A Guide to Zero Energy and Zero Energy Ready K–12 Schools

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OVERVIEW

Buildings account for nearly 40% of the energy consumed in the United States (EIA n.d.), and reducing that energy use offers many benefits to owners, occupants, and communities. The number of zero energy (ZE) buildings—which are so energy-efficient that on-site renewable energy (usually solar photovoltaics [PV]) can meet or exceed their annual energy needs—is growing steadily as the hurdles of getting to ZE are better understood and more easily overcome. Thanks to the focus on energy efficiency during planning, design, construction, and operation, these buildings cost less to operate; provide healthy, comfortable, attractive indoor environments; and can be designed and built on conventional building budgets. The number of ZE buildings in the United States continues to grow. Globally, the ZE buildings market is projected to grow to $78.79 billion by 2025 (Grand View Research 2017a), up from $8.04 billion in 2016 (Grand View Research 2017b).

Discovery Elementary, a zero energy school in Arlington, Virginia, saves the district money and provides a robust learning environment for students. Photo by VMDO Architects/©Alan Karchmer

ZE buildings are described differently—zero energy, net zero energy, zero net energy—in different regions (DOE 2015). If the output from the renewable energy system exceeds the energy needs, the building is said to be energy positive. In some situations, school owners opt to delay the installation of the renewable energy system because of financial or other constraints. These schools, dubbed "zero energy ready (ZER)," offer many of the benefits of ZE schools, including reduced utility bills. Regardless of the label, every ZE building starts with optimizing energy efficiency.

Interest in getting to ZE is particularly keen among U.S. school districts (Torcellini and Pless 2018a; Torcellini and Pless 2018b). In addition to saving money on energy, a significant benefit for many cash-strapped school districts, ZE schools are living laboratories for students, supporting districts' highest priority—creating robust learning environments. Schools are generally high-profile buildings in communities and tend to be one to three stories, which helps make ZE an achievable goal with on-site renewables (Griffith et al. 2007).

The interest in ZE K–12 schools is driven by benefits that include:

- **Student learning and success**. A ZE K–12 school focuses the school community (students, teachers, staff, and parents) on the process of achieving ZE, and on science, technology, engineering, art, and math (STEAM) subjects that can prepare students for future STEAM courses or careers.
- **Healthy, high-performance learning environments**. ZE school buildings are designed to promote health and comfort and serve as living laboratories for students and educators.
- **Sound fiscal management of community resources**. ZE schools reduce energy consumption, which reduces the school district's—and the community's—exposure to the risk of future energy price volatility. Because the cost of designing and building a school with a low enough energy use intensity (EUI or annual energy consumption per unit area) to achieve ZE can be comparable to that of a conventional school, it can be a sound business decision that frees up funds for educational priorities.
- **Sustainability leadership**. School districts are often early adopters of sustainability best practices and demonstrate leadership in environmental stewardship, fiscal responsibility, and innovative education that extends to the larger community.
- **Resiliency**. A K–12 school is often a community gathering place, and—because of its energy efficiency and on-site renewable energy production—a ZE school can be a comfortable refuge during extreme weather events and other grid outages.

As ZE schools become more common and the process of getting to ZE becomes better understood, ZE is evolving from vision to reality. The New Buildings Institute's (NBI's) *2018 Getting to Zero Status Update and List of Zero Energy Projects* publication reflects a steep rise in the number of ZE buildings, with the count increasing more than 700% in six years (NBI 2018). Of the ZE buildings on the 2018 NBI list, 18% are K–12 schools.

Procuring a Zero Energy School Building

Procuring a ZE school building is a highly involved, customized process involving a number of players (see Figure 1). In this document, procurement refers to the entire process of designing, constructing, and operating a school building. It requires that building professionals, materials suppliers, consultants, educators, facilities personnel, and others work together to develop and follow a detailed plan to achieve the desired outcome—a ZE building.

All key players must work collaboratively from early in the design process. Producing a ZE school on a conventional school budget requires an integrative design approach that considers each strategy, system, and component from the perspective of an overall goal, namely achieving an EUI—expressed in thousands of British thermal units per square foot per year (kBtu/ft^2·yr)—low enough that the building's energy needs can be met with an on-site renewable energy system.

As the energy efficiency of the ZE building increases, the size and cost of some components can be reduced—mechanical systems, for example. To ensure the building provides all the services and functions occupants expect, it's important that key players experienced with integrated design are involved from the beginning of the project.

The Players

A successful zero energy K–12 school building project involves the coordinated, collaborative efforts of multiple participants, including, but not limited to:

School owner. A team of people with decision-making and financial authority for the zero energy school project; it can include the school principal, the district superintendent, school board members, facility managers, and others.

Project team. The architects, engineers, contractor, key subcontractors, commissioning agent, school owner, owner's representatives, and others who will design and build the zero energy school.

Utility and fuel providers. Local electric, gas, and water utilities; fuel oil dealers; and propane suppliers.

Stakeholders. Anyone with an interest in the project; can include the school owner, project team, interested community members, taxpayers (schools are publicly funded), building users (teachers, students, parents, and community members), and building operators (on-site facility and energy managers, custodians, grounds personnel, and others). Stakeholders can be supporters—zero energy champions, for example—or detractors such as neighbors, employees, or others who oppose the project.

Figure 1. The players involved in a zero energy K–12 school building project

Getting to Zero

This guide was developed as part of the U.S. Department of Energy's (DOE's) Zero Energy Schools Accelerator (ZESA), a collaborative effort organized by DOE, with support from the National Renewable Energy Laboratory (NREL), and in partnership with school districts, states, and nongovernmental organizations around the country.

ZESA is one of 13 Better Buildings Accelerators DOE coordinates to demonstrate specific innovative technologies, solutions, and approaches that will accelerate investment in energy efficiency. Each accelerator is a targeted, partner-focused activity of up to 3 years designed to address persistent barriers to greater energy efficiency.

Given the complexities of achieving ZE, DOE launched ZESA in 2016 to support school districts interested in or currently pursuing ZE design goals. There are two types of participants—implementing partners and national partners—and each makes a commitment to participate for the entire 3-year duration of the accelerator. Implementing partners are state governments and school districts, and national partners are nongovernmental organizations that provide guidance and technical assistance to the implementing partners. The shared experiences and insights of ZESA partners were instrumental in the creation of this guide.

This document outlines the steps to creating a ZE school. These steps serve as a guide to ensure that a school achieves its ZE design goal and maintains its ZE status after it's occupied and operating. A few elements of successful ZE buildings include:

- Setting a measurable ZE goal and a fixed budget very early in the design and construction process and writing both into the request for proposal (RFP) and, ultimately, the contract
- Including the energy goal in all contracts for delivering the building project, including design and construction contracts
- Ensuring the ZE goal serves the school building's primary purpose, which is to function as a robust learning environment for students
- Generating enthusiasm and commitment among stakeholders for the ZE goal

- Selecting design and construction professionals who are aligned with the ZE goal and committed to meeting it
- Creating an energy model early in the design process and keeping it updated after the building is occupied and operating
- Commissioning and verifying energy performance
- Choosing a procurement process and delivery mechanism that supports the ZE goal while containing costs.

By engaging a broad range of participants (see Figure 1), it is possible to shift design and construction conventions so that ZE is a priority from the inception of a building project without sacrificing other priorities. Given the diversity of K–12 educational, procurement, and design and construction approaches around the country, however, each school district will need to make this framework its own based on local norms and practices. The steps included here can provide guidance and structure for the process of getting to zero.

Step 1. Conducting a Building Needs Assessment

Step 2. Engaging Stakeholders

Step 3. Including Zero Energy Goals in the Procurement Process

Step 4. Selecting a Design and Construction Team Committed to Zero Energy Goals

Step 5. Integrating Zero Energy Goals into Design

Step 6. Achieving Zero Energy Goals during Construction and Commissioning

Step 7. Evaluating Performance and Engaging Occupants

Step 8. Showcasing and Replicating a Zero Energy School

Ideally, the key stakeholders involved in the building project would all be at the table from the beginning, would adopt and commit to the ZE goal, and would consider ZE in each design and construction decision. The reality is likely to be that the ease with which a ZE school can be delivered (DOE n.d.-a; NBI 2018) will be unfamiliar to local participants and that existing procurement and delivery mechanisms may need to be modified to get to ZE. As ZE buildings continue to gain traction in the marketplace, these challenges will become less common, but in the meantime, school owners and ZE champions will need to be patient and persistent in advocating for ZE.

Finally, although the scope of this document is limited to new construction, the information could also be used to plan and execute strategic ZE retrofits. A few ZE retrofit resources are included in *Overview Resources*.

Fundamentally, every decision made during the process of procuring a commercial building has energy or environmental consequences, whether it is new construction or a retrofit (DOE n.d.-c). The depth of the retrofit, however, impacts the number of decisions that can be made to reduce energy consumption. All projects, regardless of size, should have an energy goal, but strategic retrofits and new construction offer more opportunities to achieve a ZE goal.

Using This Document

This document is intended to be used in conjunction with *Achieving Zero Energy: Advanced Energy Design Guide for K–12 School Buildings*; a free download is available at *https://www.ashrae.org/aedg* (ASHRAE 2018). This guide is written for a broad audience, ranging from commercial building design and construction professionals to parents, educators, school officials, members of the local community, and anyone else with an interest in supporting ZE schools.

At the end of each of the eight steps, there is a list of resources for that step. In addition, there are citations in parentheses throughout the document that refer to sources in the reference list located at the end of this document. In general, references are information sources that contain more technical content, and the resources included with each step are appropriate for less technical readers.

Each step also includes a "Partner Snapshot." These short anecdotes were provided by participating ZESA school districts and offer a quick synopsis of the district's experience with that step.

Although this guide presents the ZE process in eight distinct steps, there will inevitably be overlap. For example, stakeholder engagement (Step Two) is likely to go on throughout the project and into building operation.

Content and resources are sometimes included in more than one step. This is an acknowledgment that readers may not read this document from beginning to end but rather may focus on the sections most relevant to their current interests and tasks. Many of the organizations responsible for the resources and references in this document are committed to chronicling and supporting the proliferation of ZE buildings generally and ZE K–12 schools specifically. Readers can check their websites for current offerings and updates on this important work.

Overview Resources

Zero Energy Schools Resources

2018 Getting to Zero Status Update and List of Zero Energy Projects: *https://newbuildings.org/wp-content/uploads/2018/01/2018_GtZStatusUpdate_201808.pdf*. NBI's annual ZE status update and ZE buildings list.

Examples of school district policies, state policies, national programs, and other resources to support school districts on the path to ZE: *https://newbuildings.org/hubs/zero-net-energy/*. Materials developed by NBI for ultra-low energy building projects that consume only as much energy as they produce from clean, renewable resources.

NBI ZE resources: *https://gettingtozeroforum.org/zero-energy-schools-resources/*. Resources regarding state policies and national programs working toward ZE schools; districts pursuing ZE and the strategies they use to achieve this target; feasibility studies, assessment strategies, and other technical information about ZE school design; and case studies of successful ZE school buildings.

Zero Energy Buildings Resource Hub, an NREL/DOE website: *https://www.zeroenergy.org/schools*. Case studies, videos, and other ZE school resources.

ZE K–12 school case studies, Commercial Buildings Resource Database: *https://buildingdata.energy.gov/cbrd/search/resources/k12casestudy*. Case studies of ZE and high-performance schools.

Casey Middle School, a LEED Platinum facility in Boulder, Colorado, features a 27-kW solar bike port. Photo by Dennis Schroeder, NREL 45244

Retrofit Resources

Advanced Energy Retrofit Guide for K–12 Schools: *https://buildingdata.energy.gov/cbrd/resource/17*. General project planning guidance as well as detailed descriptions and financial payback metrics for the most important and relevant K–12 school energy efficiency measures.

American Geophysical Union's ZE renovation project: *https://building.agu.org/about-the-project/*. Information on what is anticipated to be the first ZE renovation of an existing building in the District of Columbia.

DOE's Commercial Buildings Resource Database, ZE retrofits: *https://buildingdata.energy.gov/cbrd/search/resources/zero%20energy%20retrofit*. List of ZE retrofit resources.

Garden Grove [California] School District ZE retrofits: *https://newbuildings.org/wp-content/uploads/2018/01/NBI_Case-StudyProp39_GardenGroveSchoolDist.pdf*. Six-page case study of the Santiago High School Science Building and the Ralston Intermediate Building K: Multipurpose Room and Kitchen retrofits; projects are classified by NBI as "ZE emerging"—they have a stated ZE goal, but their performance has not yet been verified with 12 months of energy use and generation data.

Los Osos [California] Middle School ZE retrofit: *https://newbuildings.org/wp-content/uploads/2018/01/NBI_Case-StudyProp39_LosOsos.pdf*. Four-page case study of the Los Osos Middle School ZE retrofit, which is classified by NBI as "ZE emerging"—it has a stated ZE goal, but its performance has not yet been verified with 12 months of energy use and generation data.

Newcastle [California] Elementary School ZE retrofit: *https://newbuildings.org/wp-content/uploads/2018/01/NBI_Case-StudyProp39_Newcastle.pdf*. Six-page case study of Newcastle Elementary School ZE retrofit, which is classified by NBI as "ZE emerging"—it has a stated ZE goal, but its performance has not yet been verified with 12 months of energy use and generation data.

Community Action Planning For Energy Efficiency: *https://neep.org/capee/*. CAPEE is a free online tool to help communities set goals and prioritize actions that lead to improved energy efficiency.

Zero Energy Schools Accelerator Partners

Implementing Partners

Implementing Partners—School Districts

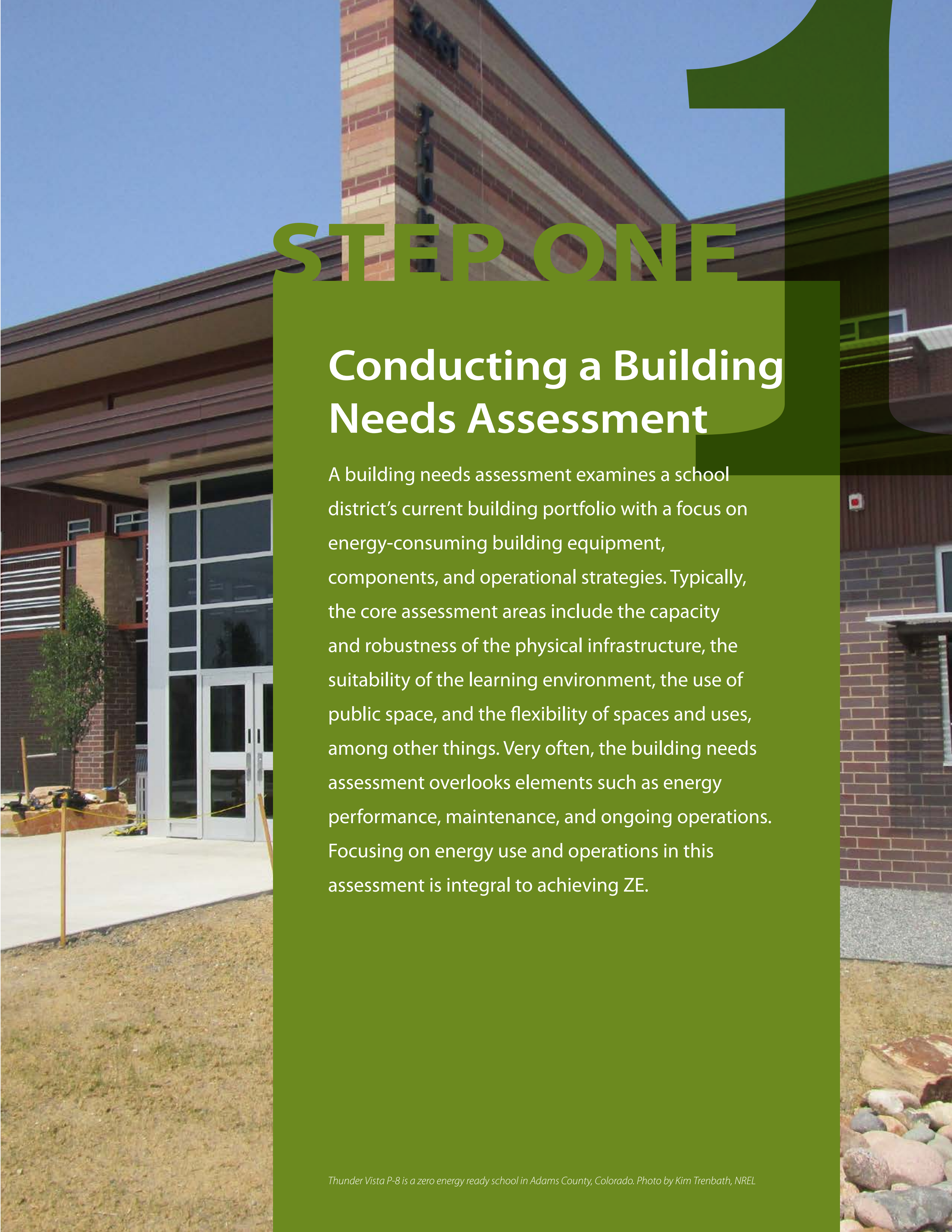
- Adams 12-Five Star Schools (Colorado)
- Alexandria City Public Schools (Virginia)
- Arlington Public Schools (Virginia)
- Baltimore City Public Schools (Maryland)
- Boulder Valley School District (Colorado)
- Douglas County School District (Colorado)
- Hermosa Beach City School District (California)
- Horry County Schools (South Carolina)
- San Francisco Unified School District (California)
- Los Angeles Unified School District (California)

Implementing Partners—State

- State of California (Division of the State Architect)
- State of Maryland (Maryland Energy Administration)
- State of Minnesota (Department of Commerce)

National Partners

- Association for Learning Environments (A4LE)
- Collaborative for High Performance Schools (CHPS)
- Geothermal Heat Pump National and International Initiative (Geo-NII)
- National Association of State Energy Officials (NASEO)
- National Energy Education Development Project (The NEED Project)
- New Buildings Institute (NBI)
- Northeast Energy Efficiency Partnerships (NEEP)
- Southern California Edison (SCE)
- The Energy Coalition (TEC)
- Rocky Mountain Institute (RMI)
- U.S. Department of Education



STEP ONE

Conducting a Building Needs Assessment

A building needs assessment examines a school district’s current building portfolio with a focus on energy-consuming building equipment, components, and operational strategies. Typically, the core assessment areas include the capacity and robustness of the physical infrastructure, the suitability of the learning environment, the use of public space, and the flexibility of spaces and uses, among other things. Very often, the building needs assessment overlooks elements such as energy performance, maintenance, and ongoing operations. Focusing on energy use and operations in this assessment is integral to achieving ZE.

