CASE STUDY
THE BOSARGE FAMILY EDUCATION CENTER

INSPIRED
BY NATURE

BY BILL MACLAY, AIA

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People visit the Bosarge Family Education Center to learn how to build a garden, to listen to a concert, or for a brief pause before touring the Coastal Maine Botanical Gardens. But, building designers hope visitors also walk away with the realization that net zero energy buildings are possible today, even in a colder climate like Maine. The center showcases the surrounding botanical beauty, and its guiding principle, “If a plant designed a building...”, resulted in a building that draws its energy from the sun, uses natural materials, harnesses daylight, and captures and reuses rainwater.

The Coastal Maine Botanical Gardens is one of the country’s youngest botanical gardens, but it has quickly risen as a top destination for visitors from Maine and across the U.S. In 2009, only two years after its opening, the gardens’ rapid growth and popularity led to the need for additional indoor space. A group of garden members explored the possibility of creating a model environmental building, and a major donor challenged the gardens to build a net zero energy building.

**Education as Inspiration**

With thousands of visitors each year, the gardens saw a significant opportunity to influence the future of sustainability in Maine and beyond by designing a building as an active teaching tool. The building outwardly demonstrates energy and resource conservation in a number of ways. The solar panels covering the south-facing roof can be seen from the parking lot; an interactive building dashboard and signage located throughout the Education Center highlight energy performance, water savings, sustainable and environment-friendly material selections, and other high performance characteristics of the project.

Additionally, a “Truth Wall,” a window through the building’s interior finishes, allows visitors to look inside the wall to see the components of the highly insulated wall assembly. Together these educational tools provide opportunities for even the most casual visitors to learn about the design process and high performance features of the building, and understand the most important lesson of the project—that net zero energy buildings are achievable today, even in cold climates.

**BUILDING AT A GLANCE**

<table>
<thead>
<tr>
<th>Name</th>
<th>The Bosarge Family Education Center</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Coastal Maine Botanical Gardens in Boothbay, Maine (50 miles NE of Portland, Maine)</td>
</tr>
<tr>
<td>Owner</td>
<td>Coastal Maine Botanical Gardens</td>
</tr>
<tr>
<td>Principal Use</td>
<td>Educational/gathering space, offices</td>
</tr>
<tr>
<td>Includes</td>
<td>Three acoustically separate, multiuse educational rooms that can open to create one large meeting room to seat 200 people; 14 offices for full-time staff with spaces for additional part-time and seasonal staff; an educational display area; a kitchen; an adjacent outdoor teaching space; and an artist-in-residence space.</td>
</tr>
<tr>
<td>Employees/Occupants</td>
<td>11 full-time employees</td>
</tr>
<tr>
<td>Occupancy</td>
<td>Office space is 100% occupied; occupancy of public/event space varies</td>
</tr>
<tr>
<td>Gross Square Footage</td>
<td>8,200</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$3.2 million (does not include cost of photovoltaic arrays)</td>
</tr>
<tr>
<td>Cost Per Square Foot</td>
<td>$390</td>
</tr>
<tr>
<td>Substantial Completion/Occupancy</td>
<td>July 2011</td>
</tr>
</tbody>
</table>
Site Design
Given the master plan for the botanical gardens and the existing layout and infrastructure, the building site was predetermined, adjacent to the existing Visitor’s Center. Located in a small valley, this site presented a challenge for maximizing the solar access critical to net zero energy success. In addition, it was important to the gardens to preserve as many of the large coniferous trees as possible.

Extensive study of the site was undertaken to maximize solar access, take advantage of views of the gardens, and create accessible pedestrian and vehicular connections to existing pathways. The result is a design that maximizes passive solar heat gain on the south wall and the opportunity to locate south-facing photovoltaic production on the roof.

A solar thermal drainback system that consists of four 54 in. × 72 in. flat plate collectors mounted on the west-facing roof with a 120 gallon storage tank provides domestic hot water. The entry, located along the visitor’s central circulation path, also allows the staff to be connected to the comings and goings of guests.

To connect intimately to the site’s nature through views and access to the surroundings, the building is designed with two wings joined by a central, transparent gallery. This gallery serves as a gateway to the gardens along a central circulation route for visitors.

