Energy efficiency strategies used at the Kinard Core Knowledge Middle School in Fort Collins, Colorado, have made it possible for the school to operate at an impressively low energy use intensity of 21–24 kBtu/ft^2·yr since 2008 (see the Kinard Core Knowledge Middle School case study in Helpful Resources). *Photo from Project Architect RB+B Architects/Time Frame Images*

Designing for the Future: Zero Energy Ready K-12 Schools

Designing, building, and operating zero energy ready K-12 schools provides benefits for districts, students, and teachers.

Optimizing energy efficiency is important in any building, but it's particularly important in K-12 schools. Many U.S. school districts struggle for funding, and improving a school building's energy efficiency can free up operational funds that may then be available for educational and other purposes.

In addition, researchers have found that many of the qualities of a very energy-efficient building—natural light, good indoor air quality, adequate ventilation, a well-designed and perated heating, ventilating, and air conditioning (HVAC) system that maintains thermal comfort, etc.—boost student attendance and performance and improve teacher retention (see *Evidence from Scientific Literature about Improved Academic Performance* in Helpful Resources).

But what if it isn't possible or desirable to install renewable energy equipment during the construction process?

The answer is to design, build, commission, operate, and maintain the school building so that it can easily accommodate a renewable energy installation—usually solar photovoltaics (PV)—when the owner is ready to install it.

What is a Zero Energy Ready School?

A zero energy (ZE) school is an extremely energy-efficient building that produces as much energy as it uses over the course of a year, typically with an on-site PV system. Although there are other methods, building professionals commonly use a metric called energy use intensity (EUI), expressed in kBtu/ft^2·yr, to measure building energy use.*

A building that uses best-in-class energy efficiency measures to reduce its EUI and that is designed and built so that on-site renewable energy can be installed at a future date with minimal disruption and expense is said to be zero energy ready (ZER). For this strategy to be effective, the owner, designer, builder, and other stakeholders must establish a firm EUI goal and champion that goal from the beginning of the design process.

Why Zero Energy Ready?

Why would an owner create a ZER building rather than installing the renewables during construction? In many locations, there are regulatory or other barriers to installing renewables such as utility tariffs, inadequate or nonexistent net metering programs, or grid infrastructure limitations.

* The EUI numbers used in this fact sheet refer to site EUI. An explanation of site and source EUI is available from ENERGY STAR® Portfolio Manager *https://portfoliomanager.zendesk.com/hc/en-us/sections/203791327-Site-Source-EUI.*

Zero Energy Ready Checklist

In addition to being extremely energy-efficient, a ZER school building has the infrastructure in place to accept a renewable energy system (assumed here to be a PV system). To prepare the building for a future PV installation, the design and construction team considers a number of factors (see *Solar Ready Buildings Planning Guide* in Helpful Resources for details):

☐ **Grid interconnection.** It can be a time-consuming process, so look into the process of interconnecting the PV system to the grid starting early in project planning, and:

- Determine whether there are fees as well as capacity and other limitations on renewable energy systems
- Research net metering guidelines
- Investigate local policies and incentives because rules vary widely from place to place; the local building department and the Database of State Incentives for Renewables & Efficiency® (in Helpful Resources) are good starting points.

☐ **Building orientation.** Optimize building orientation for solar exposure and daylighting.

☐ **Roof structure.** Engineer the roof so it can support the weight and handle the wind loading of the PV system.

☐ **System location on the roof.** Place the system such that the roof can safely accommodate installation, maintenance, repair, and inspection of the future PV system.

☐ **Fire codes.** Check local fire codes to ensure fire personnel can safely fight a fire from the roof after the PV system is installed.

☐ **Rooftop mechanical equipment.** Minimize rooftop air handlers and other equipment to allow for maximum PV coverage; if rooftop equipment is unavoidable, locate it on the north side of the roof to minimize shading of the PV panels.

☐ **Shading.** Anticipate shading from trees and other future landscaping growth, hills, existing or future buildings, and higher sections of the ZER building.

☐ **Roofing.** Choose roofing materials carefully to ensure they are compatible with a future PV system and have a long enough life that they won't require replacement during the useful life of the PV system.

☐ **PV-specific infrastructure:**

- Leave space in equipment rooms for inverters and other PV-related hardware.
- Install conduit for PV wiring.
- Locate the electrical panel so that it's convenient to the PV system.
- Leave room in the electrical panel for the PV circuit breaker(s).
- Specify and install enough electrical panel capacity to accommodate the proposed PV system plus the size of the breaker protecting the main panel.

In addition to being extremely energy-efficient, a zero energy ready school building has the infrastructure in place to accept a renewable energy system.

