Zero Energy With an Affordable Price Tag: Friends School of Portland

The Friends School of Portland is among the most energy-efficient schools in the country. *Photo ©NCOB*

Project:

Friends School of Portland
Cumberland, Maine
Pre-K through eighth grade

Project Data:

Occupancy: Standard and Summer Programs
Gross Area: 15,000 ft^2
Site area: 21 acres
Context: Suburban/Rural
Number of floors: Two
Number of students: 125
Date completed: August 2015
Cost: $3.75 million

Team:

Architect: Kaplan Thompson Architects
Engineers: Allied Engineering Company, Casco Bay Engineering, Bartlett Engineering, Blais Civil Engineers
Contractor: Warren Construction Group

Introduction

More than half of all operating school districts in the U.S. are in rural areas. These small schools operate at a different scale and have different needs than their city counterparts. In 2003–2004, 20% of public schools in the U.S. served fewer than 200 students.[1] Although the Friends School of Portland—which was designed to achieve both zero energy performance and Passivhaus certification—is an independent school, it faced financial constraints similar to those faced by many other small schools throughout the country. The project was financed through a capital campaign and a mortgage that forced a hard cost cap on the project, so the project team had to be diligent about every dollar that was spent.

Energy Data: August 2015–July 2016

	Site EUI (kBtu/ft^2·yr)	Energy Cost/ft^2	Net EUI (kBtu/ft^2·yr)
Energy Model: Design Building	9.45	–	0.57
Actual Usage	11.72	$0.82	3.67

In its first year of operation, the school site energy use intensity (EUI) was just 12 kBtu/ft^2·yr, a bit more than the 9 kBtu/ft^2·yr predicted. Although the school is among the most energy efficient in the country, the team chose to track energy usage in operations in an effort to further reduce energy consumption. With the school's simple and elegant design, the team also proved that energy efficiency and effective architecture can both be accomplished on a tight budget. Excluding site work, construction costs totaled only $196/$ft^2$.

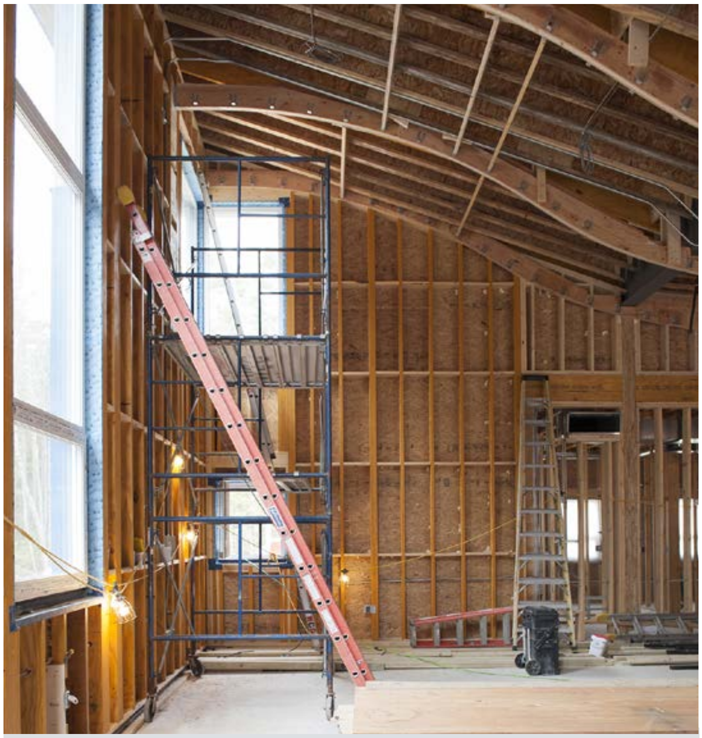
Motivation

The driver for this small school to become zero energy started with a sustainability ethic based on the Quaker values of simplicity and stewardship. Having made the decision to build on undeveloped land outside of the city, the school's building committee felt they needed to offset the environmental impact of parents driving their children to school.

To translate this set of values into a measurable goal, the design team suggested zero energy. "It was clear that sustainability was a priority, but no one was quite sure what that meant until we set the target," said Jesse Thompson at Kaplan Thompson Architects. Having a measureable goal guided the project to success.

Despite the ambitious energy goals, construction costs were far below average.