Thunder Vista P-8 is a zero energy ready school in Adams County, Colorado. Photo by Kim Trenbath, NREL

Building Needs Assessment Best Practices

In a new school with a ZE or ZER goal, here are some best practices common to successful projects from *Achieving Zero Energy: Advanced Energy Design Guide for K–12 School Buildings* (ZE K12 AEDG), a free download (ASHRAE 2018):

- Include energy as a core assessment area
- Compare the EUIs of existing schools in the district to the EUI targets for ZE schools in the ZE K12 AEDG (ASHRAE 2018, Table 3-1, p. 34)
- Study the EUI values of similar buildings in the district in enough depth to identify energy-intensive building components
- Set a measurable, absolute energy goal
- Select proper inputs for the energy model, including details about occupancy levels, comfort levels, operational hours, specialty spaces, and plug loads
- Evaluate the solar availability at the site (NREL n.d.)
- Research utility provider incentives and requirements for ZE and net metering as well as energy rates, demand charges, connectivity, maintenance charges, and any other conditions that could affect the ZE project.

Integrating Energy Efficiency Goals in a Building Needs Assessment

As noted above, a best practice for integrating energy efficiency goals in building needs assessment is to include energy as a core assessment area. Two considerations are key to understanding building energy use.

First, determine the features and components that impact energy consumption. These inputs could include details about occupancy levels, comfort levels, operational hours, specialty spaces, lighting levels, and plug load needs. The design team can then use these inputs to develop a design that includes all the energy services occupants expect. Examining existing buildings is a good starting point.

For example, occupants expect to have hot water in restrooms. The traditional solution might be a three-pipe hot water system with a circulator and a hot water boiler. A more energy-efficient and economical solution might be very low flow sink faucets with small hot water heaters located near the restroom or under the sinks that use less energy than the circulator pump alone. As a bonus, this solution would save in construction costs.

Note that for the building needs assessment, the need is to provide hot water to sinks—a performance criterion. The solution would not be specified, but rather the design and construction team would determine solution(s) during the design process. By focusing on defining the need, not the solution, design teams have the latitude they need to suggest innovative and energy-efficient solutions beyond what are typically considered during building design.

Here are some energy-related questions to answer during the building needs assessment:

- What are the acceptable ranges of indoor temperature and humidity? Can ASHRAE Standard 55 (ASHRAE 2013a) be used? These ranges might be different for different parts of the building. For example, hallways can have a larger temperature range than classrooms.
- What are the daily and annual occupancy schedules for different parts of the building?
  - » Indicate on the schedules when portions of buildings have different schedules. For example, the office area may have different hours of operation than classrooms.
  - » Identify times when whole building occupancy is different
    - ◆ During summer school, if applicable
    - ◆ If multifunction rooms, gymnasiums, and specialty spaces are used in the evenings or weekends.
  - » Consider occupancy differences because of the trend of schools being used as community focal points, which can result in higher than anticipated occupancy rates.
  - » Provide schedules as a percentage of occupancy to expedite modeling.

- What are the tasks in each space and the recommended lighting levels? Can Illuminating Engineering Society (IES) standards (IES n.d.) be used to determine lighting levels?
- What are the plug load expectations in each space, such as audio/visual, computers, etc.? How do the plug loads relate to function in the space?
- How can teacher amenities be provided? Can larger and commonly shared equipment such as refrigerators, multifunction printers, or other kitchen equipment be provided in the teacher lounge or resource center rather than in the classroom? Are space heaters used? (Space heaters are often a sign of discomfort. Buildings should be designed so that spaces are comfortable and occupants don't need space heaters.)
- Are regenerative elevators acceptable?
- What are the information technology needs, including server closets? What are manufacturer's specifications on these devices? Do the manufacturer's specifications align with the set points for those zones? (Often—and usually for historical rather than technical reasons—server closets are overconditioned, wasting energy).
- What loads can be turned off when the building is unoccupied? Examine every load. A key to achieving a ZE building is shutting down the building when it is unoccupied. Examples include WiFi routers, computers, vending machines, kitchen equipment, and sound systems, among other things.

Second, set measurable, absolute energy goals. The building needs assessment should evaluate the EUIs of schools in the district. These schools can then be compared against the EUI targets for ZE schools shown in ASHRAE 2018 (Table 3-1 on page 34). Studying the EUI values of similar buildings can help identify energy-intensive building components, assuming end uses are submetered. For new ZE schools, the EUI values of existing schools in the district and the identification of energy-intensive building components is useful background to have during design. The design team can work to mitigate energy use from energy-intensive components by substituting energy-efficient equipment that performs the same functions or reducing the use of those components through scheduling and other strategies.

Partner Snapshot: Conducting a Building Needs Assessment in Adams County, Colorado

Adams 12 Five Star Schools is located in five communities across north metro Denver, Colorado. In 2003, the district began planning healthy and high-quality learning environments for all the district's students by focusing on the design and construction of sustainable, cost-effective schools.

The effort consisted of integrating energy efficiency, lighting, acoustics, thermal comfort, and air quality criteria into district planning and design guidelines. Adams 12 uses these criteria to inform building professionals about best practices in all aspects of building design and construction.

After multiple failed bond attempts, the district acknowledged that a formal building needs assessment could help educate community members about why they should vote for the next bond. Beginning in 2014, Adams 12 began to gather information for the next bond request with assistance from the Collaborative for High Performance Schools (CHPS) and ultimately became the first school district in the nation to complete a building assessment for all schools in the district using a CHPS[1] tool.

The process involved completing several benchmarking steps including gathering school-wide building and systems data, conducting an occupant survey, collecting classroom measurements, and entering data into the ENERGY STAR® Portfolio Manager. After completing the building needs assessment for the entire district during a 3-year period, the district was able to use the results of the building needs assessment to present "report cards" to each school and community that prioritized in detail the greatest needs of each facility. In addition to the needs identified by the assessment, the district needed a new school in response to the growth of the local community.

The Thunder Vista P-8 EUI target is 26kBtu/ft²·yr, the lowest in the district. Photo by Paul Torcellini, NREL

Based on the building needs assessment and the high-performance design guidelines, the Adams 12 planning staff proposed that a healthy and low energy school be included in the upcoming bond measure to accommodate this population growth. In 2016, the voters of the Five Star community approved the district's bond request and Thunder Vista P-8 became a reality.

It likely wouldn't have been possible to secure buy-in from district leadership on a high-performance school without the results of the building needs assessment. Shifting from an anecdotal discussion of the deficiencies in our facilities to a data-driven conversation based on nationally recognized standards added credibility to the design proposal. Once the buy-in was secure, the district committed to achieving CHPS Verified™ status for the new P–8 school.

This commitment provided a structured approach to the design and construction of the first facility of this caliber in the district, and was the first step toward low energy design. The next step was to engage an experienced design team that would embrace the commitment to a ZER school. The final key step arising from the building needs assessment was setting an EUI target for the new building that would be the lowest in the district—26 kBtu/ft²·yr.

Although the successful completion of Thunder Vista P–8 is a testament to the hard work of hundreds of individuals, a project of this size and scope always needs a starting point. Conducting a building needs assessment is a relatively simple and data-driven place to start when considering low energy design.

1. *https://chps.net*

Resources for Conducting a Building Needs Assessment

ASHRAE Standard 55-2013: Thermal Environmental Conditions for Human Occupancy: https://www.ashrae.org/resources--publications/bookstore/standard-55-and-user-s-manual. Standard to determine requirements for thermal environmental conditions for human occupancy; includes requirements for temperature, thermal radiation, humidity, and air speed. Available for purchase from ASHRAE.

IES Standards: https://www.ies.org/standards/. Standards for lighting as defined by the IES. These are research-supported recommended practices for lighting, some of which are jointly published with ASHRAE.

Regional Operations & Maintenance Guide for High Performance Schools and Public Buildings in the Northeast and Mid-Atlantic: https://neep.org/sites/default/files/resources/OMG%20Update_DEC%202018%20Final.pdf. Northeast Energy Efficiency Partnerships. Assessment strategies and other information for high-performance schools.

School Building Assessment Methods, National Clearinghouse for Educational Facilities: http://www.ncef.org/pubs/sanoffassess.pdf. Detailed examples of school building assessments.

Submetering of Building Energy and Water Usage, National Science and Technology Council: http://www.allianceforwaterefficiency.org/uploadedFiles/Resource_Center/Library/submetering/NIST-2011-Submetering-of-Energy-and-Water-Use.pdf. Information on energy assessments and audits.

Updated resources for Step One: https://buildingdata.energy.gov/cbrd/search/resources/k12ZEstep1.

STEP TWO

Engaging Stakeholders

At this point in the process, *stakeholders* include direct decision makers, such as members of the board of education, school district administrators, capital project managers, and the school principal. They also include those who will use the building on a regular basis (teachers, students, parents, and community members) and those who will operate the building on a regular basis (facility and energy managers). The *project team*, consisting of architectural, engineering, construction, and commissioning professionals, also affects the project outcome, although they may not be fully engaged at this point. Ideally, the project team is at the table from the beginning of the process. Elected officials and community leaders can also influence the project and can be valuable additions to advisory boards. Some of these stakeholders may also be *school owners*—that subset of stakeholders with the authority to make decisions about the project.

Meadowlark School in Erie, Colorado, is expected to operate at the Boulder Valley School District energy use intensity target of 30 kBtu/ft^2·yr. Photo by Fred J. Fuhrmeister/Time Frame Images

During the process of stakeholder engagement, it's important to define and identify the owner and the key financial decision makers. For schools, this is often a team of people with decision-making and financial authority for the ZE school project; it can include the school principal, district superintendent, school board members, facility managers, and others; the makeup varies depending on the dynamics of the local school district. This team discusses and decides on a set of measurable goals for the project. Ideally, the team records these goals in a document ("goals contract") and all members of the owner team sign it, including the district superintendent.

In addition, community members who are not directly impacted by schools may also have a stake in a ZE school project. These stakeholders can have significant influence, especially if they oppose it. The school owner and the project team can make an effort to include these external stakeholders in the conversation and help them understand the environmental, economic, and educational benefits of ZE schools (see *Generating Excitement for Zero Energy Schools* in this step).

Taxpayers are another stakeholder group that are impacted by and can influence the outcome of a ZE project. Because most schools are publicly funded, the community at large has an impact on the funding and the ability of a project to move forward.

Utility providers should also be involved from the beginning; they can be invaluable allies or frustrating antagonists. For example, rebates can offset costs, but limits on renewables production can make it difficult or impossible to get to ZE. The local electric utility in particular should be consulted very early in the project.

What Is Stakeholder Engagement?

Engaging as many stakeholders as possible as early as possible is important, because achieving ZE performance in a school requires the active involvement of building occupants as well as support from community members, who often influence school district decisions. When stakeholders are engaged from project inception and stay involved through design, construction, and operation,

Mr. Brandt's kindergarten class at Graceland Park/O'Donnell Heights Elementary/Middle School in Baltimore built a model of their new zero energy school. Photo by Grimm + Parker Architects the likelihood of achieving the ZE design goal as well as ZE performance over the life of the building increases dramatically. Broad stakeholder involvement also improves the likelihood that the ZE school will foster a culture of resource stewardship and innovation in the community.

Stakeholder engagement may sound simple, but it is not easy. A successful ZE school project requires a team that includes school and project representatives with common goals and visions. Getting stakeholders to the table and aligning their ideas and interests with project objectives can be time-consuming and challenging. The process is crucial, however, to providing a framework for achieving and maintaining ZE.

When and How to Engage Stakeholders

Stakeholder engagement starts at the beginning of a school project and continues after the school is occupied and operating. Although it is depicted here as "Step Two," it spans the entire project.

Four critical elements of stakeholder engagement are:

- Identifying a ZE project champion
- Analyzing stakeholder groups
- Generating excitement for ZE schools
- Encouraging stakeholder collaboration.

Identifying a Zero Energy Project Champion

The school owner should identify a ZE champion or champions who will ensure that ZE goals are set and met throughout the project. The champion(s) can also foster the ZE process with the project team and the broader community, and should be identified at the beginning of the process. These individuals should ideally have the vision, passion, persistence, and powers of persuasion to lead the project through planning, design, construction, occupancy, commissioning, and ongoing measurement and verification (M&V). The champion(s) will implement a clear yet flexible communication strategy to educate, generate enthusiasm, and develop new proponents for ZE in all stakeholder groups.

The champion(s) should ensure that the ZE goals are maintained during the school design process. As challenges arise, there may be times during design when team members want to disregard ZE goals or EUI targets. The champion's job is to remind team members of their commitment to creating a ZE school. The champion may need to be prepared with examples and case studies of challenges overcome by other ZE school teams. Example case studies are in the Commercial Buildings Resource Database or on NBI's website (see *Resources for Engaging Stakeholders* in this step).

The champion role is critical. For example, if the design team isn't contractually obligated to meet a measurable, absolute EUI goal, it could respond to cost increases and other challenges with reasons ZE is not possible. The champion must remind team members that they were selected based on their ability and willingness to achieve ZE goals. If a compromise cannot be negotiated, the building owner may decide to select a new design team committed to the stated goals.

Analyzing Stakeholder Groups

Stakeholder analysis involves identifying stakeholder groups; developing an understanding of their values, goals, and messages before determining how to engage with them; and locating influential individuals within the groups. School districts may find it useful to map stakeholders based on how much they will be affected by the ZE school project and the how much influence they have on the ZE school project. The relative influence and impact of various stakeholder groups can in turn be used to develop an engagement plan.

Generating Excitement for Zero Energy Schools

The project team can generate excitement for the ZE school project among stakeholders by publicizing the benefits of a ZE school. Common messages include:

- **Lower operating costs.** K–12 schools spend more than $8 billion on energy annually, making energy the second highest operating expense after personnel costs (DOE n.d.-d).
- **Student learning and success.** The ZE building is a part of a comprehensive learning environment that allows the entire school community (students, teachers,

staff, and parents) to participate in the process of achieving ZE. Community collaboration can help ensure the building operates as energy-efficiently as possible; for example, using daylighting instead of turning on overhead lights. Because they are immersed in this living laboratory, students learn experientially that the building is a system with many interacting systems and components. Teachers can develop curricula around the building, such as projects based on energy use data. Many ZE school curricular topics fall into STEAM subjects, which can prepare students for future STEAM courses or careers.

- **Healthy, high-performance learning environments.** ZE school buildings are designed to promote health and comfort, including excellent indoor air quality, thermal comfort, visual comfort, and acoustic comfort. Student attendance and teacher retention improve in these high-performance learning environments (NBI 2017).
- **Sound fiscal management of community resources.** ZE schools reduce energy consumption, which decreases the school district's—and, in turn, the community's—exposure to the risk of future energy price volatility. ZE schools also have lower maintenance costs, because wall, window, and roof systems are more durable than standard construction (Torcellini and Pless 2018a). The cost of designing and building a ZE school can be comparable to that of a conventional school, which can make a sound business case for ZE. In many cases, the money saved on energy costs can be used for educational priorities in the operating budget. See *Resources for Engaging Stakeholders* in this step for ZE school case studies.
- **Sustainability leadership.** Building ZE schools at costs comparable to traditional buildings demonstrates the district's and community's commitment to environmental sustainability and fiscal responsibility. Early adopters demonstrate leadership in environmental stewardship and provide a learning opportunity for students and community members who attend or visit the school.
- **Resiliency.** A K–12 school is often a community gathering place, and—because of its energy efficiency and on-site renewable energy production—can be a comfortable refuge during extreme weather events and other grid outages. During the day, a ZE school provides passive energy services such as daylighting and ventilation. In addition, the PV system can be isolated from the grid so that it continues to provide electricity to the building during the day (NBI 2017). If the solar system is paired with energy storage, electricity is also available when the solar resource is not, which is especially welcome during grid outages.

Stakeholders will appreciate information and explanations that address their specific interests and concerns. Therefore, the project team should develop communication strategies that appeal to different stakeholder groups. Table 1 is a sample of various stakeholder groups and topics for communication with those groups.

The school owner can build confidence among stakeholder groups that ZE is an achievable goal by

Table 1. Communication Topics for Specific Stakeholder Groups

Stakeholder	Topic
Educators	ZE schools provide rich learning environments with teaching opportunities in sustainability, systems, and innovation, encouraging student interest in STEAM subjects.
Students	ZE schools support environmental sustainability and a high-quality learning environment. ZE schools are innovative, and learning in a ZE school provides unique opportunities that can form the basis of a career in a related field.
Parents	ZE schools are modern learning environments that expose students to innovative technologies. ZE schools provide healthy, high-performance learning environments that support student success.
School board members	ZE schools offer long-term financial savings in energy and operating and maintenance costs as well as improved student performance (NBI 2017).
Members of the community (voters)	ZE schools provide energy and operations and maintenance savings over their lifetimes, and they mitigate financial risks because construction costs can be comparable to traditional buildings and ZE schools are not subject to energy price volatility. ZE schools can also be comfortable refuges during emergencies.
Local government officials	ZE schools help achieve overall community energy goals and demonstrate the community's commitment to sustainability.
Members of community associations	ZE schools may offer community educational opportunities to promote understanding and appreciation of the benefits of ZE. In addition, schools can be a source of community pride and drivers of increased property values.

explaining that ZE schools' design and construction costs can be comparable to traditional schools and their energy and operating costs can be lower than a traditional school's. In addition, the owner can reassure stakeholders that the selected design and construction team has the skills and expertise to deliver a ZE school on time and within the agreed-upon budget. The owner can also recruit the design team to help communicate the benefits of a ZE school to stakeholders.

Different resources can be valuable for engaging stakeholders at different times during the process:

- **Case studies** are valuable throughout the design process but are particularly useful at the beginning so that stakeholders can conceptualize the benefits and possibilities of ZE schools, making it more likely they will support the process (DOE n.d.-a; NBI 2018). See also *Resources for Engaging Stakeholders* in this step for ZE school case studies.
- **Tours** of nearby ZE and ZER schools can be powerful tools for engaging stakeholders. If there are no ZE or ZER schools in the area, **tours of local ZE or ZER buildings** can raise awareness about ZE. For a virtual tour of Discovery Elementary in Arlington, Virginia, see *Resources for Engaging Stakeholders* at the end of this step.
- Design **charrettes** can encourage collaboration among stakeholders with different points of view and different needs.
- The **communication plan** guides communication with stakeholders throughout the process.
- A **knowledgeable architectural and engineering design team** with experience executing high-performance, energy-efficient design and construction can engage stakeholders throughout the design process and communicate project requirements to contractors.
- The **goals contract** signed by internal stakeholders at the beginning of the design process encourages the stakeholders and design team to maintain the commitment to ZE goals.
- **Subject matter experts** can educate team members and stakeholders.

Kindergarten students work on a model of their new zero energy school in Baltimore. Photo by Grimm + Parker Architects

Encouraging Stakeholder Collaboration

All stakeholders should be engaged during the planning and design of the school building. Design charrettes or visioning workshops can be used to bring different stakeholders together to establish or solidify ZE goals and to integrate these goals into the larger vision for the school. These charrettes or workshops are 1- or 2-day in-person meetings at which stakeholders set goals and expected outcomes. The meeting is facilitated by the design team or a third party and can uncover opportunities and challenges with interactive activities. The result of the charrette should be a report that documents problems and highlights solutions and recommended processes.