Designers of Discovery Elementary School in Arlington, Virginia, oriented the building on an east-west axis to optimize solar exposure for the future PV system and maximize daylighting without creating glare (see the *Discovery Elementary: Zero Energy Is an A+ for Education* case study in Helpful Resources). *Photo from VMDO Architects/©Alan Karchmer*

Zero Energy Ready School Best Practices

Beyond preparing for the installation of the renewable energy system, the ZER process is similar to designing and building a ZE school. As more ZER schools are completed, best practices are emerging that can help ensure the success of future projects:

- Establish a firm and specific energy goal at the beginning of the process—for example, an EUI less than or equal to 25 kBtu/ft^2·yr (see *Technical Feasibility Study for Zero Energy K-12 Schools in Helpful Resources* for climate-specific EUI targets).
- Assemble a skilled, experienced team committed to the energy and educational goals and the collaborative process.
- Involve key players—students, parents, teachers, elected officials, school district administrators, facility and energy managers, community leaders, and members of the larger community who will use the school from time to time—from the beginning and solicit their input as the process unfolds.
  - Encourage coordination between the architect and engineers to take advantage of savings and efficiencies.
  - Hold collaborative design charrettes with multiple stakeholders during the design process to increase the likelihood of meeting design goals.

As more zero energy ready schools are completed, best practices are emerging that can help ensure the success of future projects.

After a massive tornado leveled most of Greensburg, Kansas, on May 4, 2007, residents decided to rebuild as a model sustainable community, a process that included the new zero energy ready USD 422 Greensburg K-12 school (see Case Studies section of Helpful Resources). *Photo by Lynn Billman, NREL 17915*

The design and construction team for Discovery Elementary School in Arlington, Virginia, involved the community from the beginning and solicited input throughout the process (see the *Discovery Elementary: Zero Energy Is an A+ for Education* case study in Helpful Resources). *Photo from VMDO Architects*

- Perform computer modeling to reduce projected energy use by working through different design and energy efficiency iterations.
- Use the energy goal as a filter for every design decision.
- Include the energy goal in requests for proposals.
- Include the energy goal as a contractual obligation in contracts with vendors and team members.
- Emphasize energy efficiency strategies to minimize the size of the future renewable energy system.
- Ensure that the school will be operated properly to maintain its ZER status by including commissioning agents, facility managers, and operations and maintenance staff or vendors in the conversation during the design process.
- Create a tracking mechanism to capture energy data such as the U.S. Environmental Protection Agency's Portfolio Manager® (see the Online Energy Tracking section of Helpful Resources).
- Challenge the engineer to focus on the design of the thermal envelope, lighting system, and plug loads; this can make it possible to design a mechanical system tuned to these significantly reduced loads.
- Monitor construction and commissioning closely to ensure that energy and educational goals are met.
- Conduct post occupancy evaluation and engagement to ensure that ZE goals are met through operations and maintenance.
- Fully commission the building for at least a year after finishing construction, which allows the team to fine-tune energy usage and find unplanned energy users such as plug loads that could jeopardize the EUI target.
- Document the process to ensure that the ZER process is replicable.

The energy efficiency measures incorporated into Richardsville Elementary School in Bowling Green, Kentucky, reduced its annual EUI to 18.2 kBtu/ft^2·yr, making it possible to get to zero energy with this rooftop photovoltaic system (see the "Achieving Net Zero: Richardsville Elementary School" case study in Helpful Resources). *Photo by Rachel Paul Photography, NREL 18603*

In other cases, the owner can't afford the cost of the PV system in addition to the new construction or modernization costs. For most owners, however, the cost of preparing the building for the installation of a future PV or other renewable energy system is manageable.

If a ZE school building isn't possible in the short term, it's worth the effort to create a ZER school because it offers many of the same benefits as a ZE school. Energy efficiency is the first and most important step on the road to zero energy, and establishing a firm and aggressive energy consumption target early in the process helps keep the team focused on energy efficiency. Among the many benefits that result from making the building as energy-efficient as possible is that it reduces the size and cost of the future renewable energy system.

Richardsville Elementary School in Bowling Green, Kentucky, is a good example. The school reduced its annual EUI to an impressively low 18.2 kBtu/ft^2·yr with an extremely efficient thermal envelope, optimal orientation and massing, and very efficient lighting and HVAC systems. The PV system was sized for a 20-year life cycle and was not bid until the later stages of construction to ensure the lowest price (see the "Achieving Net Zero: Richardsville Elementary School" case study in Helpful Resources).

Energy efficiency is the first and most important step on the road to zero energy, and establishing a firm and aggressive energy consumption target early in the process helps keep the team focused on energy efficiency.

