EARNING THE ENERGY GRADE
Overcoming Challenges to Achieve Zero Energy in Schools

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EVERY SCHOOL DAY IN THE U.S., nearly 50 million students and about six million adults are in about 100,000 buildings that add up to about 7.5 billion gross ft² (696 million m²), according to the 2016 State of Our Schools: America’s K-12 Facilities report. This massive amount of occupied space has a lot of opportunities for energy savings.
Today, zero energy schools are out-pacing other building types with 26 verified zero energy projects and 152 more in process, according to Amy Cortese, program director at the New Buildings Institute.

As school districts face their aging infrastructure, some are electing to achieve high levels of energy-efficiency and aim for zero energy in new construction and major renovations.

From cost avoidance to increased student performance and from improved teacher retention to reduced absenteeism, pursuing high levels of energy-efficiency can be part of the solution for school districts.

The demand for zero energy schools is expected to continue growing, and schools present different challenges than other building types. Schools are traditionally strapped for funding, have increased safety concerns and operate with prolonged occupancy schedules. Building professionals with experience in zero energy schools discuss what they have faced in projects, how they have overcome those challenges and strategies to help achieve zero energy.

For Raynor Smith, P.E., Member ASHRAE, vice president for Building Clarity, the challenges that come along with zero energy schools are not exclusive to engineering strategies, construction or technology.

“It’s not just design. It’s not just construction. It’s not just operation. It’s all of it put together,” he said.

While strategies vary, high performing systems and buildings do not have to be overly complicated, they just have to perform, said Tony Hans, P.E., national director of sustainable projects for CMTA.

“Design them that way, check that they go in that way and commission them that way,” he said.

Money

Schools are historically under-funded, but even with budget restraints, achieving zero energy is possible.

Hans said cost is not the challenge stopping design teams from achieving zero energy, and studies have shown there does not have to be a significant difference in cost to build to green building standards, said Anisa Heming, director of the Center for Green Schools at USGBC.

CMTA’s first zero energy school was designed more than 10 years ago. Of that project’s budget, 22% went
to becoming zero energy. Hans said 1.3% of a more recent project’s budget is designated for the project to be zero energy.

On average, 2-3% of a project’s budget goes to renewable energy, he said. Hans credits renewable energy costs decreasing for the price drop.

If achieving zero energy is one of the owner’s primary goals early in the project, cost is not the issue. Having zero energy as a priority also helps other team members, such as contractors, understand why it is important to keep renewables in the project plans, he said.

“Zero energy doesn’t have to cost more, but it can,” said Cortese.

When managing costs, it is important to start early with an ultra-low energy target, according to Cortese.

“Teams should recognize that there are tradeoffs such as improving the building envelope, which can result in downsizing mechanical systems, which can save on first costs and lifecycle costs,” said Cortese. “Other opportunities to significantly reduce energy consumption include managing solar heat gain through proper building orientation and glazing placement, a meticulous attention to continuous air leakage control, and managing plug load energy consumption, all of which can result in energy savings.”

An operating zero energy school’s energy solutions, such as minimizing air infiltration, increasing energy performance and organizing the façade so it manages solar heat gain, can result in energy savings, she said.

Lack of Education, Exposure

Heming said lack of experience is one of the biggest barriers keeping school districts and design teams from aiming at higher building standards. School districts may be wary of their ability to operate the high performing school and are concerned with their consultants’ abilities to manage such a project and keep it within cost.

Where design teams see an increase of costs in a zero energy school project is when the team is paying for its learning curve, said Heming. Some teams’ lack of education and experience can result in changes throughout the design and construction process, which can drive up the project’s costs.

Heming pointed to the Advanced Energy Design Guide for K-12 School Buildings—Achieving Zero Energy,
which is available for free download, to help design teams learn more about strategies and solutions. Heming said the guide makes zero energy design real and shows teams how to properly set goals.

She also suggested for teams to tour existing zero energy schools, talk with architects and engineers who have experience with zero energy schools and read case studies of zero energy schools and buildings to help educate and expose themselves to the zero energy process.

Cortese said people who have completed or are working on a zero energy school have often toured another zero energy building before they started their projects.

“When people walk through a zero energy building, there’s this visceral sense of, ‘Wait. This is normal. We can do this,’” she said, adding that early research suggests people are more likely to go out and procure a zero energy project after seeing an operational zero energy building.

**Goal Setting**

Establishing an achievable zero energy target at the beginning of a project is critical to success in zero energy, according to Cortese. The energy target is often expressed as energy use intensity (EUI).

“An energy target helps organize the process and encourages the team to think of the energy budget almost like they think of a financial budget, with tradeoffs within a limit,” she said.

Hans said having a top-down approach with a clear energy goal removes barriers such as lack of knowledge and experience that tend to pull zero energy out of a project. He said if a project comes out over budget after the first round of estimating, oftentimes renewables are cut. If the owner makes zero energy a priority, renewables are more likely to be kept in the project.