The two wings meet the distinct program needs of the building: classroom and office functions. The classroom wing functions as three acoustically separate classrooms, each opening to an outdoor teaching space, or onto each other to function as one larger event space.
Energy-Efficient Design

Detailed energy modeling throughout the design process assessed numerous enclosure and building system configurations leading to the selection of a design optimized for long-term investment. The integrated design with passive solar and daylighting strategies, highly efficient mechanical and electrical systems, and super-Insulated building enclosure provides a 50% energy use reduction from ASHRAE/IESNA Standard 90.1-2007, resulting in a modeled energy use intensity (EUI) of 19 kBtu/ft²·yr, and an actual EUI of 19.2 kBtu/ft²·yr before renewables.

All below-grade surfaces are designed to achieve a minimum energy use intensity. Floor-to-ceiling windows connect this wing to the outdoors on the north and south.

The two-story office wing is oriented perpendicular to the educational wing. It provides views to the gardens from both floors through large windows that visually engage the staff in the activity of the adjacent gardens.

Landscaping around the building is composed of native and drought-resistant species, which require no irrigation. Water-saving technologies, such as dual flush toilets, waterless urinals and 0.5 gpm manually operated lavatory faucets — along with water reuse — contribute to a predicted reduction of 46% in building water use compared to a typical building (LEED baseline).

Runoff from the south roof is collected in a 1,700 gallon underground tank for reuse in the building toilets, the only permissible use allowed by Maine building code. On the north side of the building, rainwater from the roof scuppers drains through a pea stone trench into adjacent bioswales, which channel storm water runoff into the ground and gardens, minimizing garden irrigation needs and filtering the runoff before it reaches the ocean.

**BIRTH OF MAINE’S FIRST BOTANICAL GARDENS**

In the mid-1990s, a group of Maine residents, sharing a belief that Maine needed a botanical garden, acquired a 128-acre parcel of tidal shore land with nearly a mile of tidal saltwater frontage. To buy the land, several directors of the founding organization used their own homes as collateral. The Coastal Maine Botanical Gardens were born on this land, becoming one of only a handful of waterfront botanical gardens in the United States.

A later gift of an additional 120 acres brought the total garden area to 248 acres, making it the largest botanical garden in New England when it opened in 2007. The gardens attracted about 40,000 visitors in its first year. Today it hosts about 100,000 visitors annually. Visitors can stroll through ornamental gardens and traverse miles of waterfront and woodland trails, which include various plantings, stonework, waterfalls and fountains, and scenic views. The gardens, which are open year-round, offer programming throughout the seasons, such as a Fireside Book Club, age-specific gardening classes and children’s activities.

“Fairy Fridays” is for “little fairies, gnomes, elves and wizards” and takes place in the Bibby and Harold Alfond Children’s Garden. The summer program offers dancing, puppet shows, stories, dress-up, games and building fairy houses.

Source: Coastal Maine Botanical Gardens and Thornton Tomasetti
R-value of 20 with 4 in. of expanded polystyrene (EPS) rigid insulation. The above-grade walls are designed to achieve R-40 and roofs are designed as R-60 assemblies. The walls and roof are composed of 12 in., 16 in. or 18 in. 1-stud filled panels with dense pack cellulose. Large expanses of triple-glazed R-6.25 windows manufactured in Germany allow for passive solar gain during the winter. Additionally, reducing air infiltration through the building enclosure was a priority for the design team. Careful detailing based on building science, a continuous air barrier and vigilant construction practices of air sealing and blower door testing resulted in an enclosure that achieved an air infiltration rating of 0.115 cfm50/ft2 exterior surface area.

Premium efficiency lighting, a combination of LED and compact fluorescent with an automated control system and daylighting strategies, provide an estimated 60% reduction in lighting energy use over Standard 90.1-2007, and contribute to the quality of indoor conditions for occupants. South-facing windows with light-guiding blinds along with north-facing windows and skylights provide even light to the educational wing.

Glazing in the connector creates an open, airy space, while skylights highlight wall-mounted educational displays. The office wing is organized to take advantage of solar access: high windows allow for deep daylight penetration, and window treatments including roller shades allow for views even when blocking glare. Higher windows are equipped with light-guiding blinds, which bounce the light deep into the space.

Mechanical systems include a variable volume refrigerant heat pump that provides heating and cooling. This air-to-air heat pump extracts heat from the outside air during the winter and rejects heat to the outdoors during the summer.
Ventilation is provided passively through operable windows in the summer. During the winter, mechanical ventilation is provided by energy recovery ventilators, which recover 70% of the heat from exhaust air and deliver it back into the fresh incoming airstream.

