At Discovery Elementary, a zero energy school in Arlington, Virginia, the architect used building orientation and shading to maximize daylighting while minimizing heat gain. *Photo from VMDO Architects/©Lincoln Barbour*

Zero Energy Schools: The Challenges

School districts have encountered and overcome challenges to achieving zero energy in school buildings. Here's how they did it.

School buildings have a lot of potential to achieve zero energy (ZE) in new construction as well as in retrofits. There are many examples of schools operating at ZE, and many technical resources available to guide school districts and their design and construction teams through the process. When school districts embark on the path to ZE, however, they often confront challenges related to processes and a perception that ZE buildings require "new," unconventional, and expensive technologies, materials, or equipment. Here are some of the challenges school districts and their design and construction teams commonly encounter, and the solutions they use to overcome them.

Planning and Funding Phase

Challenge: High initial cost of ZE schools.

There is a perception that the energy-efficiency technologies used in ZE schools cost more than conventional technologies.

Solution: ZE does not require cutting-edge or complicated technologies.

Many schools have achieved ZE status on the same budget as a typical school, using conventional technologies, materials, equipment, and tradespeople. To meet a firm and aggressive ZE goal on a fixed budget, design and construction teams use the energy goal as a filter for every decision. The result is often innovative and effective approaches to reducing energy use.

Successful ZE schools have a few strategies in common, starting with energy-efficient thermal envelopes and lighting systems, as well as reduced plug loads (see the "High plug loads" challenge in the Building Operations and Maintenance Phase section of this document). When these elements are incorporated into the building, the team can design a smaller, less expensive mechanical system that is fine-tuned to the greatly reduced loads.

Challenge: High initial cost of renewable energy.

Getting from ZE ready to ZE requires investment in renewable energy technologies, usually solar photovoltaics (PV), which is often the single most expensive purchase of a project.

Solution: PV costs have been dropping rapidly and it is possible to install PV on a school and achieve positive cash flow from the day it is installed.

If PV cost estimates for the project aren't current, revisit the quotes as the price may have dropped. In some areas, third-party owners will install a PV system at no cost and sell power to the school for less than traditional utility power. This arrangement is called a "power purchase agreement" and is a way to get some of the benefits of an on-site PV system without purchasing the system (see Power Purchase Agreements section of Helpful Resources).

Some schools delay the PV installation, designing the building to be ZE ready. This allows students, teachers, and the school district to enjoy the benefits of an innovative, extremely energy-efficient school building with low operating costs. Then, when the money is available to install the PV system, the infrastructure is in place and the installation can be done with minimum disruption and expense (see *Designing for the Future: Zero Energy Ready K-12 Schools* in Helpful Resources).

Challenge: Utility or local government policies that place size limits or other restrictions on renewable energy installations.

In some places, utilities and/or local authorities restrict the installation of PV and other renewable energy systems or limit the value of customer-generated electricity.

Solution: Carefully research local utility and legal regulations related to renewable energy installations and engage with the utility from the beginning of the planning process. See the Utility and Government Renewable Energy Restrictions section of Helpful Resources for more information.

In most cases, the renewable energy system will periodically generate more power than the building is using. When this happens, electricity is exported from the building to the utility grid, which requires an interconnection agreement with the utility.

Here are some key interconnection questions for the utility representative:

- Is there a limit on the size of the renewable energy system? For example, many ZE schools have PV systems in the 500 kW to 800 kW range.
- Does the local electrical distribution infrastructure have constraints engineers should be aware of as they design the renewable energy system?
- What interconnection and other utility fees apply when renewable systems are connected to the grid?
- What local, state, regional, and national policies and incentives apply to the system and how are those policies and incentives administered by the local utility and building officials (see Database of State Incentives for Renewables & Efficiency® in Helpful Resources)?
- If the school's system produces more electricity than it consumes, how would that excess production be handled (this can be critical to achieving ZE)?
  - Does the utility pay for excess generation annually? If so, do they pay a retail rate, a wholesale rate, or another rate?
  - If the system produces more electricity than the building consumes in the summer, can that production offset lower production during the winter?
  - Is the utility's rate different for consumption and generation?
  - If the school building is not all-electric, can the credits for excess electricity be used to pay for another fuel? (This is important for achieving ZE in schools that use natural gas or oil for heating—see *A Common Definition for Zero Energy Buildings* in Helpful Resources for examples).
- Is it possible to oversize the school renewable energy system and share the system—and the cost of the system—with the larger community? In exchange, the community could receive electricity and renewable energy certificates.

Other partial solutions for local utility or government restrictions include:

- Adding local energy storage to prevent peak demand charges by smoothing out the building's energy demand and to provide a work-around to utility-imposed generation limits
- Laying panels flat on the roof and/or building up the edge of the roof to hide them from view if local ordinances forbid PV systems on aesthetic grounds
- Isolating the renewable energy system behind the meter and using it to meet specific loads such as lights or an ice storage system.