“If you’re trying to become zero energy, put a EUI goal into your RFP,” Hans said, adding owners should ask for previous projects’ EUIs during the bidding process.

He also recommended for one person to “wrap their arms around the process,” as opposed to how some design teams bring in different groups of people to perform certain tasks.

**Operations**

The goal is not achieved until the school is built, and the students are in class. That is because zero energy buildings are not only designed to zero, they are also operated at zero, said Cortese.

Having an operations strategy that ties to the design and construction strategy is one of the most important aspects of creating a zero energy school, said Robbie Ferris, Sfl+a Architects/Firstfloor CEO and president.

“IT’s all about operations,” he said. “Overseeing the operations of a building can take different forms for design and construction teams.

Ferris’ business, Sfl+a Architects/Firstfloor and its strategic partners including Building Clarity—where Smith works—form an integrated team for financing, design, construction and operations of zero energy schools.

Their business model depends on the school district allowing them to own the school for at least three years to ensure the proper operation of the building, he said. If permitted to own the building for a few years, Ferris said their team can work out the kinks while training the school district how to handle the high performance systems, leading to a usually smooth transition when the district buys the school.

Smith said school districts are challenged with retaining and funding the training of operations staff to help them be successful when working with advanced building system technology, so the companies’ business model could help willing school districts.

Dealing with aging maintenance staffs and fewer people coming into
trades is a real concern for school districts, said Heming. Because of these challenges, she said some school districts are focusing on highly efficient building envelopes. “If we make a really, really efficient building envelope, we have to rely less on fancy systems within the building to keep energy costs low and to get to that zero energy mark,” she said.

While zero energy schools are going to have to use some new technologies, concentrating on the building envelope makes it easier for maintenance staff to learn and maintain these buildings, she said.

Another strategy to help set school districts up for operational success is to start the project with and maintain an integrated design process.

Cortese recommended that design teams bring together a variety of perspectives such as school officials, building occupants, engineers, architects, construction and facility managers early in the process to discuss the design, construction and operation of a zero energy school. These early meetings are a chance to get everyone on a level playing field, to understand what the school’s goals are and see how everyone plays a role in achieving that goal, she said.

“The integrated design team meetings allow the building occupants and school districts to understand how the building is going to be operated and create an environment where school district staff can share what systems they are not familiar with or do not prefer,” she said.

But zero energy schools do not have to employ the most leading-edge technology. Zero energy schools currently in operation use existing technology to achieve the demanding energy goal, Cortese said.

By the time the school is constructed, the design team should make sure the operators and the building occupants, even the students, are trained to understand the building.

“They’re living laboratories that can really stimulate learning and innovation among students,” she said, adding engaging students with building operations is a way to educate the next generation about energy-efficiency and high performing buildings.

**Retrofits**

School districts vary in levels of funding, which results in different projects taking on different priorities and strategies. Projects can be retrofits and smaller-scale improvements.

“Schools are strapped for cash, so they’re not probably going to make decisions solely about energy. However when they’re making decisions for educational purposes, they can certainly integrate energy considerations into that decision making,” Cortese said.

When funding is limited, schools should manage upgrades to HVAC systems over time and take advantage of upgrading to greener technology when replacing systems and technology, she said.

Heming said schools have options for retrofits, and those can focus on a combination of both envelope upgrades and HVAC systems upgrades.

“If you focus on one of those and not the other, you can run into some real problems, so we encourage schools to look at both of them together,” she said.
Other strategies include upgrading lighting systems, said Cortese. In some schools, daylighting has been disabled through the covering of windows, so retrofits should include uncovering those windows, putting in controls that manage the glare and integrating LEDs and lighting controls, she said.

Higher levels of energy-efficiency can be accomplished through retrofits, but some schools may not be able to achieve zero energy after a partial retrofit or simple lighting retrofit, according to Cortese.

Ferris said complete renovations that include replacing the roof, windows and mechanical and electrical systems are more successful than partial retrofits to achieve zero energy. He said schools could have glass that is oriented in a way that prohibits high efficiency levels or a sprawling layout that is not conducive to energy-efficiency challenges.

Retrofits are known to bring out interesting aspects of buildings, but school retrofits have a few more challenging factors, said Cortese.

Retrofits tend to have short construction periods as most school retrofits occur during the summer construction months, she said. This is a limited amount of time when students and other occupants are not in the school buildings, but those tend to be active times for other construction projects, she said.

Cortese recommended that anyone diving into a school retrofit make sure the project’s permitting is lined up to fit within a shortened construction schedule.

Safety
Safety is a universal concern for schools, and zero energy strategies can help increase security.

Heming said ensuring school safety is an active conversation, and modern school design strategies—such as having multiple lines of sight and a navigable design that helps staff understand what is happening in various parts of the building—can support security efforts.