Christos Chrysiliou (far right), LAUSD's Director of Architectural & Engineering Services, congratulated high school graduates (left to right) Stephen Bailey, Fabian Perez, Gualberto Delgado, and Narek Ekmekchyan, who not only completed the district's Student Energy Auditor Training program, but also earned national certification as Building Analysts. Photo by LAUSD

Partner Snapshot: Engaging Stakeholders in Los Angeles, California

In 2003, the Los Angeles Unified School District (LAUSD) passed a resolution titled "Sustainability and the Design and Construction of High Performance Schools." Since then, district requirements have been updated to incorporate high-performance goals as they are established and refined during integrated design team workshops. These workshops include practitioners of relevant disciplines and a range of stakeholders, all of whom impact project design and participate in the development and review of the final project recommendations.

LAUSD stakeholders provide significant insight and input in support of the district's goal of being ZER by guiding district decisions about specific projects. They are also key contributors to the overall success of the effort. District stakeholders comprise facility representatives such as maintenance and operations staff; design and standards specifiers; representatives from the LAUSD Division of Instruction; building users and occupants; design consultants; construction representatives; and utility service providers.

ZER goal-setting efforts and the implementation of ZER strategies in LAUSD projects call for stakeholder engagement. The district has developed a comprehensive stakeholder review process that coordinates input from architectural, energy, sustainability, and other design and engineering professionals. This process also includes builder feedback throughout project design to ensure maximum participation. Over the course of the projects, LAUSD facilities teams:

- Communicate with and involve stakeholders in ZER design and construction decisions
- Analyze project progression and performance data
- Set ZER goals based on the performance data

After learning about safety and security, Student Energy Auditor Training program students at LAUSD spend time inspecting HVAC systems and learning how to review and collect data. Photo by LAUSD

- Develop strategies and update design standards to achieve district-approved guidelines or target goals
- Identify resources needed to support those strategies, prioritize investments, and align the targeted strategies to be incorporated into those priorities.

To integrate ZER into education and instruction, there is ongoing collaboration between school coordinators and the LAUSD Sustainability Initiatives Unit to implement sustainability engagement programs that promote collaboration, encourage student participation, encourage behavior that supports sustainability, and increase the overall impact of these efforts. For example:

- The **HEROES for ZERO Contest**[2] encourages students to engage in activities that help make their schools "Zero Net Energy Ready."
- The Prop 39 **Student Energy Auditor Training**[3] prepares students for future energy-related occupations and careers.
- LAUSD **emPowered** pilots an online team-based interactive energy education program in collaboration with the Alliance to Save Energy.

Finally, the district is committed to working with utility service providers, which offer valuable insights about current and future opportunities to improve energy efficiency.

All efforts involving stakeholder engagement are consistent with LAUSD's mission to educate Los Angeles youth and empower tomorrow's leaders by providing safe and healthy learning spaces that will help students lead the way to a sustainable future.

2. *http://learninggreen.laschools.org/heroes-for-zero-contest.html*
3. *http://learninggreen.laschools.org/student-energy-audit-training-seat.html*

Resources for Engaging Stakeholders

Zero Energy School Videos

Discovery Elementary School video case study: *https://www.youtube.com/watch?time_continue=35&v=2kTS4UODWwc*. Short video about Discovery Elementary School, a ZE school in Arlington, Virginia.

Introduction to ZE buildings: *https://www.youtube.com/watch?v=FysJKq5yCfg*. Brief introductory ZE buildings video from DOE.

Virtual tour of Kinard Core Knowledge Middle School: *http://www.kinardcares.org/kinard_green_school*. Kinard is a highly energy-efficient (but not ZE) school building.

School Case Studies

2018 Getting to Zero Status Update and List of Zero Energy Projects: *https://newbuildings.org/wp-content/uploads/2018/01/2018_GtZStatusUpdate_201808.pdf*. NBI's annual ZE status update and ZE buildings list.

Commercial Buildings Resource Database ZE K–12 school case studies: *https://buildingdata.energy.gov/cbrd/search/resources/k12casestudy*. Case studies of ZE or high-performance schools.

Getting to Zero National Forum school building case studies: *https://gettingtozeroforum.org/schools/*. Case studies from a collaborative of ZE building experts creating market-based solutions to get to ZE.

Charrette Resources

Getting to Zero: Zero Energy Integrated Design Charrette Toolkit for Schools: *https://newbuildings.org/wp-content/uploads/2017/10/ZEProjectGuide_NBI.pdf.pdf*. Toolkit with templates and customizable documents such as agendas, activities for precharrette preparation, discussion topics and questions, checklists, and more.

A Handbook for Planning and Conducting Charrettes for High-Performance Projects: *http://www.nrel.gov/docs/fy09osti/44051.pdf*. A guide to planning and conducting a gathering of key stakeholders, decision makers, and design and construction experts to create a high-performance building.

Other Resources for Engaging Stakeholders

Getting to Zero: Zero Energy Schools Stakeholder Engagement and Messaging: *https://newbuildings.org/wp-content/uploads/2017/10/GtZ_ZEStakeholderEngagement.pdf*. Guide to stakeholder engagement and messaging for ZE schools.

Guide to Community Energy Strategic Planning: *https://energy.gov/eere/slsc/guide-community-energy-strategic-planning*. See Step Two, "Identify and Engage Stakeholders," in this DOE planning guide.

Updated resources for Step Two: *https://buildingdata.energy.gov/cbrd/search/resources/k12ZEstep2.*

STEP THREE

Including Zero Energy Goals in the Procurement Process

The procurement process is the method used to purchase the goods and services required to design, construct, and operate a building. Most purchased items—appliances or tools, for example—are complete, discrete units and the design, engineering, and manufacturing costs are built into the price. Procuring a building is different—it is a highly involved, customized process involving a number of players. Producing a ZE school on a conventional school budget requires an integrative design approach that considers each strategy, system, and component from the perspective of an overall goal, namely achieving an EUI low enough that the building's energy needs can be met with an on-site renewable energy system.

Socastee Elementary School in Horry County, South Carolina, has a goal of producing 10% more energy than it uses. Photo by Horry County Schools

To achieve ZE, school owners should make ZE a written goal in their procurement processes. To accomplish that, owners set energy performance goals for a project and implement them with a procurement process that prioritizes the goals within budgetary constraints. Procurement processes should take full advantage of the creativity and problem-solving skills of the design and contractor teams to deliver schools that meet or exceed the performance objectives.

Although it can be challenging, school districts should align their procurement practices to prioritize energy efficiency along with critical educational priorities. Every school district has policies that outline their procurement process. These vary greatly, so school owners can modify the suggestions in this step to accommodate local norms and practices.

Procurement best practices for K–12 ZE schools fall into the following high-level categories, listed in order of importance and described in detail below:

- Establish a target EUI, usually measured in $kBtu/ft^2 \cdot yr$.
- Select contractors based on their ability to meet or exceed performance goals within the project's budgetary constraints.
- Identify the programmatic requirements for the building along with energy and other performance-based goals.
- Implement a procurement process that evaluates contractors based on a prioritized list of goals established by the school owner.
- Ensure the project team is committed to the energy goals.

Establish a Target Energy Use Intensity and Include It in the Procurement Documents

The objective of a target EUI goal is to deliver a building that provides all necessary services and maintains comfort using as little energy as possible within a fixed project budget. Establishing an energy goal and a fixed budget at the beginning of the project enables the design team and contractor to create solutions that meet both programmatic needs and energy goals. Ideally, the school owner establishes an EUI goal at the beginning of the process and includes it in the RFP. This EUI goal is included in the contract and maintained through design, construction, and operations.

Establishing the EUI goal is not standard practice for most projects, even ones that are built as "green" or "energy-efficient." Typically, an energy projection is calculated after the design is substantially complete, and energy performance is a result of the design process. In a ZE school project, energy performance is a driver of the design process.

Energy goals can be established and validated several ways, and the ZE K12 AEDG (ASHRAE 2018) is a good starting point. In this publication, computer models combined with actual building case studies were used to create energy goals for a ZER school—a school so energy-efficient that on-site renewables could meet its energy loads. Several case studies have shown that these goals are achievable across different climate zones (DOE n.d.-a; NBI 2018). To establish the target EUI:

- Use the recommended values from Table 2, which is taken from the ZE K12 AEDG (ASHRAE 2018, Table 3-1, p. 34). Demonstrate to internal stakeholders that the EUI targets are attainable by providing case studies of similar schools that achieved low EUIs (DOE n.d.-a; NBI 2018).
- Determine whether any specialty functions will be needed and add these uses to the energy total. Examples include swimming pools, ice rinks, television-quality lighting for sports fields, laboratories, technical education centers, and other spaces with higher energy and ventilation requirements.
- Adjust the EUI goal down where possible to achieve higher efficiencies, further reducing the size and cost of the on-site renewable generation required to meet the building's energy loads.

Note that both site energy and source energy values are listed in Table 2. The DOE definition of a ZE building is "An energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy." Thus, when energy purchased from the electrical grid is consumed on-site, site energy is converted to source energy to account for the energy consumed in the extraction, processing, and transport of primary fuels such as coal, oil, and natural gas; energy losses in thermal

Table 2. Target Energy Use Intensity by Climate Zone

Climate Zone	Site Energy		Source Energy	
	Primary School EUI ($kBtu/ft^2 \cdot yr$)	Secondary School EUI ($kBtu/ft^2 \cdot yr$)	Primary School EUI ($kBtu/ft^2 \cdot yr$)	Secondary School EUI ($kBtu/ft^2 \cdot yr$)
0A	22.5	22.9	69.1	70.5
0B	23.1	23.2	71.4	71.6
1A	21.3	21.1	65.5	65.0
1B	21.7	21.6	66.6	66.6
2A	20.9	21.3	63.8	65.1
2B	19.6	19.9	59.7	60.8
3A	18.8	19.1	56.7	57.7
3B	19.0	19.4	57.3	58.8
3C	17.5	17.6	52.6	52.8
4A	18.8	18.9	56.3	56.7
4B	18.4	18.5	55.1	55.5
4C	17.5	17.6	51.9	52.3
5A	19.2	19.1	57.1	56.9
5B	18.7	19.0	55.6	56.6
5C	17.4	17.6	49.7	52.3
6A	21.1	20.6	62.8	61.2
6B	19.5	19.5	57.9	57.9
7	22.3	21.5	66.2	63.7
8	25.2	23.8	71.1	70.7

To determine the locations of the climate zones in Table 2, refer to the climate zone map in the ZE K12 AEDG (ASHRAE 2018, Figure 3-2, p. 35).

combustion in power generation plants; and energy losses in transmission and distribution to the building site (DOE 2015). This conversion also applies to other energy sources delivered to the site (natural gas, fuel oil, propane, or firewood, for example).

Other guidance for establishing a target EUI includes:

- Give designers and contractors the flexibility to create solutions that meet the performance targets without adding significant additional cost or risk.
- Instead of percent reductions compared with a baseline building or existing building code, use whole-building absolute energy use targets. This strategy provides clear energy performance goals that leave no room for interpretation. Percent reduction goals require a baseline to be established, which can be time-consuming and can reduce the incentive to create energy-efficient buildings. Absolute energy targets are also preferable because they easily translate into performance targets that facility managers can use once the building is operating.
- Create target levels of energy efficiency and prioritize with the other building goals (see Figure 2). Then have contractors compete to develop the most comprehensive solution for the available budget.
- Define energy boundaries for energy consumption and generation at the facility. A common boundary is the property line, including areas covered by utility meters or fuel deliveries.

- Establish school district and campus energy efficiency priorities through the development of an energy master plan.
- Include a requirement for energy modeling throughout the design process and use it to design the building to meet the target EUI. Also require an as-built energy model to show that the energy goal has been met.
- Use the energy model as an operational tool. Variations in the actual performance can be reported as warranty claims for the contractor to correct.

Select Contractors Who Can Meet or Exceed Performance Goals within the Budget

The integration of energy goals is easier in some procurement processes than in others. The school owner should hire designers and construction contractors who understand and are committed to achieving the energy goal (see also Step Four). Contracts for design and construction should include energy and other performance criteria. When ZE is a school goal, selection of the design and construction team should be based on qualifications and best value. Selecting the lowest bid is less likely to result in a design and construction team that can deliver a ZE operational performance goal.

Design-bid-build (DBB), construction manager at risk (CMAR), and design-build (DB) are three project delivery methods often used to design and build schools. For a discussion of the advantages and disadvantages of these delivery methods in a ZE building project, see Pless et al. 2012 (p. 9–17) and the ZE K12 AEDG (ASHRAE 2018, p. 24–26).

Energy-related goals can be inserted into all three, but for the most effective process, the building owner should consider a performance-based design-build procurement process (DBIA 2009; Idaho 2014; Pless et al. 2012). With this delivery method, the owner is more likely to achieve a ZE building at a cost comparable to a traditional high-performance building by requiring that the project team deliver a building that meets the energy and other performance-based goals for a firm fixed price.

Identify Programmatic Requirements and Energy Performance-Based Goals

School owners should clearly describe the problems they would like the architect and engineers to solve. The RFP should include objectives that address the problems, but the objectives should not be so specific that they could overly constrain the design team. Allow the design team the freedom to use its problem-solving skills to develop creative solutions. The building owner should avoid using prescriptive solutions in the RFP because these will place unnecessary constraints on the designers and contractors.

The school owner's problem definition is the expression of need. It helps get to what is necessary and what could be optional. For example, a current school building may be costly to maintain. The school district may need a new building with low operating costs, reducing the district's financial exposure to potentially volatile energy costs. At the same time, the building must provide a superior learning environment.

The building owner can use this problem definition to determine the goals the designer and contractor must meet. A ZE goal could be used to reduce the district's exposure to volatile energy costs. The RFP objectives should include the EUI goal and must be measurable.

The RFP should also include a fixed budget. The selected design team should be able to meet the EUI goal within the fixed budget.

Implement the Procurement Process

Evaluate responses to the RFP based on a prioritized list of goals established by the owner and organized into tiers. A tiered goal structure can be used with any delivery method; when it's used with the design-build delivery method, however, it increases the likelihood of achieving ZE (Pless et al. 2012). The tiered EUI goals communicate the owner's project objective priorities to bidders. The tiered approach includes a critical must-have energy goal as well as harder-to-achieve optional goals. Both goals can be included in the list, and contractors can compete based on how many goals they can meet for the predetermined budget.

The owner can include energy goals and other needs in an objectives checklist sorted into the following tiers:

- **Mission critical**. Required by the contract; include at least one specific energy-related goal—such as ZE—in this section.
- **Highly desirable**. Not required by the contract but weighted heavily during the design-build team selection process. If not mission critical, general sustainability goals or aggressive EUI targets can be included in this section.
- **If possible**. Not required by the contract but can help identify the successful design-build team if a number of design competition submittals are similar. This is a good place for including goals such as highly aggressive EUIs.

These goals should be measurable. The owner needs to fully commit to these objectives so that the design-build process can address needs in a cost-effective and integrated manner. Figure 2 contains an objectives checklist developed by NREL when it was procuring its Research Support Facility (RSF), a 350,000 ft^2 ZE office building in Golden, Colorado (DOE n.d.-b); the checklist is modified for an example school.

Sample Project Objectives Checklist Using a Tiered Goal Structure

Zero Energy K–12 School Building

These are examples of energy-specific performance objectives; add others as appropriate:

Mission Critical

- Establish safe work performance/safe design practices
- Achieve top certification under third-party verified green building rating systems, such as CHPS Verified Leader or Leadership in Energy and Environmental Design (LEED) Platinum
- Attain ENERGY STAR® score of 100

Highly Desirable

- Accommodate up to 800 student plus staff capacity
- Operate at 25 kBtu/ft^2·yr
- Ensure architectural integrity
- Honor the needs of future students and staff
- Support multiple uses, culture, and amenities
- Create an expandable building
- Include ergonomics and responsive features
- Design flexible learning spaces
- Support future learning technologies and pedagogies
- Provide documentation to produce a "how to" manual
- Develop a public relations campaign implemented in real time for benefit of school and design-build team
- Allow secure collaboration with outsiders
- Provide building information modeling
- Achieve substantial completion by [anticipated date]

If Possible

- Achieve the EUI target for ZER or create a ZE building
- Attain 50% reduction from ASHRAE 90.1-2016
- Incorporate visual displays of current energy efficiency
- Achieve national and global recognition

Figure 2. Objectives checklist for an example school

Partner Snapshot: Including Zero Energy Goals in the Procurement Process in Douglas County, Colorado

The Douglas County School District (DCSD) in Colorado has a strong commitment to sustainability and green building goals. As a ZESA partner, DCSD is also committed to building and operating ZE school buildings.

In November 2018, Douglas County voters approved a mill levy override that allows the collection of additional "mills" on property taxes beyond what is allowed by the state of Colorado and a bond measure that, among other things, supports the construction of new schools to address community growth. These successful ballot issues provide funding for DCSD's sustainability and ZE efforts.

To advance those efforts, DCSD developed a request for qualification (RFQ) to ensure that the chosen project team will have the appropriate background to successfully complete the ZE project. The requirements in the RFQ are not exhaustive, but they do provide guidance for design and construction professionals interested in being involved with the ZE project.

For new construction, all new schools and buildings will be designed according to US-CHPS criteria[4] and/or LEED v4 for School Buildings,[5] as applicable. In addition, all new buildings will be designed to be ZE or ZER, with a target EUI of 25 kBtu/ft^2·yr or better.

All major renovation projects will also use US-CHPS criteria and/or LEED v4 for School Buildings as guidelines in design. Schools doing major energy retrofits will reduce existing average EUIs to the following targets:

- High schools: 40 kBtu/ft^2·yr
- Middle schools: 35 kBtu/ft^2·yr
- Elementary schools: 35 kBtu/ft^2·yr.

Each project will be assessed for energy performance, targeting a 20% or greater reduction in energy use for systems and components where applicable. Energy modeling as well as commissioning of mechanical systems will be required to ensure all systems are performing optimally. Upgrades must boost sustainability, including installing LED lighting in some locations, particularly gyms; replacing old, inefficient boilers with efficient models; replacing windows; and installing or replacing pipe insulation. New roof structures and membrane replacement will be designed to be solar-ready, and schools should work with DCSD to properly uninstall and reinstall existing solar panels on reroof projects.

Last but not least, projects should support the DCSD educational mission by striving to incorporate teachable moments through, for example, developing lessons around the construction work in the school and the energy-efficient or sustainable features; designing features that teach, such as a green wall; and including student groups in the design and construction process.