**Materials and Construction**

Beyond the high environmental goals, the owner wanted the Bosarge Family Education Center to be a beautiful recognition of Maine’s heritage, complementing the surrounding gardens and existing Visitor’s Center. However, the Gardens were restricted by a tight budget and a short construction schedule.

The design team brought a construction manager on board early in the design process to explore different ways of meeting the client’s performance and design goals while executing the majority of construction outside of the busy summer season. To meet the conflicting project requirements, reduce waste and minimize site impact, the team selected a panelized construction system. This allowed the majority of the building enclosure to be fabricated off site and assembled rapidly on site.

With the shell in place, construction inside continued through the winter, allowing construction to be completed before summer. What would typically have been a 12- to 14-month construction project was completed in less than 10 months.

The team carefully selected materials and finishes for the building to meet the owner’s goals of beauty, local sourcing, character, high performance, and environmental considerations.
recycled content, low or no toxicity, durability and low environmental impact. Eighty-five percent of the wood in the building is Forest Stewardship Council (FSC)-certified, and locally harvested wood was used for the flooring, ceilings and trim.

Natural finishes were used wherever possible, including clear wood finishes, mill finish aluminum and polished concrete. A total of 90% of on-site construction waste was recycled.

The interior is finished with non-VOC and nontoxic paints and stains. These less toxic materials combined with building science help eliminate the possibility of mold, and appropriate ventilation rates calibrated to carbon dioxide monitors help ensure good indoor air quality.

**Net Zero Energy Performance**

Solar was determined to be the best option for the on-site generation of renewable power needed to help accomplish the Education Center’s net zero energy goals. Two photovoltaic arrays totaling 45 kW were specified to cover the building loads on an annual basis.

The building consumed 19.2 kBtu/ft²·yr and the PV panels produced 23.5 kBtu/ft²·yr from November 2012 to October 2012. Of the total solar produced on site 7 kBtu/ft²·yr was consumed directly by the building before being exported to the grid. Excess solar is sent to the grid and becomes a “credit” when it cannot be used directly on site at the time of production.

The building imported the remaining 12.2 kBtu/ft²·yr from the electricity grid from their accrued credit to meet the remaining annual energy needs. The net zero energy building goal was desired by a donor, who paid for half of the building cost and made a challenge pledge to solicit other donors for the remaining building costs. The PV system was purchased through a power purchase agreement with the donor who was able to use the tax credits, and then sell the electricity to the Coastal Maine
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Botanical Gardens through a long-term agreement.

Locating all of the required PVs on the building roof was discussed; however, programmatic needs for the office space and concerns about the aesthetic aspect of one large rooftop array for the entire building led to the decision to break up the roof massing. So, the approximately 1,800 ft² rooftop array for the entire building was separated at the wooden trusses overhead, which impacted the structural approach and financial aspects. Additionally, the wooden ceilings, separated at the wooden trusses overhead, supported and enhanced the musical performance space, while allowing for acoustics that would meet the acoustic needs of the performance space. The resulting space has the beauty and performance of the German-manufactured windows are a true asset to the project.

In the end, however, the doors did not meet the requirements of the Americans with Disabilities Act Accessibility Guidelines (ADAAG), highlighting the challenges of coordinating with a company unfamiliar with ADAAG. The building opened with a temporary occupancy permit, and the exterior doors were replaced by those from a U.S. manufacturer.

Acoustics. The client’s program included a performance space that could be divided into three separate classrooms. The primary function for the performance space was musical performances, while the classrooms were intended for use by school groups. The unique needs for this space impacted the structural approach and finish selection, making it a critical item to resolve early in design.

The disparate uses called for acoustic isolation of the tall classroom spaces separated at the wooden trusses overhead, while allowing for acoustics that would support and enhance the musical performances. Additionally, the wooden ceilings, selected for their natural character, needed to support the desired sound qualities. The final solution included acoustically treated fixed and operable panels in the wooden trusses and acoustic insulation behind the wood slat ceiling. The resulting space has met the acoustic needs of the performance space, and the flexibility for one to three spaces enables a variety of uses.

LESSONS LEARNED

Windows and Doors. For performance, aesthetic and cost reasons, the owners and design team selected German-made windows and doors for the project. Coordination with a company outside the U.S. with whom the design team had never worked prompted some initial concerns. These concerns included language barriers, measurement conversions and production time, but the benefits of the product were deemed to outweigh these potential challenges. The beauty and performance of the German-manufactured windows are a true asset to the project.

