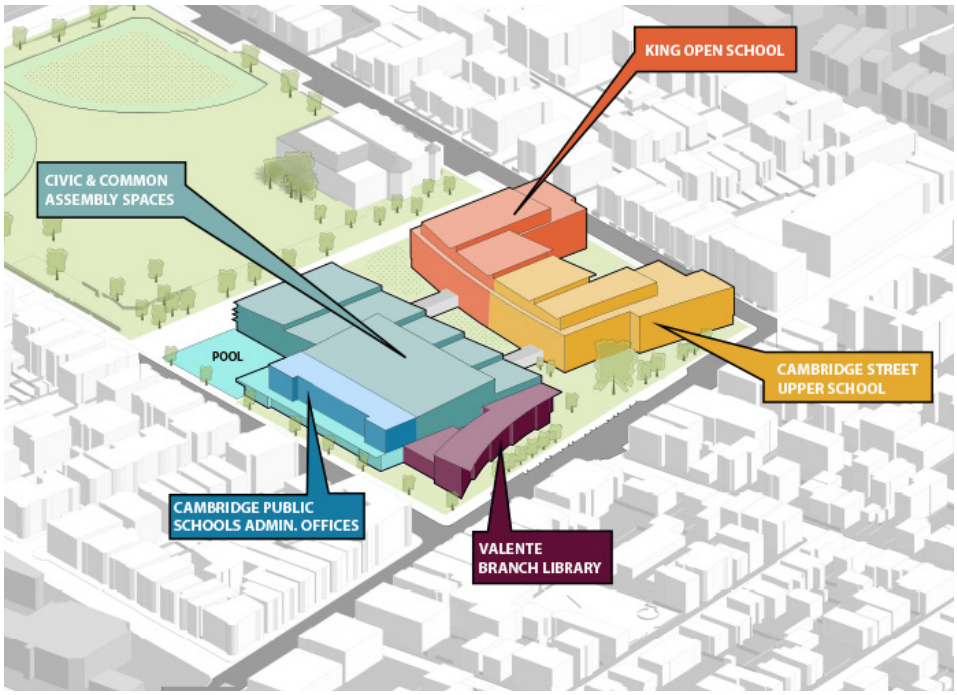

Credit ©Arrowstreet Architecture & Design

PROJECT DETAILS:

Climate Zone: 5a

Project Team Owner:
City of Cambridge

Architect: Arrowstreet Architecture and Design and William Rawn Associates

Contractor: W.T. Rich

Energy Consultant: In Posse

MEP Consultant:
Garcia, Galuska & DeSousa

Awards: LEED® Platinum, USGBC Massachusetts Green Building of the Year

Planning and Design Approach

Project Goals

The complex combines seven unique programs into a new building, replacing the existing building. The goals were to create a 21st-century learning environment while maintaining the culture and heritage of the rebuilt schools. The team was also tasked with achieving net zero emissions. To do this, they targeted an energy use intensity (EUI) of 25 kBtu/sf/yr and focused on promoting occupant wellness, reducing site impacts, minimizing water use, and providing a resilient community resource.

The 273,000 square foot, city-owned complex is split into two wings and includes space for the King Open School, Cambridge Street Upper School, Cambridge Public Schools Administration (CPS), Valente Branch Library, Department of Human Services, parking garage, and a community pool.

Stakeholder Engagement

The seven different functions in the complex meant had to explore the site constraints and design possibilities through a year long feasibility assessment. They engaged with 30 unique user groups including staff, students, parents, school alumni, public safety, community members, and future occupants. This provided real-world insight into how and when users anticipated using the structures. The interviews allowed the team to assess the space needs against the energy goals and evaluate synergies between occupant needs, energy efficiency opportunities, and economic practicality. Shared spaces and equipment were among the strategies selected to achieve both space efficiency and energy efficiency.

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THE COMPLEX CONSISTS OF:

1. King Open Elementary School
2. Cambridge St. Upper School
3. CPS District Administration
4. Valente Branch Library
5. Department of Human Services
6. Parking Garage
7. Community Pool

Feasibility Assessment

During the feasibility assessment, the design team studied the site, soils, seasonal sun paths, rainfall, and community use of the site to assess the energy production and water collection potential. Spaces were evaluated for dual purpose if possible to minimize that would have added unnecessary square footage. Studying the operating hours of each space provided insight on how to group and organize the different functions. For example, community spaces that require operation seven days a week are separate from those with more conventional hours. The partition allows energy-using systems to be turned off during non-operating hours. Similarly, the team evaluated how spaces could be optimized through shared spaces and/or equipment. Grouping pods of classrooms by grade allowed the team to reduce the number of appliances such as refrigerators and copy machines.

The academic wing comprises classrooms and is distinct from the community wing which includes services for the neighborhood. These community spaces are open seven days a week with after school and summer programs. The community wing contains the cafeteria, gyms, and auditorium, all of which require different energy demands from the academic wing.

Energy Modeling

Early energy modeling helped the team study the building orientation, solar panel arrangement, and select the most efficient HVAC system. The design team began with a base model and ran many iterations to find the most effective massing and orientation to achieve the best daylight and lowest energy load. The model also informed optimal solar orientation, slope, and massing of the roof forms to generate the most energy from the photovoltaic panels. The team anticipated that sloped roofs with flat solar panels would be the most effective layout for the complex. However, modeling proved that a flat roof with double E-W sloped solar panels is the most effective design.