4. https://chps.net/sites/default/files/US-CHPS__Criteria_2014_2016%20update_170706.pdf

5. https://www.usgbc.org/education/sessions/leed-v4-school-buildings-rv-10647aw-5076918

Teams of students at Sage Canyon Elementary School in Castle Rock, Colorado, created working renewable energy displays (this one is hydropower) for an energy expo open to the school and parents. Photo by Beth Church, DCSD

The gym at Boulder Valley School District's Douglass Elementary School uses daylighting to reduce the need for electric lighting. Photo by RTA Architects, David Lauer Photography

Ensure the Project Team Is Committed to the Energy Goals

The project team consists of the architects, engineers, contractor, key subcontractors, key stakeholders, commissioning agent, and others, and can include the school owner and the owner's representatives. The school owner develops key project requirements and an energy goal, drafts the RFP, reviews proposals, and selects the successful proposal.

Others who might be involved in ensuring the project team's commitment to the ZE goal include:

- ZE champions who encourage the use of integrative design and the modification of legacy procurement practices to achieve ZE
- Team members with building energy modeling expertise
- Team members comfortable using a collaborative, iterative process to:
  - » Develop detailed analyses for setting project goals and energy performance goals during predesign
  - » Cycle between data analysis, building simulation, and design to optimize the design; this iteration should be carried into postoccupancy as occupants determine the most energy-efficient ways to operate the building.

Procuring a ZE school requires that all project team members commit to achieving ZE. Ideally, the ZE goal is written into all contracts, but regardless of whether they are contractually obligated to meet the ZE goal, the selected architects and engineers should have a strategy for meeting the EUI goal and a commitment to executing that strategy.

Although it is an advantage for a design team to have expertise in creating ZE schools, it is not an absolute necessity. As ZE buildings become more common, more design and construction professionals will be familiar with the details of achieving low EUIs within fixed project budgets. Until then, building professionals, end users, and stakeholders need to be educated and involved in the design process to ensure the building achieves ZE during operation. An integrated design approach has proved effective in bringing all the players together to work iteratively and collaboratively from the beginning of the process.

Resources for Including Zero Energy Goals in the Procurement Process

Alternative Project Delivery (from Idaho Transportation Department Innovative Contracting Unit): *https://itd.idaho.gov/wp-content/uploads/Alternative-Project-Delivery-Workshop-2014-05-14.pdf*. PowerPoint presentation on design-build and other project delivery methods.

The Design-Build Process for the Research Support Facility: *https://buildingdata.energy.gov/cbrd/resource/1309*. In-depth look at how DOE and NREL used a performance-based design-build process to design, build, and operate a ZE office building.

An Energy-Performance-Based Design-Build Process: *Strategies for Procuring High-Performance Buildings on Typical Construction Budgets*: *Preprint*: *https://buildingdata.energy.gov/cbrd/resource/1640*. Information on the importance of defining measurable energy efficiency at the beginning of a project to ensure building performance.

How-To Guide for Energy-Performance-Based Procurement: *https://buildingdata.energy.gov/cbrd/resource/1310*. Background on the importance of establishing measurable performance-based energy goals from the beginning of a project and guidance on maintaining those goals throughout the process.

Realizing High-Performance Buildings: How to Maintain Energy-Efficient Design Intent During Building Operation: *http://www.nrel.gov/docs/fy15osti/62530.pdf*. Guide to critical aspects of building operations in very energy-efficient buildings focused on specific building systems.

Zero Energy Schools: The Challenges: *https://buildingdata.energy.gov/cbrd/resource/2487*. A fact sheet on how school districts and their design and construction teams have overcome challenges to achieving ZE in school buildings.

Updated resources for Step Three: *https://buildingdata.energy.gov/cbrd/search/resources/k12ZEstep3.*

STEP FOUR

Selecting a Design and Construction Team Committed to Zero Energy Goals

In this step, the school owner focuses on implementing a procurement process and selecting a team that can design and construct a ZE building within the project budget. Much of this step involves vetting prospective project team members, which include architects, engineers, construction firms, or combinations of these building professionals. During the competitive selection process, the school owner conducts interviews to gain insight into whether the candidates have the requisite experience and expertise to deliver a ZE building.

In addition to working toward achieving zero energy, Douglass Elementary School in Boulder, Colorado, provides a bright, inviting teaching and learning environment. Photo by RTA Architects, David Lauer Photography

Before awarding the contract, school owners should question their selected bidder or bidders to ensure they can deliver a building that achieves the objectives outlined in the checklist in the RFP. Different school districts use different procurement processes, and some are more constrained by procurement requirements than others. The nature of the questions owners ask may shift depending on the procurement process used. If the owner used a tiered approach in the RFP, the bidder must meet the *mission critical* objectives. Bidders can then be evaluated on the number of *highly desirable* and *if possible* objectives they can deliver within the budget. (See Step Three for an example of an owner's objectives checklist [Figure 2] and definitions of terms.)

In design-bid-build, the interview questions should be directed to the design team and focused on determining whether it can deliver construction documents for a school that can be built for the allocated budget and meet the ZE goal.

In construction manager at risk, the responsibility to deliver construction documents still rests with the design team; however, the construction manager provides input during the design process to ensure that the building can be constructed within the budget. Here, questions focus on the ability of the two entities to work together to achieve the goals even though they may have no contractual ties.

For design-build, the contract is with the contractor, creating a single point of accountability. The owner focuses on the contractor's ability to supervise the design and deliver the entire project on budget while meeting performance goals.

The selected bidder should demonstrate an ability to address energy goals in the earliest design stages. This approach will allow the designer to achieve energy goals at a lower cost than "adding on" energy efficiency measures at the end of design process. Considering energy efficiency elements early can also impact other design decisions and the systems necessary to support building operations, creating opportunities for cost savings. The most effective strategies from both an operational and cost perspective are integrated into the architecture of the school building. (See *Design Strategies* in this step for more detail on passive and simple energy efficiency strategies.)

Table 3 includes interview questions to help school owners evaluate bidders—one of which will be the future project team (described in Figure 1)—and select the team that is most likely to achieve the energy and building performance goals. The Guidance for the School Owner column provides guidance for evaluating the bidder's response. This column could include examples of answers that show competence or weaknesses. A checkmark in the last three columns indicates whether the questions are appropriate for the DB, DBB, or CMAR project delivery mechanisms. When using design-build, the bidder is usually a contractor. In instances of design-bid-build, the bidder is a design team (architect and engineer). With construction manager at risk, the bidder is the construction manager and the design team.

The questions in Table 3 are divided into energy goal-related and nonenergy questions. The questions are intended as a small representative sample set that may provide insight into some energy aspects, but they are not intended to be a comprehensive interview question list.

Other Strategies for Selecting a Design and Construction Team

Below are descriptions of best practices for selecting a design team/contractor that building owners should consider:

- Write calculation methods into the RFP that bidders should use to demonstrate how their design performs against project objectives/measurable goals. These can be described in the RFP's appendix. These calculation methods are energy calculations and modeling approaches that can be applied to any solution. One example is requiring that an energy model be developed and used throughout the design process.
- Write measurable energy performance goals into contracts to incentivize the contractor to achieve the energy goal. The contract can contain assurances from the contractor or architect that the energy goal will be met. Part of the payment could be withheld until building performance is substantiated. After a year (or more) of operation, energy data can be used to determine if the building is meeting the energy goal. If it is, the contractor receives the incentive payment.

Table 3. Evaluating Project Teams

Interview Question	Guidance for the School Owner	DB	DBB	CMAR
Energy goal-related questions (in order of importance)				
Explain how the energy goals in the RFP will be met. Alternative question (if no energy goals are in the RFP/objectives checklist): What should the energy goals be for this project? What quantity of on-site renewables will it take to achieve ZE?	The bidder should be able to reiterate the energy goals, know how to measure them, and understand that meeting energy goals is a key determinant of project success. If it's up to the designers to set the energy goal, they should be able to ballpark the EUI during the interview. The correct response will be around 20–25 kBtu/ft²·yr or less. They should be able to discuss the strategies and infrastructure required for on-site renewables, including utility connections. They should be familiar with possible alternative financing mechanisms. Can the bidder show examples of previous work that is consistent with or better than these energy numbers? At a minimum, bidders should have measured EUIs from previous projects.	X	X	X
How should energy goal success be measured? Can those energy goals be guaranteed?	Substantiation of energy performance is critical for meeting energy goals. Energy goals are either articulated as part of the owner RFP or by the design team. Ideal goals are measurable at the site or building meter, such as kBtu/ft²·yr. Teams can offer to substantiate energy goals by developing energy models and keeping those models updated throughout construction. In some cases, teams will offer to guarantee performance for a year (or more). (Guaranteed performance can be harder to enforce contractually than substantiated models.)	X	X	X
How will the project be managed to ensure energy goals are met? Alternative question: How will the team build a ZE school within the budget?	Teams should describe how energy modeling will affect and can guide the architectural design (including the building envelope) as well as the mechanical and electrical systems. Teams should describe how energy feature costs will be balanced with other costs to arrive at a solution that is within the budget.	X	X	X
How will the team ensure that this school building will have low utility bills after commissioning and during the next 30 years?	Durability and operational longevity should be part of the design. Simplicity of systems is also important. The design team must show that its solutions can be easily maintained, given the owner's maintenance budgets and expertise. For example, solutions such as increased insulation are more robust than complex heating, ventilating, and air-conditioning (HVAC) systems.	X	X	X
How will the design team know that the contractor selected to build the design will meet the budget?	The contractor should provide assurance that it can construct the building as designed for its bid price. Owners need to make it clear that they will not change the intent of the plans even when the contractor can show the change(s) will result in cost savings (often with an energy penalty).		X	X
How can the school owner be assured that the team is representing the owner's interests to meet programmatic needs and established energy goals?	Bidders will always indicate that they are meeting the interests of the owner. They should provide references and those references should verify that bidders met or exceeded measurable project goals such as energy use in past projects.	X	X	X
How can the school owner be assured that the construction team will produce a quality building?	The bidder should describe incentives it will use to ensure that the construction team builds the building according to the plans and that the building meets energy and other measurable goals.		X	X
Describe other school projects the team has designed and built that have met energy performance targets. Describe those targets and the processes used to meet them. Alternative question: Describe examples of low-EUI school buildings the team has designed that were built within a fixed budget.	The projects should have measurable goals such as an EUI target, ZE, or a percent energy reduction relative to a code or standard. The bidder could provide examples of how it would meet a rating system. Building owners should use caution to ensure that the rating system meets their requirements. Trading off green materials for long-term energy efficiency is not advised.	X	X	X

Interview Question	Guidance for the School Owner	DB	DBB	CMAR
Energy goal-related questions (in order of importance)				
Describe a project that used a design-build approach with performance-based targets to design and construct a school building with a specified energy goal. Follow-up question: Describe the process the team used to meet an energy goal within a fixed budget.	Examples of actual building energy performance (case studies) within a budget should be discussed.	X		
How will the team ensure that energy goals remain a central focus throughout the building delivery process?	Energy models should be updated from concept to completion and should demonstrate that energy goals continue to be met. Construction flaws can also be modeled (e.g., poor insulation installation). If a material substitution is needed, then it can also be modeled to determine that it doesn't adversely impact the energy budget, a process similar to assessing impacts within a fixed cost budget.		X	X
Discuss strategies the team will use to achieve the energy goal.	For detailed guidance on a few strategies, see the *Design Strategies* section in this step.	X	X	X
Nonenergy Questions				
How does the building design enhance the learning environment?	The first priority for any school is optimizing the learning environment for students. Energy efficiency and energy goals can enhance that learning environment by, for example, integrating energy efficiency and renewable energy strategies into the curriculum to make the building a living laboratory, using the money saved through reduced energy use to enrich educational programs, providing a healthier indoor environment through daylighting and better air quality, and improving students' overall educational experience with a beautiful and functional building design.	X	X	X
What are the potential risks associated with the design? How will those risks be mitigated?	What will the contractor do if the owner's goals are not met (energy and others)? How is risk minimized?	X	X	X
How will the constructability of the design be ensured during the design process?	Work with manufacturers to ensure success; provide examples of strategies being successfully employed on other projects.		X	
Describe any potential safety hazards and how the team will address those hazards.	Examples might include installing equipment in hard-to-access locations, PV panels near roof edges, etc. Ideally, design solutions would minimize risk broadly, including routine maintenance. (Can all the filters be easily changed? Can HVAC equipment be replaced without intruding into classrooms and other occupied parts of the building?)	X	X	X
How can reducing safety hazards be tied to the energy performance of the building?	Integration is key. A better thermal envelope might mean less rooftop equipment. Dedicated mechanical rooms mean no rooftop HVAC maintenance as well as better energy performance and clear roofs for PV systems.	X	X	X
Describe how the team will work with various stakeholders in the school district to meet the performance goals.	Give examples in which there was a stakeholder issue and a win-win solution resulted.	X	X	X
What are some examples of nonenergy benefits of energy efficiency strategies?	The bidder should be able to articulate the nonenergy costs and benefits of energy efficiency strategies. For example, a window system can provide ventilation, view glass, and daylighting. The bidder could describe the benefits of good air quality, full-spectrum lighting, and thermal comfort that can result from tight, well-insulated envelopes and reduced ductwork.	X	X	X

The last three columns are DB (design-build), DBB (design-bid-build), and CMAR (construction manager at risk).

- Select a bidder with the expertise to develop computer energy models of the proposed building and use the models throughout the design and into operation to ensure the building is meeting energy goals. Energy modeling can be used by the designer to determine and refine energy efficiency strategies integrated into the building envelope and structure, such as daylighting, thermal mass distribution, natural ventilation, and solar shading. It can also be used to assess active energy efficiency strategies and to understand the thermal-physical dynamics and trade-offs that systems have on one another.
- Require that the successful bidder have the expertise to develop energy models of the as-built building to substantiate that the contractual energy requirements are met. The bidder should also have the expertise to update the energy model with operational sequences and occupancy schedules during building operation and compare the model output with submetered energy use data to determine where the model is accurate and where it is not.

Design Strategies

The selected design/contractor team should be able to articulate best practice design strategies related to performance-based design and energy efficiency. The school owner should look for a designer/contractor team that:

- **Articulates the nonenergy-related costs and benefits of energy efficiency strategies.** Although the RFP will focus on energy efficiency, the design team should be able to describe non-energy costs and benefits to stakeholders, who may care less about energy efficiency and more about the non-energy benefits. For example, when NREL constructed the RSF, 18 centrally located network-connected high-quality printers were installed and 300 individual desktop-connected printers were removed. This not only reduced the plug loads (an energy-related benefit), but also provided building occupants with well-serviced printers, a nonenergy-related benefit. The consolidation also reduced the variety of ink and toner cartridges NREL purchased, saving money because of economies of scale, a second non energy benefit.
- **Understands that modular or repeated design strategies are ways to save money on construction costs.** Highly replicable building-block modules are the most cost-effective design and construction strategies. Taking advantage of this will help reduce costs. In contrast, unique space types or design elements add cost. If a space type or building feature can be replicated, then doing so can save money. For example, designing classrooms on the same side of a building to have the same basic structure and windows will reduce design and construction costs. These can be designed as modules with identical features (e.g., lighting/controls/windows). Construction costs can be minimized if modules are produced off-site and then

The National Renewable Energy Laboratory's Research Support Facility is a zero energy office building that cost the same to build as a conventional building. Photo by Dennis Schroeder, NREL 45244

Partner Shapshot: Selecting a Design and Construction Team Committed to Zero Energy in Hermosa Beach, California

Sustainability is important to the school district in Hermosa Beach, California, a small seaside town in Los Angeles County. When, in June 2016, the community passed a $59 million facilities improvement bond with 59% of the vote to address its overcrowded and outdated educational facilities, the opportunity to create a ZE campus and maximize energy efficiency for its other schools was a high priority. The passage of the bond created the Measure S School Facilities Project, which funded the reconstruction of Hermosa North School as well as renovations to Hermosa Valley School and the modernization and some new construction at Hermosa View School.[6]

District officials knew that selecting a design and construction team committed to ZE goals would be especially important for North School, a new elementary school to be built on the site of an existing school that had been closed for decades. They wanted North School to be a sustainability showcase and a rich learning environment in which students could explore and understand the features and benefits of a ZE school.

Measure S was developed over many years and reflects extensive input from the community (for more information on engaging stakeholders, see Step Two in this document). Before they issued an RFP, the district rallied community resources, including sustainability advocates, elected officials, and interested community members and involved them in the solicitation and interview process for the design team.

To demonstrate the required experience, the district asked respondents to provide examples of previous ZE and energy-efficient projects. The successful firm, SVA Architects, had completed the ZE Downtown Educational Complex for Oakland Unified School District and the University of California at Davis West Campus Village, a large ZE student housing development.

During the finalists' interviews, the district and community members on the interview panel asked follow-up questions about the ZE design process and the lessons from those projects that could be applied to the Hermosa sites. The district also ensured that the architects' engineering consultants had the necessary experience and expertise to design the mechanical, electrical, and plumbing systems required for a ZE school.

After it selected the design team, the district ensured that the ZE goals for the sites were included in the contract language. In addition, it incorporated the additional energy modeling required to verify that the projects would achieve their ZE goals within the scope of the design services.

6. *https://hbcsd.org/District/Department/22090-Measure-S*

Thanks to community support for a facilities improvement bond in Hermosa Beach, California, Hermosa North School will be reconstructed as a zero energy school. Image by SVA Architects, Inc.

St. James Intermediate School in Myrtle Beach, South Carolina, which opened in August 2017, serves fifth and sixth grades and has a goal of producing 10% more energy than it uses.
Photo by Horry County Schools

transported to the site for installation. Repeatability allows the module's construction processes to be replicated, eliminating the need to develop different processes to construct rooms with varying features.

- **Explains the importance of simple and passive energy efficiency strategies.** The designer should strive to reduce long-term maintenance costs where possible by specifying simple, durable, passive systems with low life cycle costs. Examples include effective thermal envelopes, thermal mass, daylighting and reduced lighting power density, and overhangs for shading. In addition, right-sizing HVAC systems is a simple strategy for reducing cost and energy use.
- **Includes equipment with best-in-class energy efficiency.** The designer should be knowledgeable about commercially available energy-efficient equipment and have experience integrating it into buildings and developing procurement guides for future equipment purchases.
- **Solicits input on the constructability of the design.** Early in the process, the designer should solicit input from construction experts about whether the design can be built within the construction budget.

Challenges

One of the biggest challenges when selecting a team or teams to design and build a ZE school is ensuring that the energy goals are considered throughout the design and construction process. In design-bid-build, for example, designers (architects and engineers) estimate construction costs during the design process. If the construction contractor's estimate is higher than the designer's, the design may have to be modified to meet the budget. Equipment included in the design expressly to meet energy goals may have higher up-front costs than less energy-efficient choices. Switching the energy-efficient options for the less energy-efficient options to meet the budget could ruin the building's chances of meeting EUI targets, and, in turn, achieving ZE. School owners should be aware of these trade-offs and put processes in place that prevent these energy efficiency compromises. One strategy is to use a performance-based DB process that requires the DB team to deliver a ZE building at a fixed price.