[1] Provasnik, S., KewalRamani, A., Coleman, M.M., Gilbertson, L., Herring, W., and Xie, Q. (2007). Status of Education in Rural America (NCES 2007-040). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC.



The undulating ceiling of the Meeting Room is shown here under construction. *Photo ©NCOB*

Naomi Beal, chair of the Friends of School of Portland building committee, also introduced the idea of doing Passivhaus certification, but it wasn't a requirement. "This is a young school with a small budget, and because it is private, there wasn't the possibility of obtaining government grants," Beal said. "We decided that we would make decisions in a way that would not eliminate the possibility [of achieving Passivhaus] but not commit to it from the outset."

By the time the project got through design development, the design was only a couple inches of insulation away from what was required by Passivhaus. This was a result of the team making excellent massing and orientation decisions about the building in the beginning, according to Beal. "We ended up so close to the goal that it was reasonable for us," Beal said. The school then set out to become the first school in Maine to attain Passivhaus certification.

Design and Construction Process

Getting the right design team on board was a bumpy road. The project originally employed an architect that pursued design features at the expense of the zero energy goal, insisting for example that there be a glass hallway at the southern portion of the building. "It was beautiful and artistic," Beal said. "But it put us over both our cost budget and our energy budget."

"It's important for the architect to understand that if the owner is asking for these kind of energy goals, he can't just design what he wants and then slap on some extra insulation," Beal said. The project transitioned to a new design team. "Our final design is quite a bit more modest. It is not as fancy or ostentatious, but it is what we wanted," Beal said.

In contrast to the first architect, the new design team found success by pursuing an integrated design. They worked with the mechanical engineers on the depth of the floorplan to ensure that the optimal amount of daylight penetrated each classroom, they analyzed how surface area affected heat loss, and they looked at several different roof configurations to maximize energy efficiency while meeting building height guidelines. Each decision was analyzed alongside its impact on energy use.

Despite the ambitious energy goals, construction costs for the Friends School of Portland were far below the average for the Northeast, which was estimated to be $400.36/ft^2 in 2015[2] (construction costs in this region are higher than anywhere else, and reporting is consistent).

One factor that kept costs so low was that a solar array was provided as a part of a power purchase agreement (PPA) with Ocean View at Falmouth, a retirement community located in Falmouth, Maine. A project bid for the panels came in at

Technologies

Windows	Triple-glazed windows with a solar heat gain coefficient of 0.62 and a glass U-factor of 0.15
Envelope	**Wall:** 2″ x 6″ walls with dense-packed cellulose in the framed cavities and 4″ of exterior polyisocyanurate. (Total R-value of 47) **Roof:** Ventilated truss roof with 26″ of loose cellulose (R-91) **Foundation:** Slab-on-grade with 8″stem walls insulated with 5″ exterior expanded polystyrene insulation and 2″ of interior expanded polystyrene (R-28) **Subslab:** 12″ of expanded polystyrene (R-48), dropping to 4″ where concrete is thickened for load-bearing walls
Heating, Ventilating, and Air Conditioning	Mini-split air-source heat pumps provide heating and cooling. Operable windows for passive ventilation and energy recovery ventilators for mechanical ventilation
Renewable Energy System	One hundred forty-four 255 W solar panels, 36 kW of peak output

[2] Abramson, Paul. "20th Annual School Construction Report: National Statistics, Building Trends & Detailed Analysis." School Planning and Management.

$82,680, just 3% of the final construction costs, but Ocean View offered to fund the entire purchase and installation of the panels and receive federal tax credits in return. After seven years, the school will have the opportunity to purchase the solar panels outright. In the interim, the school pays Ocean View for the power that the panels generate.

Other cost-reducing measures are credited to the project team. "One of the things that we did was structure the building to have trusses with blown insulation above," said Phil Kaplan, principal at Kaplan Thompson Architects. That meant that if more insulation was needed, the crew could simply pour a few more bags of loose cellulose into the attic cavity rather than trying to add more rigid insulation, which would have cost much more in labor to install. In fact, when the team was analyzing whether to add Passivhaus performance to its zero energy goal, they determined that it would only cost an additional $500 to upgrade the building envelope. The robust envelope also allowed the project to operate with a simple mini-split heating, ventilating and air conditioning system.