Through early iterative energy modeling studies, several HVAC plant systems and various energy conservation measures were evaluated. Measures were reviewed individually and interactively to select the lowest energy load options for the budget. The results proved that a geothermal heat pump system fit the energy needs best.

The early energy studies allowed the team to make site-specific decisions.

Energy Efficiency Strategies and Features

Envelope

Buildings in the complex are organized to promote solar access. The orientation maximizes daylight and targeted a 40% window to wall ratio. Windows include double-insulated spandrel glass and are thermally broken to minimize heat transfer. The roof design maximizes the number of photovoltaic panels by organizing roof vents and walkways to coordinate with renewable energy production. The envelope includes an average R-28 wall and R-40 roof insulation which will reduce the building's heating, cooling, and lighting needs and help maintain a comfortable environment for the occupants.

Lighting and Daylighting

The team's approach was to utilize daylighting before electric light. Daylighting studies highlighted opportunities to maximize daylight and control glare. Sensors indicate when to provide electric lighting in classrooms that mimic daylighting to enhance student comfort and alertness. In offices, task lighting supports more detailed activities. Vacancy sensors turn off lights when rooms are empty. Electric lights are all LED and use an average of 0.29 watts/sf. The LEED credit for Interior Lighting - Lighting Quality was achieved through high-quality lighting, material surface and furniture selection, and connection to the outdoors. The lighting optimizes productivity, comfort and well-being of the occupants and is predicted to use 30-50% less energy than code.

HVAC

Deep energy savings must be achieved in HVAC systems to achieve an overall low EUI target. The team studied various possibilities and opted for a decoupled system where the heating and cooling are independent of the ventilation system.

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Ground source heat pumps use refrigerant to transfer heat through 197 pipes buried in the earth. In the winter, the ground becomes a heat source for the refrigerant and in the summer, it is a heat sink, taking advantage of the moderate ground temperature. The heat pumps raise and lower the temperature of the refrigerant and pump it through pipes to heat and cool the space radiantly. The radiant heating and cooling systems are quiet and thermally comfortable.

The outside air system with energy recovery operates the demand-controlled ventilation and humidity conditioning. Displacement ventilation supplies air at a low velocity from supply diffusers. This minimizes the feeling of blowing air and is much quieter than a traditional system, creating an optimal environment for learning. The exhausted return air heat is captured through the energy recovery system to preheat/cool the outside air, reducing energy consumption. Decoupling the ventilation from the heating and cooling decreased the size of the distribution ducts and reduced the energy needed to move the air through the buildings.

Domestic Hot Water

The complex is all-electric. Electric water heaters serve the core of the complex while the kitchen has dedicated solar thermal panels. Excess hot water from the panels is used for the pool. Low flow water fixtures throughout the complex reduce the hot water demand.

Renewable Energy Generation

Nearly 3,600 photovoltaic panels are expected to provide between 60-80% of the complex's annual energy demand. The solar array occupies almost all available roof, awnings, and a portion of the facade. Panel locations were carefully considered to avoid baseballs and other flying objects from the neighboring field. The 1.3-megawatt system is expected to provide 80% of the complex energy demands. Carbon offsets will address the remaining 20% energy to meet the net zero emission goal.

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Occupant Engagement

In addition to impacting the design, the feasibility assessment informed building operations and helped to create the content for the two operation manuals, one for the academic wing and the other for the community wing. Understanding how the occupants will use the space informed the occupant education materials. Public digital dashboards will explain the sustainability features and why they are important. The dashboard will report the sustainability measures, including energy consumption and production. Displays will also explain how to get involved in keeping the complex sustainable. This sustainability-rich complex provides a unique opportunity for the school district to create a sustainability curriculum for the students, one where they can use the building itself as a tool in learning about energy and climate.

On the operations side, the design and construction team conducted in-person trainings for the building staff before opening. The trainings were recorded for future staff viewing to minimize information loss during staff turnover.

King Open/Cambridge Street Upper Schools Complex is the first project to comply with the City's new requirement for all new municipally funded buildings to meet net zero emissions, as defined in their Net Zero Action Plan. The process and technologies utilized in the campus are well suited to other regional projects and experiences on this project will help guide others in the future

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National Grid is working to develop a Zero Net Energy (ZNE) Building program, for Rhode Island, in the next five years. To determine the best approach and necessary support to the building industry, National Grid is looking to partner and assist with projects that are working to achieve ZNE goals. The learnings from these pilot projects will allow National Grid to launch a full program in the future.

The Zero Net Energy Building Pilot Program is focused on maximizing energy efficiency and load reduction through design, construction and building operations before addition of on-site renewable energy generation.

Funding for this pilot is limited and will be based on first-come, first-serve basis. Learn more at www.nationalgridus.com/RI-Business/Energy-Saving-Programs/

New Buildings Institute (NBI) developed this case study on behalf of National Grid. For more ZNE resources, visit www.gettingtozeroforum.org/resource-hub

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