Using a compact floor plan is beneficial for both security and energy-efficiency reasons, said Ferris. A compact floor plan is generally more secure because it has a single point of entrance and multiple points of visibility. Those layouts tend to use less energy than sprawling floor plans with multiple entry points and limited sight lines, he said.

Heming said schools can be designed with increased safety measures while maintaining strategies such as daylighting, which she said has been proven to increase students’ cognitive function. The State of Our Schools report adds that daylighting has been shown to increase students’ abilities to focus and retain information. Safety can be maintained through the design of the school grounds, such as through swales and berms, and school siting, such as orientation in relationship to the road and the school approach, while allowing daylight into classrooms.

“We are firmly supportive of the idea that daylight in classrooms is a non-negotiable,” she said.

Occupancy
While zero energy can be achieved in schools, there are a few differences between schools and other building types.

Notable differences are schools’ occupancy schedules and occupancy types, said Heming. Schools’ occupancy schedules affect energy use estimates and some energy modeling decisions, she said.

Schools act as centers for their communities and can be used for 12-16 hours a day unlike commercial spaces, she said. This limited downtime is a challenge for maintenance, especially in a district that struggles with allocating funding and time for facility staff to stay current on green building and zero energy building strategies.

Because schools are community
In Horry County, S.C., five energy positive schools including Socastee Elementary School (shown) use hollow concrete planks on the school’s second floor to circulate heating and cooling throughout the building when electrical costs are high to reduce peak energy consumption.

centers, they are often used during severe weather events and recovery periods.

“Zero energy strategies, such as daylighting, good air quality, natural ventilation, can increase a school’s resilience, or adaptability to operate during and after a severe event or a power outage,” said Cortese.

Sometimes the school can be islanded, and the school’s renewable power sources can keep the power on to allow people to charge cell phones during an emergency, she said. Zero energy schools can have critical power infrastructure even when the grid might not be accessible.

“If we’re looking at zero energy as a strategy for climate change and for future disaster management and for other community services, then making our schools zero energy is a no brainer,” said Heming.

Because of these considerations and how long schools tend to remain occupied, selecting systems to achieve high levels of efficiency for a considerable amount of time is important.

Not unlike selecting systems for other building types, climate, location and ability to operate systems are taken into consideration, said Smith. Factors such as access to geothermal energy, soil conductivity and hours of operation are a few examples.

Life-cycle costs tend to be a district’s first and foremost concern, he said. Most schools use systems that have about 15-20 year life-cycles, and districts typically struggle to get adequate funding to repair and replace those systems, leading to short-term fixes, he said.

If the design team can find a piece of equipment or a specification on a system that lasts longer than comparable equipment, that is good news for a school district, Smith said.

**Strategies**

For energy positive and zero energy projects, there are different approaches that must strike a balance among all the systems, especially the building envelope and the mechanical systems, said Heming.

A major strategy is focusing on a tight building envelope that includes high-value insulation, windows and well-sealed joints between materials, said Heming. Tight building envelopes combined with smart and efficient ventilation increase passive survivability for resilience and better hold indoor climates.

Roofs should be light-colored or green roofs, which positively affect insulation and storm water management, said Heming.

As renewable energy is a major player in zero energy buildings, roofs should be designed to hold...
such power sources as solar PV, or other parts of the building should be designed to optimize other power sources such as geothermal energy.

In some projects, other strategies such as better daylighting through solar tubes fight for roof space with the solar PV, said Hans. On the Discovery Elementary School project, the largest zero energy school in the U.S., Hans said the design team had to work around the solar tube layout to design for the solar PV.

“These two things can happen together. You have prime solar real estate on your roof. You have to design those things in collaboration with each other,” he said.

Other schools use an energy-efficient strategy that takes advantage of multi-story school buildings. In Horry County, S.C., five energy positive schools use hollow concrete planks on the schools' second floors to circulate heating and cooling throughout the buildings when electrical costs are high to reduce peak energy consumption, said Ferris.

Schools should be properly oriented to make use of free resources such as daylight, natural ventilation, solar heat gain and air inflation to reduce the heating and cooling loads as much as possible for efficient equipment, said Cortese. She also recommended separation between building conditioning systems and ventilation systems.

“Once you reduce the lighting load, the mechanical load and the envelope load, about half of what’s left can be plug loads. That really relies on the occupants to effectively manage their energy use,” she said.

Inside the building, high efficiency HVAC and mechanical systems, LED lighting systems and control systems are suggested.

Smith recommended to use an air cleaning device to lower outdoor air ventilation rates. While those devices can cost more than a traditional air filter, air cleaning devices lower the school's cooling and heating capacity, which lowers the HVAC, renewables and electricity costs.

“If you look at any of those single things by themselves, a lot of owners select not to do them [based] on their first cost. But if you look at how all those technologies work together, that’s where the sweet spot is,” he said.

While there are different strategies to choose from, design teams should make the decisions together and in an integrated way, said Heming, adding that teams get better results when they are on the same page early and work together.