Natural daylighting in the library at the USD 422 Greensburg K-12 School in Greensburg, Kansas, reduces energy use and costs. *Photo from McCownGordon Construction, NREL 17871*

Predesign Phase

Challenge: Site limitations on optimal east-west building orientation.

Ideally, the building would be aligned along a long east-west axis to maximize the daylighting potential, minimize glare, and reduce solar heat gain. However, some projects cannot take advantage of this optimal orientation.

Solution: While side lighting is difficult on east and west facades, top lighting through tubular daylighting devices, daylighting monitors, and clerestories can be used.

Perform climate-specific energy analysis to determine when heat gain is desirable and when it is not. Implement passive strategies based on the local climate to reduce heat gain. Such strategies include shading, reducing the window-to-wall ratio, and improving glazing properties. See Chapter 5, Daylighting Recommendations, in the *50% Advanced Energy Design Guide for K-12 School*s in Helpful Resources for more information.

Challenge: The design firm and other stakeholders are unfamiliar with the process of working toward zero energy goals.

It is important that the school's design and construction team is aware of and capable of meeting a ZE school's energy and educational goals. The team must also be aware that the process requires a higher level of collaboration and communication than a conventional school construction project.

Solution: Clearly define building criteria and objectives during planning, recognize that changes to one system or component affect the performance of others, and acknowledge the importance of fostering and maintaining collaborative relationships among project team members and other key players.

Have an owner's representative (typically a commissioning agent or an architect who may or may not compete for the actual project) produce an owner project requirements (OPR) document. Energy goals are a critical part of a ZE school building OPR, and energy use intensity (EUI) targets should be included in the document. Select a design team that meets as many OPR criteria as possible—especially a strong commitment to achieving the energy goal on a fixed budget and a willingness to embrace a collaborative process—through a competitive procurement process. See *Realizing High Performance Buildings: How To Maintain Energy-Efficient Design Intent During Building Operation* in Helpful Resources for guidance on how to develop energy targets in an OPR.

Construction Phase

Challenge: Building energy performance is compromised during construction.

Solution: Require that the contractor submit a quality assurance/quality control (QA/QC) plan and appoint a QA team to perform on-site inspections. The QA/QC plan should demonstrate how the specified components will be installed to meet specified performance targets. Also, a QA team should oversee the construction work. Along with the commissioning agent, the QA team should perform regular on-site inspections and maintain an issues log.

Kinard Middle School in Fort Collins, Colorado, operates at a low EUI of 21–24 kBtu/ft^2·yr thanks to careful daylighting design and a very energy-efficient building envelope.
Photo from Project Architect RB+B Architects/Time Frame Images

Building Operations and Maintenance Phase

Challenge: High plug loads.

Plug loads are mainly the result of equipment and devices introduced by the building's occupants—the design team has little control over how occupants use the building. Plug loads can account for an increasingly large portion of the energy use in a building and can produce heat, increasing cooling loads.

Solution: The school district should benchmark plug loads in existing facilities and provide that information to the ZE design team to help them estimate plug loads. The district should also hold the team accountable for meeting the total EUI goal, including plug loads.

In most cases, plug load values for existing schools will not be the target values for a ZE school; however, they can serve as a reference to help the design team estimate plug loads in the energy model. Once the school is occupied, the plug load energy use information can be compared with the target end-use plug load EUI value in the energy model. If the loads are higher than the target, the building manager and commissioning agent can develop strategies to reduce and manage these loads. Occupants should also be educated about the devices that are permitted in the building and those that are not (see the "Misuse of the building by occupants and operators" challenge in the Building Operations and Maintenance Phase section of this document).

See the Plug Loads section of Helpful Resources for specific solutions.

Challenge: Kitchen energy use.

Kitchens can account for a large percentage of energy use in a building.

Solution: Include a kitchen consultant on the design team and work with school personnel to determine the capacity, duration, and time of kitchen equipment use.

Provide the kitchen consultant with target EUIs and have the consultant work with the heating, ventilating, and air conditioning (HVAC) design team to minimize the amount of ventilation air required. Ventilation air should be turned down/off when no one is cooking. Some types of cooking have outsized impacts on ventilation loads. For example, eliminating frying reduces ventilation needs.

Challenge: Misuse of the building by occupants and operators.

"Buildings don't use energy, people do" is a common phrase heard at Kinard Middle School, an extremely energy-efficient school in Fort Collins, Colorado. The best building envelope and the most efficient HVAC system cannot keep a building operating at ZE if occupants are not aware and engaged. Controlling energy use and ensuring that the building operates as designed is key to achieving ZE.

Solution: Educate occupants and operators about how to use the building, develop building manuals for them, and provide feedback on how their behavior affects building performance.

Easy-to-use building manuals with intuitive graphics are good ways to educate occupants about the building. Features with specific design intent should be called out in the building manuals. Signage for light switches, thermostats, window blinds, and operable windows should be clear and well-labeled. Real-time building performance feedback tools (i.e., energy dashboards) can make occupants aware of how their actions affect energy performance.