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The Value of Zero Energy Ready Schools

Dramatically reducing energy consumption has many positive economic, educational, and environmental impacts for multiple stakeholders. Here is a sampling of the benefits of ZER schools for school districts, teachers, and students.

School District Benefits

- Competitive first costs; a ZER school can be designed and built within a typical school construction budget using conventional materials, equipment, and tradespeople
- Reduced operating costs, which free up additional money for classroom and other educational needs and decrease the school district's fixed costs for decades to come
- Improved safety and reliability during power outages, thanks to daylighting and a tight building envelope to maintain thermal comfort.

Teacher and Student Benefits

- Healthy indoor environment, reduced absenteeism, and improved academic performance (see *Evidence from Scientific Literature about Improved Academic Performance* in Helpful Resources)
  - Better indoor air quality
  - Bright, welcoming, comfortable spaces.
- Enhanced learning environment
  - The school becomes a living laboratory for science, energy, and technology
  - Students benefit from hands-on learning; they personally see the workings of an extremely energy-efficient building every day.
- Pride in their beautiful and innovative school.

Looking to the Future

As the price of PV continues to drop (see *U.S. Solar Photovoltaic System Cost Benchmark: Q1 2016* in Helpful Resources), districts with the foresight to maximize the energy efficiency of their school buildings and prepare them to accept renewable energy systems will be glad they did. And so will the students and teachers who learn and work in these buildings for decades to come.

Helpful Resources

Solar Ready Buildings Guidelines

Solar Ready Buildings Planning Guide
https://buildingdata.energy.gov/cbrd/resource/1644
National Renewable Energy Laboratory

Case Studies

Kinard Core Knowledge Middle School
https://buildingdata.energy.gov/project/kinard-core-knowledge-middle-school
U.S. Department of Energy

"Stronger, Better, Greener: Kiowa County Schools" (Greensburg, Kansas)
http://www.hpbmagazine.org/attachments/article/11966/12Su-Kiowa-County-Schools-Greensburg-KS.pdf
High Performing Buildings magazine

Rebuilding It Better: Greensburg, Kansas
http://www.nrel.gov/docs/fy11osti/49315.pdf
National Renewable Energy Laboratory

"Achieving Net Zero: Richardsville Elementary School"
http://www.hpbmagazine.org/attachments/article/11817/12F-Richardsville-Elementary-School-Richardsville-KY.pdf
High Performing Buildings magazine

Zero Energy With an Affordable Price Tag: Friends School of Portland
http://www.nrel.gov/docs/fy17osti/68782.pdf
National Renewable Energy Laboratory

Zero Energy Building Pays for Itself: Odyssey Elementary
http://www.nrel.gov/docs/fy17osti/68781.pdf
National Renewable Energy Laboratory

Zero Energy Is an A+ for Education: Discovery Elementary
http://www.nrel.gov/docs/fy17osti/68774.pdf
National Renewable Energy Laboratory

Zero Energy Definitions

A Common Definition for Zero Energy Buildings
https://buildingdata.energy.gov/cbrd/resource/1938
U.S. Department of Energy

Improved Academic Performance and Teacher Retention

Evidence from Scientific Literature about Improved Academic Performance
https://www.epa.gov/iaq-schools/evidence-scientific-literature-about-improved-academic-performance
U.S. Environmental Protection Agency

Zero Energy Building Databases

Getting to Zero Database
http://newbuildings.org/resource/getting-to-zero-database/
New Buildings Institute

Building Catalog: Case Studies of High Performance Buildings
https://buildingdata.energy.gov/
U.S. Department of Energy

Photovoltaic Costs

U.S. Solar Photovoltaic System Cost Benchmark: Q1 2016
http://www.nrel.gov/docs/fy16osti/66532.pdf
National Renewable Energy Laboratory

Zero Energy Ready on Typical Construction Budgets

An Energy-Performance-Based Design-Build Process: Strategies for Procuring High-Performance Buildings on Typical Construction Budgets
https://buildingdata.energy.gov/cbrd/resource/1640
Preprint, National Renewable Energy Laboratory

Grid Interconnection Standards

Database of State Incentives for Renewables & Efficiency®
http://www.dsireusa.org

Feasibility Study

Technical Feasibility Study for Zero Energy K-12 Schools
https://buildingdata.energy.gov/cbrd/resource/1981

Design Guides

Advanced Energy Design Guide for K-12 School Buildings: Achieving 50% Energy Savings
https://buildingdata.energy.gov/cbrd/resource/1100

An advanced energy design guide for zero energy schools is under development
www.ashrae.org/aedg

Online Energy Tracking

U.S. Environmental Protection Agency ENERGY STAR Portfolio Manager
https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager ■

U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

For more information, visit: energy.gov/eere/buildings

DOE/GO-102017-5028 • September 2017