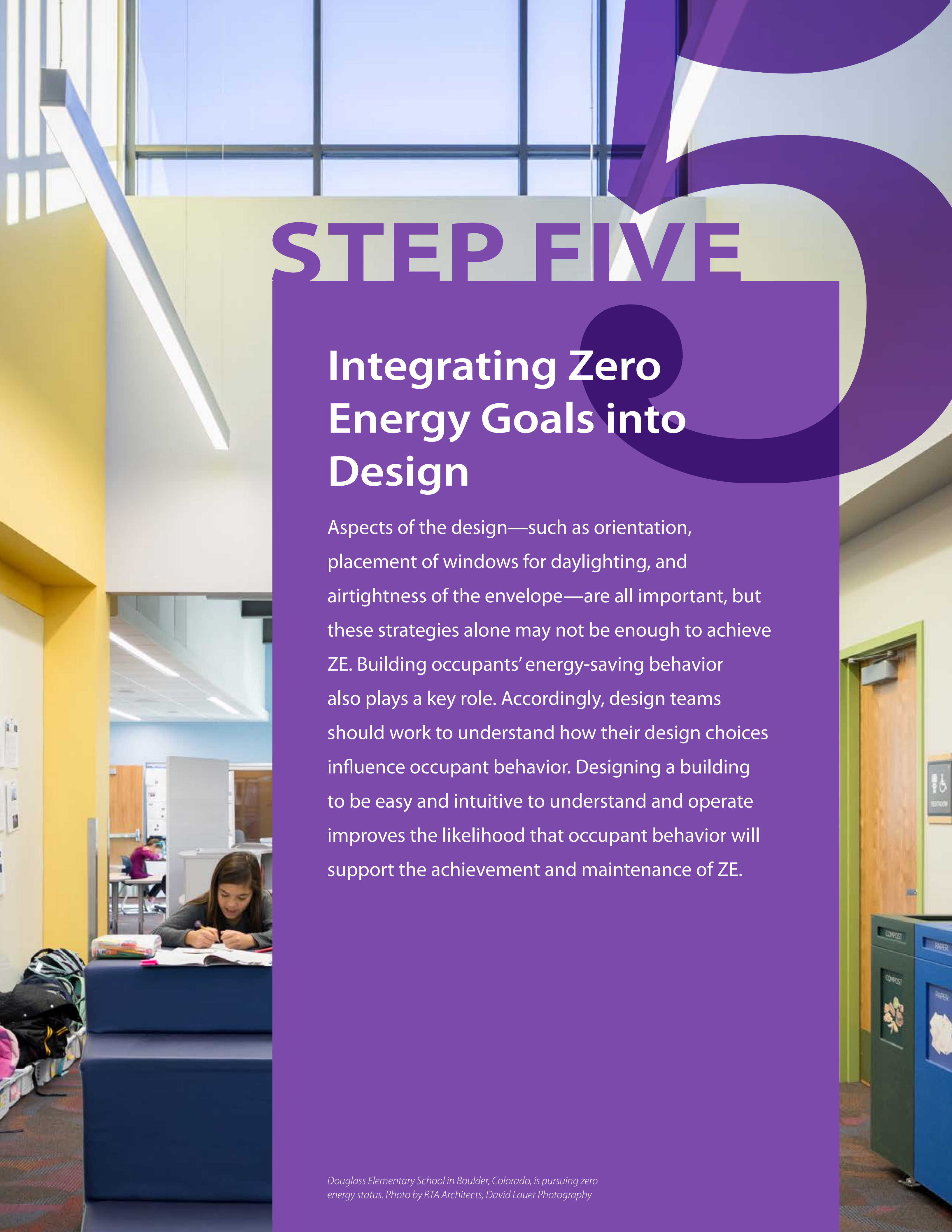
Resources for Selecting a Design and Construction Team

An Energy-Performance-Based Design-Build Process: *Strategies for Procuring High-Performance Buildings on Typical Construction Budgets*: *Preprint*: *https://buildingdata.energy.gov/cbrd/resource/1640*. Information on the importance of choosing a design team committed to the project goals.

*How-To Guide for Energy-Performance-Based Procuremen*t: *https://buildingdata.energy.gov/cbrd/resource/1310*. Information on integrating the owner, design team, builder, estimators, subcontractors, commissioning agent, and others from the beginning of a project.

Zero Energy Schools: Architects Take the Lead: *https://buildingdata.energy.gov/cbrd/node/2491*. Fact sheet on the importance of hiring a project team committed to meeting the ZE goal.

Updated resources for Step Four: *https://buildingdata.energy.gov/cbrd/search/resources/k12ZEstep4.*



STEP FIVE

Integrating Zero Energy Goals into Design

Aspects of the design—such as orientation, placement of windows for daylighting, and airtightness of the envelope—are all important, but these strategies alone may not be enough to achieve ZE. Building occupants' energy-saving behavior also plays a key role. Accordingly, design teams should work to understand how their design choices influence occupant behavior. Designing a building to be easy and intuitive to understand and operate improves the likelihood that occupant behavior will support the achievement and maintenance of ZE.

Douglass Elementary School in Boulder, Colorado, is pursuing zero energy status. Photo by RTA Architects, David Lauer Photography

Design Considerations

Aspects of the design—such as orientation, placement of windows for daylighting, and airtightness of the envelope—are all important, but these strategies alone may not be enough to achieve ZE. Building occupants' energy-saving behavior also plays a key role. Accordingly, design teams should work to understand how their design choices influence occupant behavior. Designing a building to be easy and intuitive to understand and operate improves the likelihood that occupant behavior will support the achievement and maintenance of ZE.

For example, designs can place stairs in the line of sight from the entranceway and place elevators out of the line of sight. If the stairs are visible from the entrance and the elevator is less noticeable, occupants who only need to go up one or two flights may opt to take the stairs rather than spending time looking for the elevator.

In addition, easily accessible light switches with simple on/off operation give occupants control over light levels. Complicated light switches frustrate users and lead them to override lighting controls, defeating the purpose of an energy-efficient lighting system. Lighting systems can have manual on/off controls, with a sweep function for after-hours shutdown. This preserves user control features while adding measures to prevent wasting electricity on unnecessary lighting during periods when the building is unoccupied.

Mechanized windows—windows connected to a motor and a controller that are programmed to open automatically when the outside weather conditions are ideal—can also save energy. Through this strategy, the building can be quickly cooled and naturally ventilated without any action on the part of the occupants. Windows can also be manual as long as occupants are trained in their use and the school cultivates a culture that supports proper operation.

The design can also use signs and other features that display information about the energy use, energy production, and energy efficiency features of the school. These can be energy dashboards, information placards, tours, and even see-through walls and/or floors that give occupants and visitors a view of building systems.

Specifying submeters that measure energy end uses makes it easy to monitor building energy use on a granular level. Energy dashboards show students, teachers, and visitors the school's energy use and production. A dashboard can display building energy use or data from the submeters in real time so that occupants can become familiar with the energy use patterns in the school and get involved in maintaining and improving the school's energy performance. Dashboards should be appropriate for the school's grade levels and available online. The energy dashboard communicates to all that energy efficiency is a school community priority, which reinforces occupant behavior that supports ZE. Discovery Elementary in Arlington, Virginia, has a dashboard that is age-appropriate for elementary school students. Figure 3 is a screenshot of this dashboard, which shows power consumption, power production, and net power.

Building signage can inform students and other occupants about energy-efficient systems and passive design strategies in the school. Signage is important to remind

Figure 3. Energy dashboard screenshot for Discovery Elementary in Arlington, Virginia, taken at 2:23 p.m. Eastern Standard Time, January 8, 2019

building occupants of energy-saving opportunities. For example, signs can remind occupants to turn off lights when a room is not occupied or to turn off equipment and devices when not in use to manage plug loads.

See-through building sections are also effective ways to display energy efficiency features. NREL's RSF, a ZE office building, provides viewing opportunities into the floor as well as acrylic walls around the mechanical room.

The building design should consider occupants' needs along with energy performance. For example, a common energy efficiency feature in ZE schools is classroom daylighting; to deliver savings, the windows that provide daylight need to be free of obstructions. At the same time, teachers need space to post information around the classroom as part of their instruction. In this case, teachers should be encouraged to keep windows free of obstructions, and the design should provide ample space for posting informational displays or accommodating student work in other areas of the classroom.

See-through building sections, like this "truth wall" at Emerald Elementary School in Broomfield, Colorado. Designed by RB+B Architects and Fielding Nair International, Photo by Paul Brokering Photography

Include Energy Expertise in the Quality Assurance Team

A quality assurance (QA) team is crucial to ensuring that energy goals established early in the process are achieved in practice. There are different ways to organize contracts and people to ensure high-quality results. Often, a QA team includes school district staff that are technical experts and an external commissioning authority (CxA) accountable to the owner. The school owner should contract directly with the CxA to ensure that the CxA is committed to the ZE goals. The CxA operates as an owner's technical advocate. Ideally, the CxA is engaged as early as possible in the design process. The CxA can help develop a procedure to verify the energy goals and serve as the mechanism to validate that the goals have been met. The CxA should contribute to the owner's project requirements (OPR), a document that establishes the owner's expectations for the project.

Design Quality Assurance

The goal of QA during the design phase is to ensure that the design meets the requirements of the RFP. The QA team should require the designer to substantiate energy goals throughout the design process. The RFP should include an energy use calculation methodology as well as guidance on the modeling capabilities required for the job. The design team should develop an energy model of the proposed building early in the design process, update it at every decision point, and use it to support all design (and construction) decisions.

The energy model can help designers think through architectural decisions that impact energy performance. These include building orientation, massing, and layout, as well as energy efficiency strategies integrated into the building envelope and structure, such as daylighting, thermal mass distribution, natural ventilation, and solar shading.

Key Checkpoints for Meeting Energy Goals

If measurable and absolute energy goals are included in the contract, then—ideally—meeting them during the design process will be straightforward. However, some key checkpoints to track energy goals are listed below for different stages of design, and some of the checkpoints include the location of additional relevant information in the ZE K12 AEDG (ASHRAE 2018).

Schematic Development through the Construction Documentation Phase

- **Establish a QA team** with clear roles to oversee the QA process. This team could be a mix of in-house technical experts and an external CxA; see the ZE K12 AEDG (ASHRAE 2018, p. 38).
- Have the design team **develop an energy model** that incorporates different passive and energy efficiency technologies to meet the EUI target. The energy model should be based on the findings uncovered during the building needs assessment (Step One in this document) and provide verification that the model represents the building as built. As part of the team selection process, bidders should also have previously provided evidence of their modeling expertise by presenting other projects in which model predictions agreed with operational measurements within acceptable error bounds; see the ZE K12 AEDG (ASHRAE 2018, Chapter 4, p. 45).
- **Discuss the simulation results** with the design team and identify any areas that might pose a challenge to meeting the EUI target.
- **Compare the end-use breakdown** of the energy model with the examples in Bonnema et al. 2016.
- **Update the energy model** throughout the design to reflect the latest design. The model should include current specifications such as equipment efficiency and insulation values; see the ZE K12 AEDG (ASHRAE 2018, p. 46).
- During the design process, **clearly document the modeling inputs** used to achieve the EUI target. These inputs can be used later to compare the measured data with the simulation results.

Planning for Quality Assurance during Postoccupancy

- Larger school districts typically **appoint an energy manager** to oversee the energy performance of the district. If a full-time appointment is not possible,

Partner Snapshot: Integrating Zero Energy Goals into Design in San Francisco, California

The San Francisco Unified School District (SFUSD) requires school building design teams to reduce energy use to the point that new school buildings can achieve ZE. To facilitate the process, SFUSD provides guidance for project teams to ensure that the completed schools meet their energy goals. Toward that end, SFUSD requires that architects use the following strategies during the process of creating new buildings:

Integrative design. All projects begin with an architect-led design charrette focused on identifying the strategies and systems necessary to meet the district's EUI target of less than 20 kBtu/ft^2·yr. At a minimum, the project manager; Sustainability Office representative(s); buildings and grounds personnel; design team staff; commissioning agent; and electrical, mechanical, and civil consultants will attend. When it's feasible, a design-build procurement process is used to optimize the benefit of this approach.

Energy modeling. Building form, massing, orientation, and roof layout (among other design parameters) have a significant impact on energy usage and solar energy production. Therefore, design decisions will be evaluated against a constantly refined energy model from the earliest stages of a project. In this way, project architects will have many opportunities for course correction should site conditions or nonenergy parameters make achievement of ZE goals difficult. Modeling inputs should be clearly documented so that deviations can be identified after the building is occupied.

Commissioning. Commissioning agents hired by SFUSD will be brought into the design process early and will follow the project through design, construction, and postoccupancy to ensure that the design intent is achieved

Further, SFUSD provides detailed energy efficiency design guidelines. To achieve the levels of energy efficiency required to get to ZE, designers should

The 50-kW PV system on Alvarado Elementary School in San Francisco provides 20%–30% of the school's electricity and is a tool for teaching students about environmental stewardship. Photo by SFPUC

consult the ZE K12 AEDG (ASHRAE 2018).[7] SFUSD also provides guidelines for designers to follow during the design process in its OPR.[8] Here is a summary:

- **Energy**. New buildings should be designed to achieve a modeled EUI of 15–20 kBtu/ft^2·yr, a value that allows rooftop solar to offset yearly energy usage for a typical 2–3 story San Francisco school.
- **Form and siting**. Buildings should be simple and compact, oriented and sited for maximum solar access, integrated into the landscape, and with a depth and layout that allows daylight harvesting, natural ventilation, outside views, and the use of thermal mass.
- **Maintenance**. Every effort should be made to facilitate maintenance access to building systems (without ladders/lifts and without disturbing classes), and design teams are encouraged to expose the functional elements of the building for students to see.
- **Envelope**. To minimize the heating load, roof, wall, slab edge, and door insulation should be continuous and optimized through building modeling to comply with the building's EUI target.
- **Windows**. Windows size and specifications should be tuned based on building orientation. Assembly U-factor should be less than 0.30 on all sides (including roof) and thermally broken frames are required.
- **Lighting**. Whenever possible, buildings should use natural light to meet lighting needs.
- **Heating**. Space conditioning should be limited to permanently occupied areas; no conditioning is needed in foyers, hallways, restrooms, or closets. *No fossil fuel-based heating (natural gas) is allowed*.
- **Cooling and ventilation**. Occupied spaces should rely on natural ventilation unless schools are located close to a major pollutant source (e.g., freeway, major arterial).
- **Hot water**. Design teams shall specify heat pump and/or point-of-use water heaters set to 120°F and place these close to the point of use and/or in a warm part of the building.
- **Metering**. All completed projects shall contain smart meters as well as a networked touch screen.
- **Plug loads**. Expected plug loads should be discussed with the information technology department and factored into modeling results.
- **Solar**. In general, SFUSD plans to add solar only after having occupied a building for at least 1 year. However, design teams need to estimate the amount of solar capacity available so that EUI targets for the building can be modified to match expected power generation.

7. *Achieving Zero Energy: Advanced Energy Design Guide for K-12 School Buildings (free download): https://www.ashrae.org/aedg*
8. *SFUSD Project Requirements: https://gettingtozeroforum.org/wp-content/uploads/sites/2/2017/08/OwnersProjectRequirements_SFUSD.pdf*

train the building manager(s) to track building energy consumption. A monitoring plan and monitoring equipment should be included in the building budget; see the ZE K12 AEDG (ASHRAE 2018, p. 39).

- **Install monitoring-based commissioning systems** to automatically diagnose faults during operation; see the ZE K12 AEDG (ASHRAE 2018, p. 40–41).
- If the EUI exceeds the target, pinpoint the problematic area(s) using the **submetering reports**. Use the energy model inputs and results to determine the source(s) of the increased energy consumption.
- Install an **energy dashboard** with easy-to-understand graphics. It can be used as a tool to engage occupants and ensure the building is hitting the EUI target; see the ZE K12 AEDG (ASHRAE 2018, p. 15–16)
- Contract to calibrate the model after occupancy.

Aligning Energy Goals with Educational Opportunities

A ZE school building provides multiple learning opportunities for students. All occupants of the ZE school must work together before and after they move into the building to ensure the building is performing well and achieving its ZE goal. Students will learn how aspects of the building interact with one another and how this relates to sustainability and environmental stewardship.

Teachers can capitalize on these learning opportunities by incorporating energy efficiency, renewable energy, and sustainability into school curricula (see the Discovery Elementary video case study in *Resources for Integrating Zero Energy Goals into Design*). Not only are elements of the building educational, but designers can also work with teachers to develop curricula that stimulate student interest in the ZE aspects of the building.

Energy dashboards and building signage can enhance student learning. Energy dashboards can include data from student experiments as well as other sustainability considerations, such as student transportation modes, recycled materials, and quantities of uneaten food. Dashboards can be online so that teachers can access them in the classroom and students can access them at home. Teachers can assign research projects that integrate energy dashboard data and can refer to building signage during lessons about energy efficiency and sustainability.

Resources for Integrating Zero Energy Goals into Design

The Design-Build Process for the Research Support Facility: *https://buildingdata.energy.gov/cbrd/resource/1309*. In-depth look at how DOE and NREL used a performance-based design-build contract process to design, build, and operate a ZE office building.

Discovery Elementary School video case study: *https://www.youtube.com/watch?time_continue=35&v=2kTS4UODWwc*. Short video about Discovery Elementary School, a ZE school in Arlington, Virginia.

Example energy dashboard: *http://158.59.255.83/* or go to *https://discovery.apsva.us/* and click on Energy Dashboard in the left-hand menu. Discovery Elementary School, a ZE school in Arlington, Virginia, uses an age-appropriate energy dashboard as a teaching tool for students and the community.

Functional Performance Testing within the Building Envelope Commissioning Process: *https://www.brikbase.org/sites/default/files/best2_knight.pdf*. Information on commissioning the entire building envelope, from design through construction.

Guide to Operating and Maintaining EnergySmart Schools: *https://energy.gov/sites/prod/files/2013/11/f5/ess_o-and-m-guide.pdf*. Information on how smart energy choices in schools can create lasting benefits for students, communities, and the environment.

How-To Guide for Energy-Performance-Based Procurement: *https://buildingdata.energy.gov/cbrd/resource/1310*. Background on the importance of establishing measurable performance-based energy goals from the beginning of a project and guidance on maintaining those goals throughout the process and evaluating whether they have been achieved.

Updated resources for Step Five: *https://buildingdata.energy.gov/cbrd/search/resources/k12ZEstep5.*

STEP SIX

Achieving Zero Energy Goals during Construction and Commissioning

After taking steps during the design process to verify that energy goals will be achieved, the school owner's focus turns to maintaining targeted performance during construction and commissioning (ASHRAE 2013b). This step outlines strategies for QA during construction, including the role of a commissioning team at different stages of the project. The commissioning team ensures that building systems are functioning as expected so the school building achieves its energy efficiency goals and meets the EUI target.