Helpful Resources

Kitchens

50% Advanced Energy Design Guide for K-12 Schools, Chapter 5, Kitchen Equipment, Equipment and Design Guidelines, ASHRAE
https://www.ashrae.org/standards-research--technology/advanced-energy-design-guides/50-percent-aedg-free-download

Occupant and Operator Guidance

Sustainable Design Guide, Chapter 10: Education, Training, and Operation—Building Occupant and Operator Roles, Los Alamos National Laboratory
https://energy.gov/sites/prod/files/2013/12/f5/sustainable_guide_ch10.pdf

Energy dashboards such as this one at Discovery Elementary School, a zero energy school in Arlington, Virginia, can make occupants aware of how their behavior affects energy use in the building. *Photo from VMDO Architects/©Lincoln Barbour*

An Office Building Occupants Guide to Indoor Air Quality, Environmental Protection Agency
https://www.epa.gov/indoor-air-quality-iaq/office-building-occupants-guide-indoor-air-quality

Realizing High Performance Buildings: How To Maintain Energy-Efficient Design Intent During Building Operation, National Renewable Energy Laboratory
http://www.nrel.gov/docs/fy15osti/62530.pdf

Occupant Engaged: A High Performance Building Control Concept for Engaging Occupants as Users of Efficiency Controls, National Renewable Energy Laboratory
https://www.slideshare.net/shantipless/occupant-engaged-a-zeb-control-concept-for-engaging-occupants

Performance after Construction

Functional Performance Testing within the Building Envelope Commissioning Process, Building Research Information Knowledgebase
https://www.brikbase.org/sites/default/files/best2_knight.pdf

Research Support Facility Workshop Session II: Performance-Based Design-Build Process, National Renewable Energy Laboratory
https://buildingdata.energy.gov/cbrd/resource/1168

Plug Loads

ENERGY STAR® Building Manual, Chapter 10. Facility Type: K–12 Schools, ENERGY STAR
https://www.energystar.gov/sites/default/files/buildings/tools/EPA_BUM_CH10_Schools.pdf

Fact Sheet: Reducing Plug Load Energy Consumption, Sustainable Stanford
https://sustainable.stanford.edu/sites/default/files/resource-attachments/plug_load_fact_sheet.pdf

Plug and Process Loads, Better Buildings Initiative, U.S. Department of Energy
https://betterbuildingsinitiative.energy.gov/alliance/technology-solution/plug-process-loads

Plug Load Best Practices Guide – Managing Your Office Equipment Plug Load, New Buildings Institute
https://newbuildings.org/sites/default/files/PlugLoadBestPracticesGuide.pdf

Plug Loads, National Energy Education Development Project
http://www.need.org/files/curriculum/guides/PlugLoads.pdf

Guide to Operating and Maintaining Energy SMART Schools, U.S. Department of Energy, *https://energy.gov/sites/prod/files/2013/11/f5/ess_o-and-m-guide.pdf*

50% Advanced Energy Design Guide for K-12 Schools, Chapter 5, Plug Loads: Equipment and Control Guidelines, ASHRAE
https://www.ashrae.org/standards-research--technology/advanced-energy-design-guides/50-percent-aedg-free-download

Power Purchase Agreements

Power Purchase Agreement Checklist for State and Local Governments, National Renewable Energy Laboratory
http://www.nrel.gov/docs/fy10osti/46668.pdf

Solar Power Purchase Agreements, Environmental Protection Agency
https://www.epa.gov/greenpower/solar-power-purchase-agreements

Photovoltaic Costs

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

Utility and Government Renewable Energy Restrictions

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

State Net Metering Policies, National Council of State Legislatures
http://www.ncsl.org/research/energy/net-metering-policy-overview-and-state-legislative-updates.aspx

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

A Guide to Community Solar: Utility, Private, and Nonprofit Project Development, National Renewable Energy Laboratory
https://buildingdata.energy.gov/cbrd/resource/1979

Engaging with Utilities and Regulators, Regulatory Assistance Project
http://www.raponline.org/wp-content/uploads/2017/03/rap_epri_solsmart_engaging_utilities_and_regulators_2017_jan_25.pdf

Zero Energy Ready Schools

Designing for the Future: Zero Energy Ready K-12 Schools
U.S. Department of Energy

Zero Energy School Case Studies

Zero Energy Building Pays for Itself—Odyssey Elementary, Woods Cross, Utah, National Renewable Energy Laboratory

Zero Energy Is an A+ for Education—Discovery Elementary, Arlington, Virginia, National Renewable Energy Laboratory

Zero Energy with an Affordable Price Tag—Friends School of Portland, Cumberland, Maine, National Renewable Energy Laboratory

Zero Energy Schools

Cost Control Strategies for Zero Energy Buildings: High-Performance Design and Construction on a Budget, National Renewable Energy Laboratory
https://buildingdata.energy.gov/cbrd/resource/1655

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

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