"The insulation wasn't a big cost driver," said Jesse Thompson, another principal at Kaplan Thompson Architects. "The contractor thought the windows would be expensive, but it wasn't really that bad." The most difficult coordination was actually choosing the doors, according to Thompson, because there were so many factors to consider: fire ratings, durability, security, etc. "But you would have had to do that with any school; the zero energy stuff was straightforward," he said.

The contractor also had a huge part to play in keeping costs down. Knowing that some subcontractors might not want to take the risk or escalate their bids if they were responsible for more air sealing than they were familiar with, the general contractor took full responsibility and supervised the subcontractors very carefully. The school ultimately achieved 0.32 air changes per hour at 50 Pa in airtightness, roughly two times better than what is required under Passsivhaus guidelines.

Costs

Construction cost including site work (not including PV)	$248.00/ft^2
Construction cost not including site work	$196.00/ft^2
Mechanical and plumbing cost	$22.20/ft^2
Electrical cost	$28.37/ft^2
Thermal and moisture cost	$29.04/ft^2
Doors and windows cost	$15.54/ft^2
Carpentry cost	$48.42/ft^2

Airtightness was a high priority for the project, and the building turned out to be twice as airtight as Passivhaus standards require. *Photo ©NCOB*

That is not to say that compromises weren't made for the low cost. The original design had a meeting room and a gym, but the budget wouldn't allow for both, so the building committee decided to build the meeting room first and reserve a gym for Phase II. There is also not a full-service kitchen located in the school. A kitchenette includes an oven, sink, and microwave, but students bring bag lunches, and events are catered—very typical of rural schools. "Having to accommodate a ventilation hood for a range top would have been more challenging," Kaplan said. There are proven strategies for achieving zero energy performance with a full-service kitchen, Kaplan said. "This project just had the benefit of not needing to."

On the other hand, some features unrelated to energy use added cost but were incorporated because they were important to the client. For example, white pine from the site was custom milled into long boards to use as benches in the meeting room. The boards were so large that they would not fit into a kiln, so the project team had to air dry them. "It probably was not the cheapest way to build that part of the building, but the team managed to do it in the most affordable way possible to still achieve the desired effect," Beal said.

Perhaps even more significant than the low construction cost is the impact that this high-performing building has on operating costs. The total cost to operate the building in the first year was only $12,344, or $0.82/ft^2 (including the PPA), according to Beal. And the design team believes that cost can be reduced further by ceasing to set the temperature setpoints back at night, thus avoiding high-demand charges to warm the space in the morning. "I feel that it was such a gift that was given to the school to have very low energy costs for the life of the building," Beal said. "Not being vulnerable to unpredictable heating costs is a huge advantage when you're doing your budgeting."

Careful detailing at transitions helped the project achieve Passivhaus performance. *Photo ©David Kurtis*

Lessons Learned

In the first year of operation with a functioning photovoltaic system, the school's energy use was higher than predicted, so the school has not quite achieved its zero energy goal.

The building team, however, is continuing to work with the school to get consumption down and has already identified several culprits. For example, the mechanical room was being heated and cooled, even though it is not necessary for it to be a conditioned space. The school's heating setpoint was also mistakenly set to 72°F when the energy model assumed a setpoint of 68°F. One mistake isn't so easy to fix: the LED parking lot lights weren't included in the energy model. Lessons learned include:

White pine from the site was custom milled into long boards to use as benches in the meeting room. *Photo ©David Kurtis*

- Ensure alignment between energy models and actual occupancy expectations.
- Follow up to identify sources of excessive energy use.
- Build some leeway into your model to take up slack for small details that are often missed.

All in all, compared to a conventional school of similar size, the energy use intensity of Friends School of Portland is incredibly low: 11 kBtu/ft^2·yr compared with 63 kBtu/ft^2·yr—the average for this size and building type.[3]

"If this school can do it on the budget that they had, then anyone can do it," Kaplan said. "Every building has to have a shakedown once it opens, but we are seeing it beginning to perform better and better, and the building is bright and cheerful. It has been a big success."

Resources

Zero Energy Buildings Resource Hub (zeroenergy.org)

ZNE Schools Fact Sheet

Green Schools Investment Guide for Healthy, Efficient, and Inspiring Learning Spaces

Roadmap for the Integrated Design Process ■

[3] U.S. Environmental Protection Agency. (2012). Data Trends: Energy Use in K-12 Schools. Energy Star Portfolio Manager.