Emerald Elementary School in Broomfield, Colorado, is a beautiful low energy building that provides a bright, vibrant learning environment for students and teachers. Designed by RB+B Architects and Fielding Nair International, Photo by Paul Brokering Photography

Quality Assurance

By the time construction begins, the school owner should have a QA team in place that includes in-house technical experts and an external CxA accountable to the owner. The concept of the QA team was introduced in Step Five, though ideally the QA team would regularly review and provide feedback at all stages of design and construction. Its comments and the steps taken to address its concerns should be documented. One of the important steps in this review is that the CxA should review the construction documents covering the systems that will be commissioned.

Accountability

Whether the designer or the contractor is responsible for quality at different stages of the project depends on the delivery mechanism (i.e., design-build, construction manager at risk, or design-bid-build). During the design phase, the QA team should ensure that the design meets the energy goals in the RFP and contract. During the construction phase, the QA team should ensure that contractors are building according to the plans and that the building is meeting design specifications. Table 4 identifies the accountable party for each project delivery mechanism during design and construction.

Construction Quality Assurance

A QA technique used during construction is to require the contractor to match the energy model to the as-built condition of the building. This should be the contractor's responsibility for design-bid-build project delivery. The contractor will often hire energy modelers and CxAs to ensure that it can meet its contractual obligation to achieve the energy targets.

Two key strategies in energy-performance-based construction are:

- **Require that contractors submit a QA/quality control plan** that demonstrates how they will achieve the required performance of different components. The building envelope is one of the critical components, including leakage rates; see the ZE K12 AEDG (ASHRAE 2018, p. 39).
- **Perform on-site inspections** and maintain an issues log; see the ZE K12 AEDG (ASHRAE 2018, p. 38–39). The QA team should perform periodic site inspections and systematically document the findings, solutions proposed, and follow-up actions taken. Refer to *Appendix K—Issues and Resolutions Log* in ASHRAE 2013b for an example of how to maintain an issues log.

Component Commissioning in a Zero Energy School

In a ZE school, commissioning of the following components is an especially important part of the QA process:

- **Building envelope**—walls, roof, and windows
- **Building systems**—HVAC, lighting, and renewable energy
- **Indoor environmental quality**—air quality, light quality, and acoustical performance.

Table 4. Accountability for Different Project Delivery Mechanisms

Phase	Project Delivery Mechanism		
	Design-Build	Construction Manager at Risk	Design-Bid-Build
Design	Because the contract is awarded to the construction contractor, who then hires the designer, the contractor is responsible for ensuring that the design meets the energy goals of the RFP and contract.	The construction manager serves as an advisor during the design process, but the designer is responsible for ensuring that the design meets the energy goals of the RFP and contract.	The designer is responsible for ensuring that the design meets the energy goals of the RFP and contract.
Construction	The contractor is responsible for ensuring that the building is constructed to specifications that will meet the energy goals of the RFP and contract.	The construction manager is responsible for constructing the building according to the designer's plans.	The contractor is responsible for constructing the building according to the designer's plans.

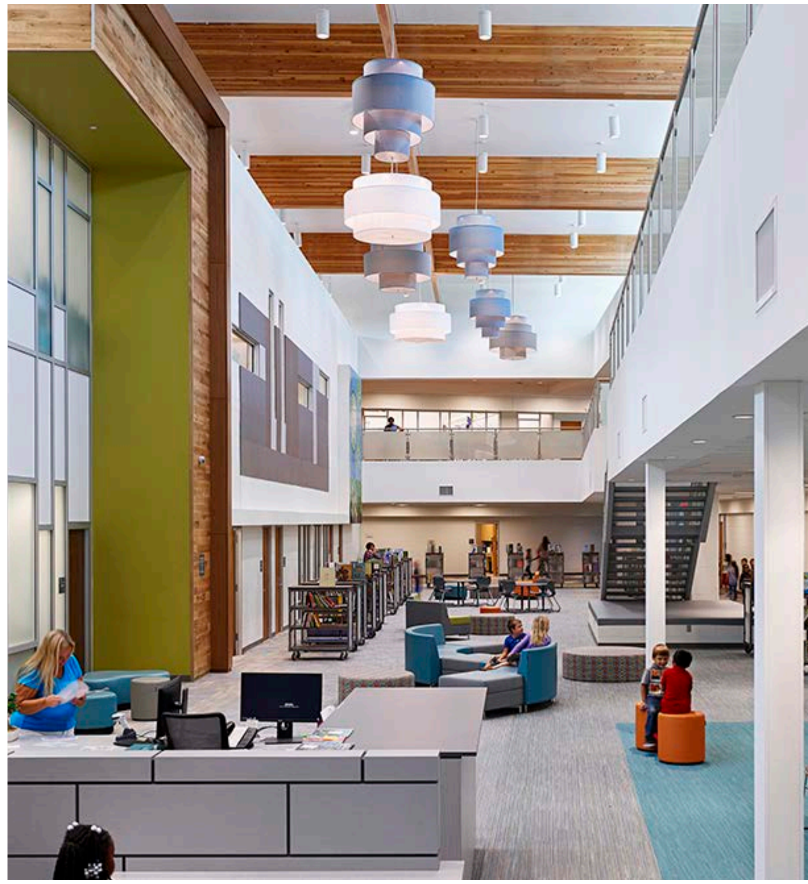
Envelope and building system commissioning focuses on the performance of building systems, and indoor environmental quality commissioning focuses on the health and comfort of the building's occupants. Guidance documents are available for performing detailed commissioning of a building. Refer to *Resources for Achieving Zero Energy Goals during Construction and Commissioning* at the end of this step for examples.

Information about commissioning these components is in the ZE K12 AEDG (ASHRAE 2018, p. 39–41).

Measurement and Verification

M&V is a phase that spans 12–24 months after the building is occupied. In this phase, the CxA, design team, contractor, and energy modeler work with the owner to track energy performance. If the measured EUI deviates from the predicted EUI, the source of the anomaly must be identified and the problem resolved.

Defining the M&V scope is extremely important but often neglected. The scope should be discussed with the entire team, appropriate roles should be defined, and responsibilities for meeting the energy target should be assigned. The M&V process can be used to show that the school is achieving ZE or ZER operating performance. If it is not, courses of action to achieve the energy target should be discussed.



In addition to its low energy use, Socastee Elementary School in Horry County, South Carolina, is a beautiful, comfortable building. Photo by Horry County Schools

Resources for Achieving Zero Energy Goals during Construction and Commissioning

Achieving Zero Energy: *Advanced Energy Design Guide for K–12 School Buildings*: Free download at https://www.ashrae.org/aedg. See Quality Assurance and Commissioning, p. 38–41.

ASHRAE Standard 202-2013—*Commissioning Process for Buildings and Systems*. https://www.ashrae.org/technical-resources/bookstore/commissioning-essentials. Available for purchase.

Commissioning Your Building during Design and Construction for a Healthy School Environment: https://www.epa.gov/schools-healthy-buildings/commissioning-your-building-during-design-and-construction-healthy-school. Summary of why commissioning a school is important and a resource list of helpful sources and organizations. Includes *Building Commissioning, Part of Indoor Air Quality Design Tools for Schools*: https://www.epa.gov/iaq-schools/building-commissioning-part-indoor-air-quality-design-tools-schools.

DOE-recognized building commissioning certifications: https://betterbuildingssolutioncenter.energy.gov/workforce/participating-certifying-organizations. List of certification programs that have received accreditation from qualified accreditation bodies.

Indoor Air Quality Guide: *Best Practices for Design, Construction and Commissioning*: https://www.ashrae.org/technical-resources/bookstore/indoor-air-quality-guide. Free download.

Whole Building Design Guide: *Building Commissioning*: https://www.wbdg.org/building-commissioning. Guide to the importance of building commissioning from predesign through operations.

Updated resources for Step Six: https://buildingdata.energy.gov/cbrd/search/resources/k12ZEstep6.

Partner Snapshot: Achieving Zero Energy Goals during Construction and Commissioning in Boulder, Colorado

In 2014, voters in Boulder County, Colorado, approved a bond program that included funding to advance the Boulder Valley School District's (BVSD's) sustainability goals as outlined in its *Sustainable Energy Plan*.[9] These goals include reducing the BVSD building portfolio average EUI to less than or equal to 30 kBtu/ft²·yr by Fiscal Year 2050, which aligns with the district's intention to make all new buildings in the district ZE or ZER.

As a result of the bond program, the district has built four new schools, all of which have exceeded the district's average EUI for a similar school. The schools are evaluating performance and engaging occupants to further reduce the building EUIs.

The results are encouraging. In Fiscal Year 2018, Creekside Elementary operated at an EUI of 42 kBtu/ft²·yr, Douglass Elementary averaged 43 kBtu/ft²·yr, Emerald Elementary was at 46 kBtu/ft²·yr, and Meadowlark Pre-K–8 hit the district target of 30 kBtu/ft²·yr. The PV system removed from the old Creekside school will be reinstalled on the new building and will provide much of the building's energy.

BVSD used several strategies to ensure that the new schools' energy goals would be maintained during construction and commissioning. Through a rigorous RFP process, the district selected a third-party energy consultant, which has been involved at every stage of each project, creating an arc of continuity for energy goals.

BVSD doesn't include energy goals in its design and building contracts—there are no penalties for missing or incentives for hitting energy targets—but everyone involved is well-acquainted with the district's energy priorities. From the beginning of the process, the owner (BVSD) and the energy consultant, who is also the energy modeler, strongly and regularly emphasized the importance of energy efficiency.

Despite the fact that BVSD has no contractual authority beyond reiterating the importance of meeting or exceeding the project energy goals, the design and construction process required frequent meetings involving all the players. This gave BVSD and the energy consultant multiple opportunities to remind the construction manager/general contractor (CMGC) to consider energy efficiency in every construction decision. And, of course, the CMGC and architect have bragging rights when they meet or exceed the goals.

The energy consultant also provides commissioning services to confirm that new equipment and systems are operating properly. Once commissioning is complete, the consultant provides M&V services to verify that the building is performing as designed. M&V can uncover problems missed during commissioning. If the measured EUI deviates from the predicted EUI, the energy consultant identifies and corrects the problems.

To engage students and staff and encourage friendly competition, BVSD has a districtwide dashboard that displays real-time energy use by school.[10] The dashboard tracks electricity use, can help modify occupant behavior toward efficiency, and rewards schools for their efficiency efforts.

9. *https://www.bvsd.org/green/Documents/BVSD%20Sustainable%20Energy%20Plan%2009262013.pdf*

10. *https://buildingos.com/s/bvsd/Storyboard/?chapterId=2504*

Daylighting is an important feature of any low energy building; the lunchroom at Emerald Elementary in Broomfield, Colorado, is a cheerful, daylit space. Designed by RB+B Architects and Fielding Nair International, Photo by Paul Brokering Photography

STEP SEVEN

Evaluating Performance and Engaging Occupants

After the teachers, staff, and students move in and begin to work and learn in the school, it's time to examine the energy data and evaluate whether the building is performing according to the energy model and design specifications. Occupant behavior directly impacts energy use and is a factor in whether the building achieves ZE. Although the design of the building can encourage occupants to minimize energy use (see Step Five), engaging occupants after they've moved into the building can also expedite their learning process about how they can help ensure that the building operates as efficiently as possible.

St. James Intermediate School in Myrtle Beach, South Carolina, is one of five low energy schools built in the district from 2017–2018. Photo by Horry County Schools

Evaluating Performance

At least a year's worth of energy use data is used to calculate whether the school building is meeting its ZE performance target. In a ZE building over the course of a full year, the balance of energy production minus energy use should be zero or positive.

Evaluating performance should be a continuous process, and it can take longer than a year to achieve ZE. The building operator should be able to instantaneously find the energy balance for a year by accessing information from the school's energy management information system (EMIS), which will indicate whether the building is on track to meet its ZE target. In addition to being shared back to the main district office, this information could be displayed on an age-appropriate dashboard such as the one at Discovery Elementary in Arlington, Virginia. The Discovery dashboard shows power consumption, power production, and net power (see *Resources for Evaluating Performance and Engaging Occupants* as well as Figure 3).

If a school does not have the capability to monitor continuously, the performance evaluation can be done using utility bills. However, the fine-grain data that result from submetering by building end use are helpful to gain insight into building operation and to spot issues that could jeopardize ZE operation.

To accurately assess that the building is meeting its ZE goal, the energy calculation needs to include all metered data from all purchased energy sources. DOE 2015 explains the calculation in detail.

Metering and Submetering to Measure Actual Energy Performance

First, care must be taken to ensure that the meters and submeters used for performance evaluation are installed properly, so that they provide useful information about whether the building is operating as designed.

The configuration and placement of electric panel boxes should be planned during design. Ideally, these panels boxes are designed so that each represents a building end use (lighting, plug and process loads, refrigeration, HVAC) that can be captured with its own submetering device. The submeter should be the property of the building owner (most likely the school district), so that the owner controls the data. PV production and whole-building energy use should be metered separately. The system could be set up so that equipment with relatively large loads—kitchen equipment such as refrigerators, for example—can be individually submetered. Data from submeters can be compiled in and accessed from an EMIS. The ZE K12 AEDG contains a helpful submetering diagram (ASHRAE 2018, p. 142).

Developing a Calibrated Model

After the building is occupied, the designer and contractor should deliver to the owner an accurate set of as-built plans. An as-built energy model that reflects the completed building should be included with these plans, and occupancy schedules can be updated continually to reflect the operations and actual occupancy of the building.

The ZE K12 AEDG includes a description of the calibrated model (ASHRAE 2018, p. 46). The calibrated model reflects the as-is building including as-installed equipment and as-tested performance information. During M&V, comparing this model to actual building performance can uncover hardware, control, or occupant behavior issues that need correcting.

Comparing Modeled Performance to Actual Performance

The metered energy data should be compared with the calibrated building model. The quality of the comparison improves as the meter data resolution becomes more granular, further emphasizing the need to plan the submetering during the design phase. The occupant engagement plan, discussed below, can outline who will be responsible for this comparison. It could be the building operator, but in a school, the comparison could be completed by students as a learning tool. One teacher or student group could assume ownership of these calculations, for example. Measured data can be entered into the U.S. Environmental Protection Agency's ENERGY STAR Portfolio Manager (EPA n.d.) to track the performance of the building. There are also other tracking options, including manual tracking on spreadsheets.

If the metered energy data do not match the building model, then something in the building's operation needs to be addressed. The building operator or student group in charge of monitoring could drill into the data to identify the root cause of the anomaly. If the high energy consumption is a malfunction of a component of the building system, the building operator should fix the problem. These malfunctions are called building "faults." Systems are emerging for building fault detection and diagnostics that can automatically detect and diagnose faults in the building system.

If the higher-than-planned energy consumption is related to occupant behavior, the school community could work together to reengage occupants with the school's ZE goals. For example, monitoring energy use may reveal that computers are always left on (e.g., for automatic updates at night). The school community could develop a plug load management plan that would require that computers be turned off at night. The school could work with the school district's information technology team to schedule specific times for updates and power down the computers at other times. Controls could be implemented through the computers' power settings or by using advanced power strips.

Making the Most of the Building Warranty

Most equipment in a building comes with a warranty, and most construction contracts contain a warranty period during which the contractor is responsible for repairing or replacing equipment or systems that don't perform as specified. Consider holding the contractor accountable for performance by stipulating that any equipment that is not performing properly creates a warranty issue that the contractor is contractually bound to correct so that the building meets the design specifications. If energy-specific performance goals are included in the contract, missing one of those goals after the building is occupied would trigger a warranty claim if the cause can be traced to equipment or control issues.

Engaging Occupants

Occupant engagement includes facilities management staff training and school occupant training. Facilities management is most likely to be in charge of ensuring that the school building achieves ZE performance. The facilities staff needs to understand how the building operates, how the mechanical systems operate, and how to encourage energy-saving occupant behaviors through

Douglass Elementary in Boulder, Colorado, is working toward zero energy status, a reflection of the Boulder Valley School District's commitment to sustainability. Photo by RTA Architects, David Lauer Photography

strategies such as walk-throughs. Facilities staff should also know whom to call for system maintenance and repairs.

Training can inform occupants about their roles in meeting building energy targets and about how to use the building to optimize energy efficiency. Training needs to be continuous, because each school year brings new students into classrooms.

Developing a Plan

A recommended practice for ensuring occupant engagement is to develop an occupant engagement plan and implement it. This plan must include regularly scheduled checks of the submetered energy data collected and managed by the school's EMIS platform, identify who is responsible for this task, and describe how they will do it. In addition, the plan needs to identify who will monitor the data and how they will do it. The plan must also include a training plan for building occupants. The training should include information on the building systems, their operation, and their importance to energy savings. Ideally, the plan would:

- **Identify the parties responsible** for monitoring the building energy data and verifying that the building is ZE; energy reporting may be required for certain certification programs.

- **Include training details for building occupants** so that training plans include information about who will receive the training (students, teachers, facilities staff); who will administer the training; what information will be included in the training; and how frequently and when the training will be held (e.g., the beginning of the school year).
- **Identify a point of contact** who understands the building operation and knows what to do when something isn't working properly; this should be included in this staff member's job description, and the plan should also include continuation measures that specify who will continue the training when the current point of contact retires or leaves the school.
- **Describe a process** for building occupants to communicate building malfunctions to the main point of contact. For example, if a student notices that lights are continuously on, he or she might be instructed to notify someone in the front office, who in turn would verify the issue and report it to the point of contact.
- **Describe strategies for occupant engagement in maintaining the building's ZE status**. This could be a student team or club responsible for monitoring the building and ensuring that occupant behavior supports building energy efficiency goals (e.g., no art obstructing daylit windows) or specific classes (science, math) that take on this responsibility.
- **Include a way for the school administration to communicate roles and responsibilities**. In other words, create a communication plan through teacher/student/parent handbooks, administrative bulletins, or in-service teacher days.
- **Include the maintenance schedules for items related to energy-efficient building systems**, because maintenance staff may not be familiar with them.

The real value of time spent planning is captured as time savings and effectiveness during plan implementation. School owners should clearly assign responsibilities and make sure that the plan is implemented as intended. The following approaches can help:

A **user manual** can encourage ZE-friendly occupant behavior. It can be used for occupant training and can also include basic information on how to operate the energy efficiency features of the building. School district representatives in charge of the procurement can require the construction contractor to provide a user manual. User manuals could be delivered as both a manual and a PowerPoint presentation, so that the information can be easily inserted into presentations or posters.

Building signage and information placards placed on energy efficiency features can inform students and other occupants about energy-efficient systems and passive design strategies in the school. Signage is important to remind building occupants of energy-saving opportunities. For example, signs can remind occupants to turn off lights when a room is unoccupied or to turn off equipment and devices when not in use to manage plug loads.