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Monitoring. It was important to the building owner to include within the building design an energy monitoring program that would track net zero energy performance and provide a more detailed breakdown of energy use within the building. A detailed monitoring system was developed that could meter each subsystem separately to understand their contribution to the whole building’s energy consumption including lighting, heating and cooling, ventilation, hot water heating, plug and miscellaneous loads, rooftop PV production, and other on-site PV production.

However, during the first year several challenges arose involving the design, installation, data interface and owner coordination of the monitoring system. This meant that only the utility data—how much energy was imported from and exported to the grid—could be collected. Consequently, during the first year of the building operation, when system tuning should be taking place, no data was available to determine how much energy the systems in the building were actually consuming.

The project team needs to ask what the questions are that the monitoring will answer, who will track the data and how it will be tracked, and identify all of the possible ways to achieve the answers desired. Multiple options exist to decipher building data, such as utility meters, submeters or PV inverters. After clear goals are established, coordination by the monitoring personnel between electricians, plumbing, and HVAC contractors is necessary.

It is also necessary to have a comprehensive view of all monitoring costs. Since equipment costs represent only a fraction of total monitoring costs (roughly 5% to 10%), an additional budget must be established for troubleshooting, gathering at least two years of data and analyzing the data. Personnel need to take “ownership” of the monitoring data collection for consistency of collection and data downloading beyond the first two years. Since many of the monitoring systems are new, having at least two ways to track the data to confirm energy use and production is helpful, especially within the first year when the monitoring system can be used to identify issues with the building systems. Energy monitoring is a relatively new and evolving arena, so all of the equipment should be specified from one vendor to make sure all of the components are compatible, and an experienced installer should be selected.

Educating Building Owners. One of the challenges with any high performance building is educating the building owners and facility managers on best practices for using the building. At the Coastal Maine Botanical Gardens, the intent was to provide this education as soon as the owners moved into the building. However, it took significantly longer to get the right people at the table to learn about the building operation, due to staff turnover and scheduling. As a result, systems were not functioning optimally and automatic controls were under used. Once the building owners and designers discussed the daily, monthly and yearly operation requirements of the building, operation has been much smoother for everyone.
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from November 2012 to October 2013. The building used a total of 46,040 kWh (19.2 kBu/ft²·yr). The 45 kW solar array produced 56,395 kWh, which more than offset the full year building energy use.

In addition to meeting net zero energy goals, the building is successfully achieving program goals. Gardens staff report that the building is comfortable and enjoyable.

Collaborative Process
The Bosarge Family Education Center is the result of an integrated design process spearheaded by the owner’s sustainability consultant on the project, who helped the owner set and retain the project goals, select the architects and fulfill the LEED Platinum documentation requirements. The sustainability consultant also directed the educational displays that included the installation of an interactive energy monitoring system.

The building was designed collaboratively and equally by two architecture firms, which together led an integrated design and construction team. The local firm was the architect of record and was responsible primarily for construction documents and construction administration, while the design architect led the net zero energy portion of the project.

The two firms collaborated on the building enclosure with the envelope fabricator and on-site builder. The enclosure and exposed structure were manufactured in the fabricator’s plant and erected on the building site — resulting in a two-month reduction in the construction time line to open the building in time for summer. All firms participated heavily in all aspects of design sharing and learned from each firm’s individual expertise.

An integrated design process included highly interactive and collaborative design work sessions throughout the design and construction process. Additional team members involved in the integrated design included the energy consultant; structural, mechanical and electrical, and civil engineers; a landscape architect; lighting designer and construction manager.

Other team members included numerous Coastal Maine Botanical Gardens staff, board members, donors and community members. These on-site design charrettes enabled the team to make informed choices about the site; building systems and materials; renewable strategies and budget alignment.

Conclusion
The Bosarge Family Education Center exemplifies the Coastal Maine Botanical Gardens’ commitment to environmental sustainability and helps fulfill its mission to protect, preserve and enhance the botanical heritage and natural landscape of coastal Maine through horticulture, education and research. Through the integrated design process the gardens’ environmental goals were realized.

ABOUT THE AUTHOR
Bill Maclay, AIA, LEED AP is founding principal of Maclay Architects in Waitsfield, Vt.
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