Jennings Creek Elementary, a zero energy school in Bowling Green, Kentucky, cost $1.5 million less to build than the average Kentucky school and is expected to operate at 20 kBtu/ft^2·yr, saving more than $165,000 a year in energy costs. Image by Sherman Carter Barnhart Architects

ZE schools offer **leadership and learning opportunities** that can encourage groups of students to become stewards of the ZE building. Student groups can assume responsibility for giving ZE tours and encouraging energy-saving occupant behavior. Members of sustainability clubs or participants in a class that takes responsibility for occupant behavior are good candidates to be student ZE champions. Kinard Core Knowledge Middle School in Fort Collins, Colorado, is a ZER school with an annual EUI ranging from 21 to 24 $kBtu/ft^2 \cdot yr$, measured from 2008 to 2014. Kinard has student sustainability clubs, and the members give building tours to discuss the school's approach to reducing energy, water use, and food waste with visitors. Horry County Schools in Myrtle Beach, South Carolina, has similar clubs called "green teams." Fifth graders at Discovery Elementary School in Arlington, Virginia, also give building tours. The student energy champions and building signage provide continuous energy efficiency education opportunities, which are important in schools because there are new students every year. Although staff turnover is less of an issue than student turnover, the building should be easy to operate, allowing transient occupants and new staff hires to quickly learn behaviors that promote energy savings.

The person responsible for addressing building operation issues could be the same person responsible for **monitoring**, **collecting**, **and reporting energy data**. In addition, periodic building walk-throughs are needed. These are similar to and can be combined with safety walk-throughs. The person doing the walk-through inspects the building and addresses issues of energy waste. In addition, the master maintenance schedule needs to be regularly updated.

Using Occupant Surveys

Surveys and questionnaires solicit occupant feedback on comfort and other building-related issues that can be useful to building managers. The building manager could develop the survey or work with a teacher or student group that develops and administers the survey, analyzes results, and addresses issues identified in the survey through an action plan.

Perkins Eastman, the architects who designed the high-performance Dunbar High School in Washington, D.C., developed a performance evaluation framework that

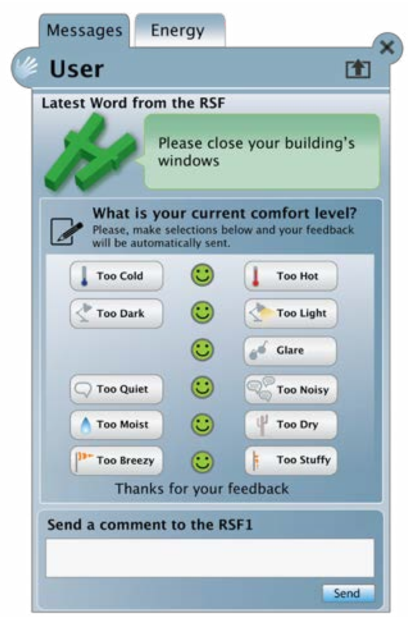


Figure 4. The building manager for NREL's RSF surveyed occupants on comfort using a desktop application that captures and addresses occupant comfort in real time. Graphic by Marjorie Schott and Kyle Benne, NREL

incorporates both quantitative building measurements and qualitative occupant feedback focused on daylighting, thermal comfort, acoustics, and air quality. Their occupant engagement strategy also included preoccupancy data collection.

The presentation *Human Factors and Post-Occupancy Evaluation* describes how the building manager for NREL's RSF surveyed occupants on comfort using a desktop application that captures and addresses occupant comfort in real time (see *Resources for Evaluating Performance and Engaging Occupants* and Figure 4). Although the RSF is an office building, some of the comfort questions are relevant to ZE schools. The survey asked occupants about their level of comfort relating to indoor air temperature and humidity, lighting, glare, air quality, and noise. Instead of direct measurements, the data captured by the app are based on the occupant experience and perception. The survey also included questions related to building function, such as light switch operability and room functionality.

Data collected from occupant engagement can inform subsequent ZE buildings. See *Step Eight: Showcasing and Replicating a Zero Energy School* for a description of how ZE successes and data collected from a school district's existing ZE buildings as part of an occupant engagement program can be used to improve the procurement process for subsequent ZE buildings.

Partner Snapshot: Evaluating Performance and Engaging Occupants in Horry County, South Carolina

Horry County Schools in South Carolina opened three new ZE schools in 2017 and two in 2018. The five schools, four middle and one elementary, use similar designs. Each school building has two stories with an atrium, a hybrid geothermal system, daylighting, LED lights with control systems, a PV system on the roof, and a goal of producing 10% more energy than it uses.

The district wanted an energy-efficient, high-performance school that generated more energy than it used and provided a collaborative learning environment. Achieving energy positive status involved reducing the energy demands of the building and installing PV panels to generate electricity that is used in the building and sold to the local utility.

For example, the use of natural light reduces the energy required for lighting and provides natural light to classrooms and interior spaces through numerous clerestory windows. Sunshades allow for flexibility in siting the building by screening windows on south, east, and west facades from direct sunlight; all glazing on those elevations in the new schools have sun shades in accordance with ASHRAE 189.1.

The school board enlisted the same design-build team to ensure consistency and replicability across all five projects while maintaining the focus on achieving ZE. The district's strategic plan prioritizes the expansion of opportunities for both students and teachers to learn and grow in science, technology, engineering, and math. The energy goals of the five new zero energy projects are embedded into learning goals for students with classrooms serving as living laboratories for experiential learning about passive design, on-site energy generation, energy efficiency, and the built environment.

Horry County has learned valuable lessons during the process of designing, building, and operating its ZE schools.

Allow enough time to evaluate building performance. Horry County used a design-build procurement process that included a 3-year performance contract requiring the design-build team to optimize the building and achieve the ZE goal. A year and a half into the process of evaluating building performance, the design-build team is still tweaking controls and fine-tuning the mechanical system.

Contract directly with an independent commissioning agent and an independent firm that provides test and balance services early in the design process. When these professionals are at the table from the beginning of the project, there are opportunities to review systems and identify small problems before they become big problems that are time-consuming and expensive to correct.

Research local utility rate structures and buy/sell arrangements for distributed PV early in the design process. Once the building is using the least possible energy to operate—the new Horry County schools have EUIs of 22–23 kBtu/ft^2·yr—that energy must come from the on-site PV system to achieve ZE. In Horry County, however, the district buys electricity for \$0.17–\$0.18/kWh and sells the PV output for \$0.03–\$0.04/kWh. In addition, the utility only allows the schools to use 25% of the electricity the PV systems produce in the buildings and utility demand charges further erode energy savings. This has been disappointing because the school board's original interest in ZE schools was driven by the prospect of generating free solar electricity and selling the excess back to the utility.

Use submetering and other strategies to monitor how and when energy is used. Until energy storage is affordable and commonplace, it is critical that building owners and operators know specifically how much energy the building is using and when that use occurs. Most high-performance buildings today do not have energy storage, which means a building would be more likely to achieve ZE or energy positive status in a regulatory environment in which the utility bought the output of the renewable energy system at retail rates and ZE and energy positive schools were not subject to high demand charges. If utility billing rate and usage issues are not understood and evaluated early in the design process, the building could meet or even exceed its energy goal but still not achieve its anticipated energy cost savings.

Engage students, teachers, and facilities staff in the operation of the building. Horry County is using staff support and on-site mentoring to form and maintain an EnergyWise (Wisdom Is Saving Energy and the Environment) club at each school. EnergyWise is a program developed by EDUCON Educational Consulting, Inc. The district is also using information and resources from the National Energy Education Development (NEED) Project,[11] including NEED energy science kits and the opportunity to participate in the Youth Achievement Awards competition, to develop teacher curricula and support student energy clubs and other energy activities (see *Occupant Engagement Resources* in *Resources for Evaluating Performance and Engaging Occupants* for more information).

11. *https://www.need.org*

The students at St. James Intermediate School in Myrtle Beach, South Carolina, can join energy clubs to learn more about their school's innovative features. Photo by Horry County Schools

Resources for Evaluating Performance and Engaging Occupants

Occupant Engagement Resources

Curricula and other educational materials from the National Energy Education Development Project (NEED):

https://www.need.org/curriculum.
All curriculum guides are available at no cost.

https://www.need.org/Files/curriculum/guides/BlueprintSchoolEnergyTeam.pdf. A tool for schools to reduce energy consumption by adopting school energy policies and forming a student energy team.

https://www.need.org/youth-awards. This program, which is free for participants, combines academic competition with recognition for those who achieve excellence in energy education in their schools and communities.

Measuring Up: Using Pre- and Post-Occupancy Evaluation to Assess High-Performance School Design: *http://www.perkinseastman.com/dynamic/document/week/asset/download/3436982/3436982.pdf.* White paper that describes the mixed-methods process that architectural firm Perkins Eastman developed to evaluate school building performance postoccupancy; includes a standard survey tool to assess perceptions and a sensor network and protocol for testing school building performance.

Occupant engagement example from higher education: *https://betterbuildingsinitiative.energy.gov/implementation-models/comprehensive-occupant-engagement-program*. Northwestern University's comprehensive occupant engagement program.

Using an app to collect and respond to occupant comfort: *https://www1.eere.energy.gov/buildings/publications/pdfs/rsf/0208_nasa_human_factors_post_occupancy.pdf*. Presentation entitled *Human Factors and Post-Occupancy Evaluation* that highlights how the Building Agent Tool (a desktop app—see Figure 4) captures and addresses occupant comfort in real time at the RSF, a ZE office building on NREL's Golden, Colorado, campus.

Occupant Survey Resources

Indoor environmental quality survey from the Center for the Built Environment: *https://www.cbe.berkeley.edu/research/briefs-survey.htm*. Available for K–12 and other building owners to use as a fee-based service; survey takes approximately ten minutes to complete.

Operation and Maintenance Resources

Example energy dashboard: *http://158.59.255.83/* or go to *https://discovery.apsva.us/* and click on Energy Dashboard in the left-hand menu. Discovery Elementary School, a ZE school in Arlington, Virginia, uses an age-appropriate energy dashboard as a teaching tool for students and the community.

Guide to Operating and Maintaining EnergySmart Schools: *https://energy.gov/sites/prod/files/2013/11/f5/ess_o-and-m-guide.pdf*. Information on how smart energy choices in schools can create lasting benefits for students, communities, and the environment.

Plug Load Resources

Plug loads: Advanced power strips: *https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/how_to_use_advanced_power_strips.pdf*. DOE's Better Buildings Alliance has resources for using advanced power strips in commercial buildings, and the strategies on its website can be applied to schools.

Plug and process load management resources: *https://betterbuildingssolutioncenter.energy.gov/alliance/technology-solution/plug-process-loads*. DOE's Better Buildings Alliance has resources for controlling plug and process loads in commercial buildings, and the strategies on its website can be applied to schools.

Portfolio Manager

U.S. Environmental Protection Agency's *ENERGY STAR® Portfolio Manager®*: *https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager*. A secure online tool to measure and track energy and water consumption, benchmark the performance of one building or a whole portfolio of buildings, and compare energy use targets to similar existing buildings nationwide.

Specific School Resources

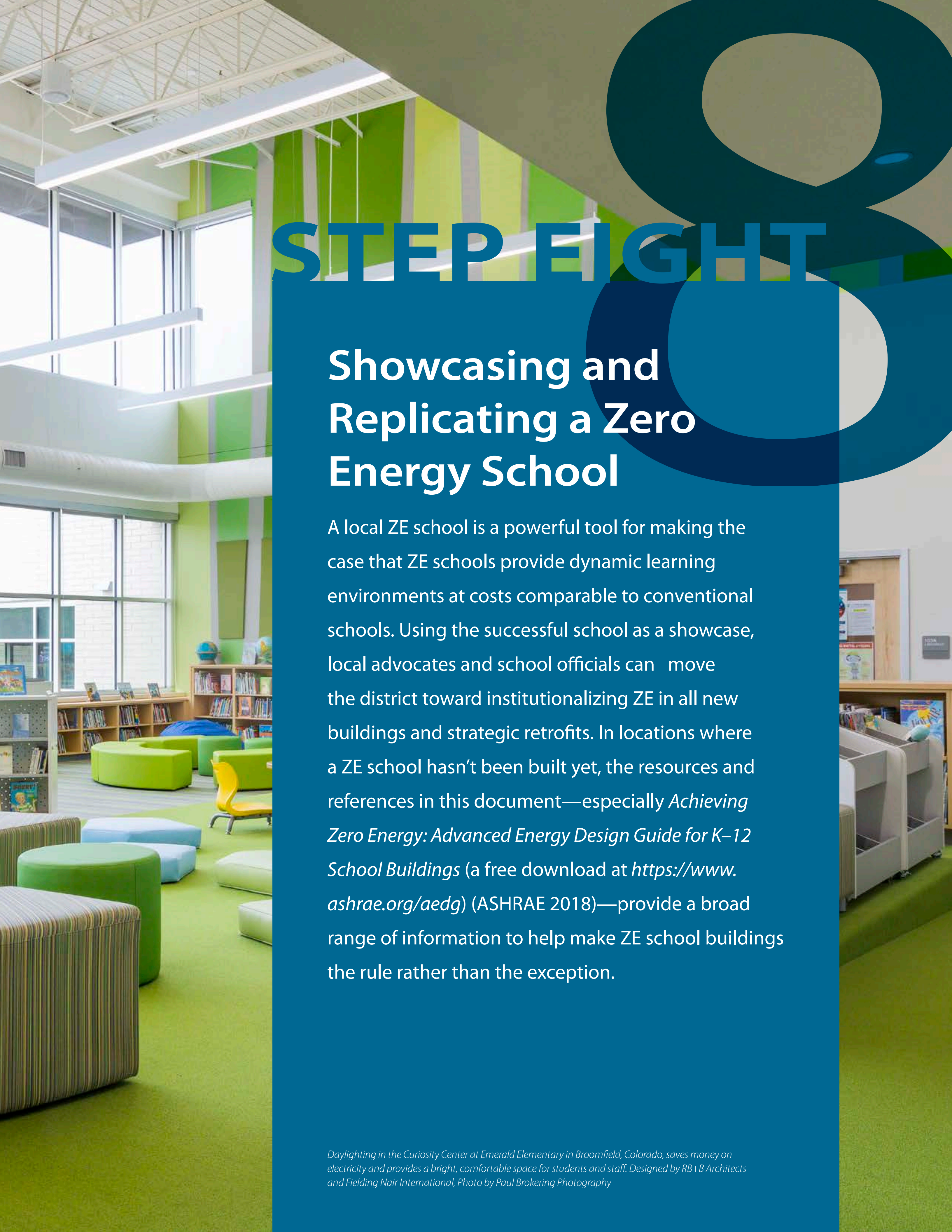
Virtual tour of Kinard Core Knowledge Middle School: *http://www.kinardcares.org/kinard_green_school*. Kinard is a highly energy-efficient (but not ZE) school building.

Horry County Schools: *https://www.horrycountyschools.net/*. Located in Myrtle Beach, South Carolina, Horry County Schools has student sustainability clubs called green teams.

Dunbar High School: *http://www.perkinseastman.com/project_3405944_dunbar_high_school*, *http://www.perkinseastman.com/dynamic/document/week/asset/download/3436982/3436982.pdf*. Perkins-Eastman, the architectural firm that designed Dunbar High School in Washington, D.C., developed a performance evaluation framework that incorporates quantitative building measurements and qualitative occupant feedback.

Updated resources for Step Seven: *https://buildingdata.energy.gov/cbrd/search/resources/k12ZEstep7.*

STEP EIGHT



Showcasing and Replicating a Zero Energy School

A local ZE school is a powerful tool for making the case that ZE schools provide dynamic learning environments at costs comparable to conventional schools. Using the successful school as a showcase, local advocates and school officials can move the district toward institutionalizing ZE in all new buildings and strategic retrofits. In locations where a ZE school hasn't been built yet, the resources and references in this document—especially *Achieving Zero Energy: Advanced Energy Design Guide for K–12 School Buildings* (a free download at *https://www.ashrae.org/aedg*) (ASHRAE 2018)—provide a broad range of information to help make ZE school buildings the rule rather than the exception.

Daylighting in the Curiosity Center at Emerald Elementary in Broomfield, Colorado, saves money on electricity and provides a bright, comfortable space for students and staff. Designed by RB+B Architects and Fielding Nair International, Photo by Paul Brokering Photography

By documenting the strategies that made the ZE school successful and creating compelling stories around the experience, continuously improving school performance and affordability, and institutionalizing ZE so that it becomes standard practice, school districts can make ZE schools commonplace. As the story becomes widely known, stakeholders will see ZE buildings as fundamental to the school district's culture and not as a one-off experience.

Documenting for Zero Energy Replication

Replicating a ZE project requires documentation that goes beyond keeping records of the design and building process. This documentation could include (but is not limited to) important decisions, barriers, and successes, including successful stakeholder and occupant engagement efforts. It also includes measuring and recording data (such as building energy data) to verify that the school building is operating at a low EUI.

Someone can be appointed as project "historian" or "story developer" to take charge of collecting this information. This person can identify the people best suited to tell the story to stakeholders, including members of the design team, teachers, principals, administrators, facilities maintenance personnel, students, and parents. The historian/story developer might use recorded interviews with subsequent transcription, open- or closed-ended questionnaires, or reflective writing or interviewing to capture anecdotes.

Telling the Zero Energy Story

The information captured during this process can be used to develop a story about how the district achieved a ZE school building and the benefits it provides for teaching and learning. The story will help those who hear it understand that although there may be challenges as the ZE process evolves, the outcome—ZE schools—is well worth the effort. The story should engage listeners so they will tell others and will view ZE schools as the preferred choice for future buildings in the school system.

Discovery Elementary School in Arlington, Virginia, is a zero energy building that saves the district more than $100,000 per year on energy costs. Photo from VMDO Architects/©Lincoln Barbour

The historian can create a press release, presentations, and handouts with consistent messaging about the district's first ZE school building. These will be useful resources that other district representatives (including the ZE champion, teachers, architects, engineers, facilities maintenance representatives, capital planners, construction managers, and school principals) can use to communicate with stakeholders and the broader community. It is helpful and engaging to build the story around the experiences of the people involved, and school district representatives can add their own personal twists to the stories when communicating with stakeholders.

ZE schools offer a rich array of narrative hooks that can be tailored to specific audiences. For example:

- **For administrators and school boards**, focus on affordable initial design and construction costs, predictable energy pricing over the life of the building, and superior educational outcomes
- **For facility managers and operations and maintenance personnel**, emphasize the use of simple and passive systems for heating, cooling, and lighting that reduce operations and maintenance costs, time, and effort
- **For educators**, describe how teachers in ZE schools have multiple opportunities to engage students in STEAM activities and how enthusiastic students are about their ZE schools
- **For community members**, explain what students, teachers, facility managers, administrators, and others love about these buildings and how a ZE school can become a gathering place for locals when school is not in session and a refuge in the event of a weather or other disaster.

Problem Solving. As with any building system, technologies used in ZE buildings sometimes fail or work incorrectly. As they tell their story, school owners should avoid generalizations about technologies that don't work well. Replacing an energy-efficient technology with a standard technology, for example, can have a significant negative impact on whole building energy use.

School owners should also avoid blanket policies that rule out specific technologies because of a previous bad experience. Technologies improve over time, so prohibitive policies may make it unnecessarily harder (and often costlier) to achieve ZE in the future. A better strategy is to describe the desired outcome and emphasize durability or reliability rather than identifying a specific technology.

Overall, the narrative should emphasize the importance of consistently considering the impact on the EUI goal as each challenge arises. This problem-solving approach is critical for replication because rather than discrediting technologies, it keeps all options open to designers or contractors competing to design and build the next ZE school. In addition, identifying the root cause, whether it is user error or an issue with a specific component, will help the building manager address the problem by educating building occupants, performing routine maintenance and repair, or submitting a warranty claim. The school district should document the issues and the approaches to resolving them and include the information in their storytelling.

Photographs. Create a repository of photos of the ZE school building that can be used without copyright issues; this allows school district representatives to use the photos in presentations and for other purposes. Be mindful that architects' photos are often owned by a professional photographer or the architectural firm and require explicit permission to use. Although photographers are often willing to allow one-time pro bono use of their work, it can be time-consuming to track them down and obtain permission. In some cases, schools can hire a photographer who—for an hourly or flat fee—will provide images to the school for unrestricted use as long as the photographer is credited. A school employee can also take photos for unrestricted use.

An example of a source of photos that can be used with attribution is NREL's image library (see *Resources for Showcasing and Replicating a Zero Energy School* in this step), which contains many images, for example, of the RSF, NREL's ZE office building. The photos include pictures of the construction, specific RSF features, and the interior and exterior of the completed structure. These photos are frequently used by NREL staff in publications and presentations; they can also be used outside of NREL at no charge with proper attribution.

If a photo contains people, a model release is likely required to use it. Some schools require parents to sign a model release for their minor children as part of the registration process, although they can usually opt out. Photos of children whose parents choose not to sign the release should not be used.

Quotes. Collect quotes from happy occupants, owners, designers, and others. For a story tailored to parents of future students, the focus could be on student learning gains in a ZE building and could include relevant quotes from current students, teachers, and parents. Sometimes these quotes can be captured on video; see the Discovery Elementary School video case study at the end of this step for examples.

Website. Create a carefully curated, regularly updated website to tell the ongoing story of district ZE schools. Include the text of the OPR, RFP, and other documents. Showcase, in real time, the energy consumption and production of the building with an online dashboard.

Signage. Use signage in the school to point out energy efficiency features and components.

Data. Support claims with evidence. Summarize energy use and financial data in a way that makes sense to the intended audience and places the ZE school in a broader context. Stakeholders want to know that the ZE building is cost-effective, so include accurate cost data. Details to include in the story can include:

- Construction cost
- Building size
- Operational EUI compared with design EUI, and these can be contrasted with the typical range of EUIs within the school district to highlight the superior performance of the ZE school
- Energy features
    - » Experiences of students, teachers, and other occupants, which can include impacts on student academic performance and attendance, teacher retention rates, and overall occupant health (NBI 2017) (see also *Resources for Showcasing and Replicating a Zero Energy School* in this step).

Real world example. In presentations, videos, and other communications, the team that designed and built the ZE Discovery Elementary School in Arlington, Virginia, tells a compelling story that addresses energy and educational goals, costs, and the design process. For examples of storytelling that have led to institutional change in Arlington, Virginia, see *Resources for Showcasing and Replicating a Zero Energy School* in this step.

Continuous Improvement

The process of designing, building, and operating a ZE school will likely improve each time it is repeated. A thorough evaluation of the most recent ZE school project reinforces this continuous improvement. The ZE project team will want to gather the information outlined in the *Documenting for Zero Energy Replication* section of this step to improve design, construction, procurement, and contracting processes.

The best way to replicate and improve on the previous ZE project is by using a procurement process tailored to ZE for the new building. An effective approach is to have an open procurement competition for the second ZE building that seeks to improve upon the cost and energy performance of the previous ZE building. The designers and contractors who worked on the previous project now have experience achieving the ZE goal, and they can use the lessons learned to further reduce building energy use in subsequent projects. A bidding process that provides competitive pressure for the design and contractor team to produce a better design, take a fresh look at technologies and design techniques—which are always evolving—and propose a design that reflects the current state of the art is ideal.

A district's second ZE building may face unique challenges. Expectations will be higher because the district has already proved it can accomplish ZE with its first building, but issues are just as likely to arise. With a second building, there is still a learning curve and the district and larger community may not have fully institutionalized ZE buildings (see *Institutionalizing Zero Energy* in this step for approaches to remedy that). To address these challenges, the school district can manage stakeholder expectations and set reasonable goals.

Partner Snapshot: Showcasing and Replicating a Zero Energy School in Arlington, Virginia

The success of the Arlington Public Schools' (APS') Discovery Elementary School, which opened in September 2015, has paved the way locally for additional ZE schools. Other districts can use the well-documented APS experience to replicate the process in their communities.

Alice West Fleet Elementary is the next APS elementary school under construction, and it has a ZE goal. Fleet's design and construction process differs from Discovery primarily in its project delivery method (see Step Three: *Including Zero Energy Goals in the Procurement Process* and Step Four: *Selecting a Design and Construction Team Committed to Zero Energy Goals* in this ZE K–12 schools document).

APS learned from Discovery that a design, bid, build approach left the school division vulnerable to risk in three ways: schedule delays, cost overruns, and quality assurance during construction. To address these issues, APS decided to use a CMAR delivery method for Fleet Elementary. CMAR allows APS to partner with a general contractor at the initial design stage, and that contractor works closely with the design team and the owner on trade-offs as the design develops.

Another major difference between Discovery and Fleet is that APS purchased Discovery's PV system. During Fleet's design and construction process, local economic conditions are different and construction costs are rising. Under these conditions, APS recognizes the importance of finding procurement alternatives for the PV arrays needed to achieve Fleet's ZE goal. Solar power purchase agreements (PPAs) are great mechanisms for local school districts to have on-site solar at little to no up-front cost. Recently, APS awarded a PPA contract to a Virginia firm to provide solar arrays for Fleet and four other schools. Using a PPA allows APS to meet the ZE target at Fleet within the existing budget.

The example of Discovery Elementary, a successful ZE school, has helped APS institutionalize support for ZE. Discovery gives stakeholders, community members, and project teams confidence that the process can and should be repeated. With this success, APS has been able to generate support within the broader community for ZE as a realistic energy target for county and school buildings, especially for new construction. To streamline the process, APS has established performance criteria in its new construction RFPs that target ZE.[12] In June 2018, the school board adopted the 2018–2024 Strategic Plan with stewardship as one of its core values. Stewardship encompasses the ability to create safe, healthy, and environmentally sustainable learning environments.

This is nothing new—Arlington County has been supporting the design, construction, and operation of high-performance buildings that reduce environmental impact since 1999. In 2008, it formalized its policy for integrated facility sustainability (PIFS) for all government buildings. Because Discovery continues to operate as a ZE building, county building and energy managers and

The success of Discovery Elementary School, a zero energy school in Arlington, Virginia, has been the impetus for other ZE schools in the area. Photo from VMDO Architects/©Alan Karchmer others can examine the building and its operational data and use that to inform current building projects. Arlington County is in the process of updating PIFS for new construction and major renovation (also called the Green Building Policy) to include EUI targets and ZER goals. One of the PIFS goals is to set a community standard for sustainable building practices. In addition to Alice West Fleet Elementary, APS' next ZE school, Arlington County's Lubber Run Community Center will be a ZER building.

Discovery demonstrates that a ZE school not only reduces energy costs (by about $100,000 per year in Discovery's case), but can also enhance and improve the working and learning environment for staff and students—all within a conventional school budget. The design team did not sacrifice other sustainability goals to achieve ZE. Discovery's healthy, durable school design includes natural daylight and improved indoor air quality. The design team's attention to detail in the flexible learning spaces, enhanced indoor environment, and extremely energy-efficient building envelope and systems resulted in an optimal working and learning environment for staff and students.

Steps Four (*Selecting a Design and Construction Team Committed to Zero Energy Goals*), Five (*Integrating Zero Energy Goals into Design*), and Six (*Achieving Zero Energy Goals during Construction and Commissioning*) in this document were critical to Discovery's success. Although APS has long had environmental sustainability design goals and LEED benchmarks for new construction, Discovery's design team took APS to the next level by championing the ZE energy target. The design team's previous experience designing ZE schools and its commitment to seeing the project through the construction process and into operation made ZE achievable. The design team's approach to a sound building envelope, constructability, a target energy use intensity of 21 $kBtu/ft^2 \cdot yr$, and continued involvement after the building was occupied established a level of trust with the owners and demonstrated to APS a sound process for building ZE schools.

12. https://www.apsva.us/wp-content/uploads/2015/05/RFP-02FY18-for-NES-at-Reed-AE-v10.pdf, APS Performance Criteria in RFP for the New Elementary School at the Reed Site, p. 6–7.

Institutionalizing Zero Energy

Institutionalizing ZE means that ZE design, construction, and performance becomes routine, happens in most district buildings, and entails continuous improvement so that each new ZE building achieves a lower EUI and/or a lower cost, surpassing the performance of previous ZE buildings. It involves post-project communication and stakeholder engagement (building on elements of Step Two and the storytelling guidance in this step), but—perhaps more importantly—it also involves including energy targets and performance criteria in policies, plans, and practices that influence energy performance in school facilities. Here are some key approaches (Cortese et al. 2018).

The **facility master plan** is an evolving document that assesses existing school facilities, establishes how to accommodate current and future needs, and addresses significant deferred maintenance challenges. Often developed by a leadership team consisting of administrators, demographers, architects, engineers, and other consultants, the facility master plan serves as a guide for investments and capital improvements across the district's portfolio. Not all districts have a facility master plan, and not all facility master plans mention energy performance.

Educational specifications provide information to architects for the design of school facilities and include space, furnishing, site, program, and performance requirements for various school types (primary, middle, secondary) and space types (classroom, labs, common spaces, etc.).

School districts use **OPRs** to formally outline objectives and expectations for a particular construction project. They describe the project, budget, functional space and use requirements (i.e., building program and occupancy patterns), design process expectations, sustainability goals, building components, and equipment specifications and specific performance criteria. An OPR document can guide overall district objectives and can be modified for a particular project. Including energy targets and the role of renewables is an important part of an OPR on a ZE project. For an example of an OPR focused on sustainability, see *Resources for Showcasing and Replicating a Zero Energy School* in this step.

Energy benchmarking is "the practice of comparing the measured performance of a device, process, facility, or organization to itself, its peers, or established norms, with the goal of informing and motivating performance improvement (DOE n.d.-e)." Like the rest of the commercial building market, schools are beginning to benchmark their building performance. In most districts, however, schools are not using benchmarking to strategically evaluate energy performance or develop approaches to improve energy performance. An exception is California, where the California Energy Commission requires benchmarking as a prerequisite for securing Proposition 39 funds. (Eligible local educational agencies can request funding by submitting an energy expenditure plan application to the California Energy Commission.)

Resources for Showcasing and Replicating a Zero Energy School

American Geophysical Union's ZE renovation project: *https://building.agu.org/about-the-project/*. Intention is to be first ZE renovation of an existing building in the District of Columbia, and has an extensive outreach effort.

Designing for the Future: *Zero Energy Ready K–12 Schools*: *https://www.nrel.gov/docs/fy17osti/68883.pdf*. Four-page fact sheet focused on the benefits of designing and building ZER K–12 schools.

Discovery Elementary School video case study: *https://www.youtube.com/watch?time_continue=35&v=2kTS4UODWwc*. Short video about Discovery Elementary School, a ZE school in Arlington, Virginia.

Evidence from scientific literature about improved academic performance: *https://www.epa.gov/iaq-schools/evidence-scientific-literature-about-improved-academic-performance*. A series of articles on how comfortable, healthy school environments improve student performance and teacher retention.

Hood River Middle School: *https://energytrust.org/pathtonetzero/*. With funding from the Energy Trust of Oregon, the Hood River Middle School science center provides a living laboratory for students and a path to ZE in larger projects.

NREL's image library: *https://images.nrel.gov/bp/#/*. Collection of photo resources related to renewable energy and energy efficiency.

SFUSD [San Francisco Unified School District] Project Requirements: *https://gettingtozeroforum.org/wp-content/uploads/sites/2/2017/08/OwnersProjectRequirements_SFUSD.pdf*. OPR developed by SFUSD.

Zero Energy Schools: Architects Take the Lead: *https://www.nrel.gov/docs/fy17osti/68882.pdf*. Four-page fact sheet focused on Discovery Elementary School in Arlington, Virginia.

Zero Energy Schools: The Challenges: *https://www.nrel.gov/docs/fy17osti/68881.pdf*. Four-page fact sheet focused on ZE school challenges and solutions.

Updated resources for Step Eight: *https://buildingdata.energy.gov/cbrd/search/resources/k12ZEstep8.*

Richardsville Elementary, the first zero energy public school in the United States, operates at an EUI of kBtu/ft²·yr, and produces more energy than it uses. The district receives an annual refund from the electric utility of more than $30,000 for the excess generation. Sherman Carter Barnhart Architects, Photo by Joshua White

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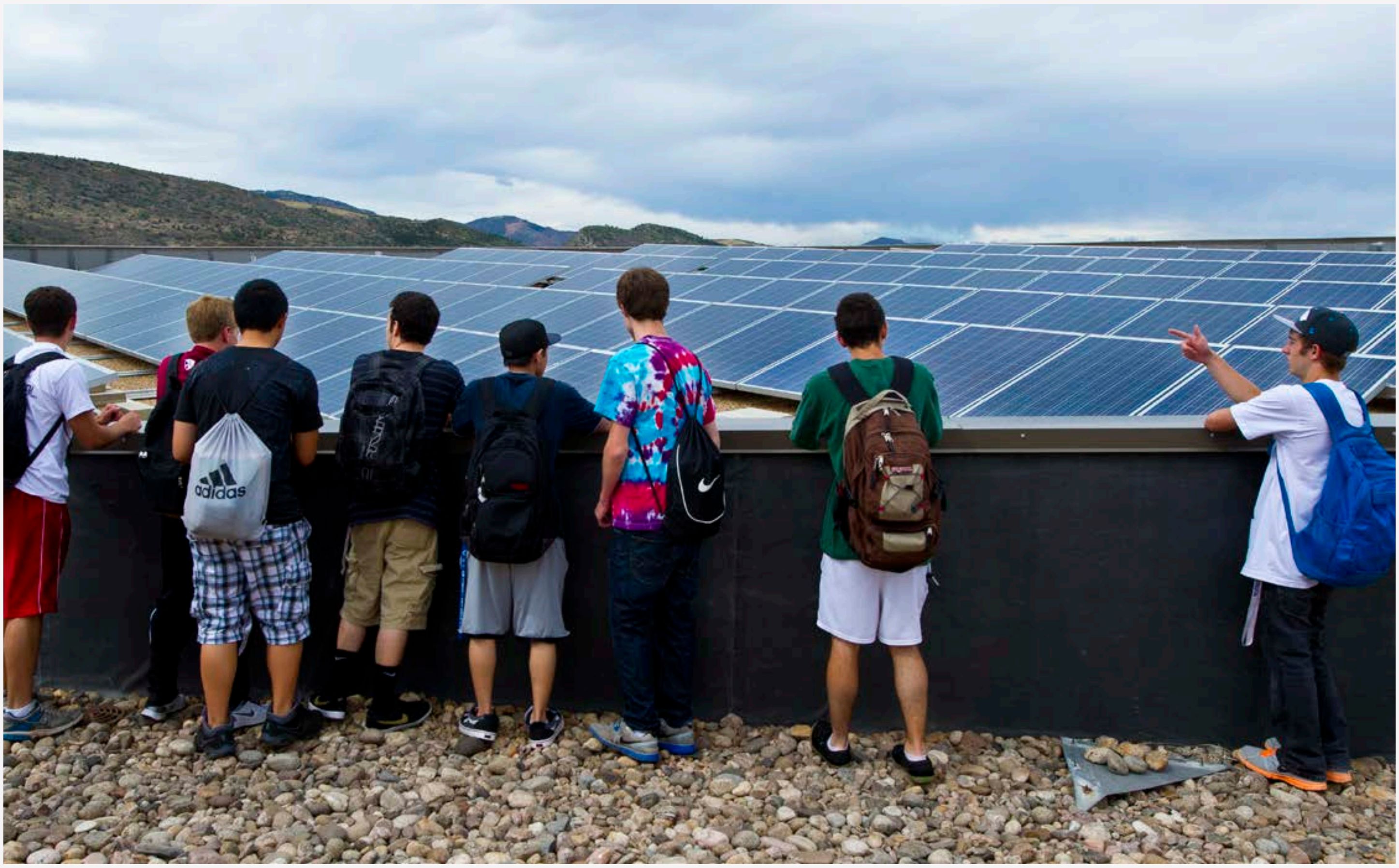
Acronyms

APS	Arlington Public Schools
BVSD	Boulder Valley School District
CHPS	Collaborative for High Performance Schools
CMAR	construction manager at risk
CxA	commissioning agent
DB	design-build
DBB	design-bid-build
DOE	U.S. Department of Energy
DCSD	Douglas County School District
EMIS	energy management information system
EUI	energy use intensity
HVAC	heating, ventilating, and air conditioning
IES	Illuminating Engineering Society
$kBtu/ft^2{\cdot}yr$	thousand British thermal units per square foot per year
LAUSD	Los Angeles Unified School District
LEED	Leadership in Energy and Environmental Design
M&V	measurement and verification
NBI	New Buildings Institute
NREL	National Renewable Energy Laboratory
OPR	owner's project requirements
PPA	power purchase agreement
SFUSD	San Francisco Unified School District
STEAM	science, technology, engineering, art, and math
PV	solar photovoltaic
QA	quality assurance
RFP	request for proposal
RSF	Research Support Facility
ZE K12 AEDG	Achieving Zero Energy: Advanced Energy Design Guide for K–12 School Buildings
ZESA	Zero Energy Schools Accelerator
ZE	zero energy
ZER	zero energy ready



Students from Chatfield High School in Littleton, Colorado, examine the photovoltaic system on the roof of their school during an engineering class. Photo by Dennis Schroeder, NREL 22274

Meadowlark School is a new energy-efficient pre-K through eighth grade facility in Erie, Colorado. Photo by Fred J. Fuhrmeister/Time Frame Images

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