# Driving Market Adaption of Zero Energy Schools


*Solome Girma, U.S. Department of Energy*
*Paul Torcellini, National Renewable Energy Laboratory*
*Shanti Pless, National Renewable Energy Laboratory*
*William Livingood, National Renewable Energy Laboratory*
*Cody Taylor, U.S. Department of Energy*
*Jason Hartke, U.S. Department of Energy*



## ABSTRACT

The U.S. Department of Energy (DOE), as part of its ongoing strategy to advance energy efficiency in the new construction market, has developed an ambitious plan to accelerate the market adoption of zero energy buildings (ZEBs). This multi-faceted ZEB initiative is designed to engage and move the market toward what may seem an impossible task—from buildings that consume energy to those that are energy neutral or produce energy. The technical feasibility of ZEBs has been well justified by the fact existence of many zero energy buildings. Examples such as the Research Support Facility at the National Renewable Energy Laboratory and the Bullitt Center have shown that such buildings are viable and owners are willing to build them. While there is not enough of a market to establish generalities around the cost premium, if any, owners are discussing this level of performance.

The K-12 schools subsector represents the ideal building type to lead the market to shift from buildings as energy consumers to buildings as energy producers; these so-called zero energy schools (ZE schools) are designed and built to maximize energy efficiency while using renewable energy to offset remaining energy needs. To drive this paradigm shift, it is important that ZE schools have a strong business case for their construction. This paper documents the information used to examine the technical resources required; the methods needed to move these technical resources to school decision makers; and the recognition, certification programs, and campaigns that will be a catalyst to move to ZE schools. The goal of these strategies is to provide the right information and motivation to decision makers so that zero energy schools become routine in the built environment and not the occasional novelty they are today. The paper prioritizes the key areas to ensure market uptake of ZE schools.


## Introduction

In the United States, more than 130,000 K-12 schools host 55 million students and 3.8 million teachers (NCES 2012). Many public officials lack the tools to evaluate the conditions of their school buildings, assess the energy consumption of these buildings, or effectively motivate the building of new energy efficient schools.

Growing student populations, rising community expectations, aging buildings, constrained operating budgets, and increasing energy bills are major challenges schools face. It is estimated that it will take $271 billion to bring public K-12 school buildings up to working order and into legal compliance. An estimated additional $271 billion investment is required to meet education, safety, and health standards (USGBC 2013).

Energy consumption plays a significant role in the operational expenses for schools, which make up the third largest sub-sector of commercial-building energy usage and account for

10% of the total energy consumption in this sector. Even though the energy use intensity of schools has decreased between 2003 and 2012 by 17%, the growth in the number of educational buildings has created an increase in energy consumption by almost 3% (EIA 2016).

Each year, taxpayers spend $6 billion on utilities for schools, and it is estimated that a quarter of this cost can be saved by implementing energy efficiency measures. Consequently, schools spend more on energy than on textbooks and computers—an amount second only to salaries (DOE 2007). Figure 1 shows U.S. energy use by building sector.

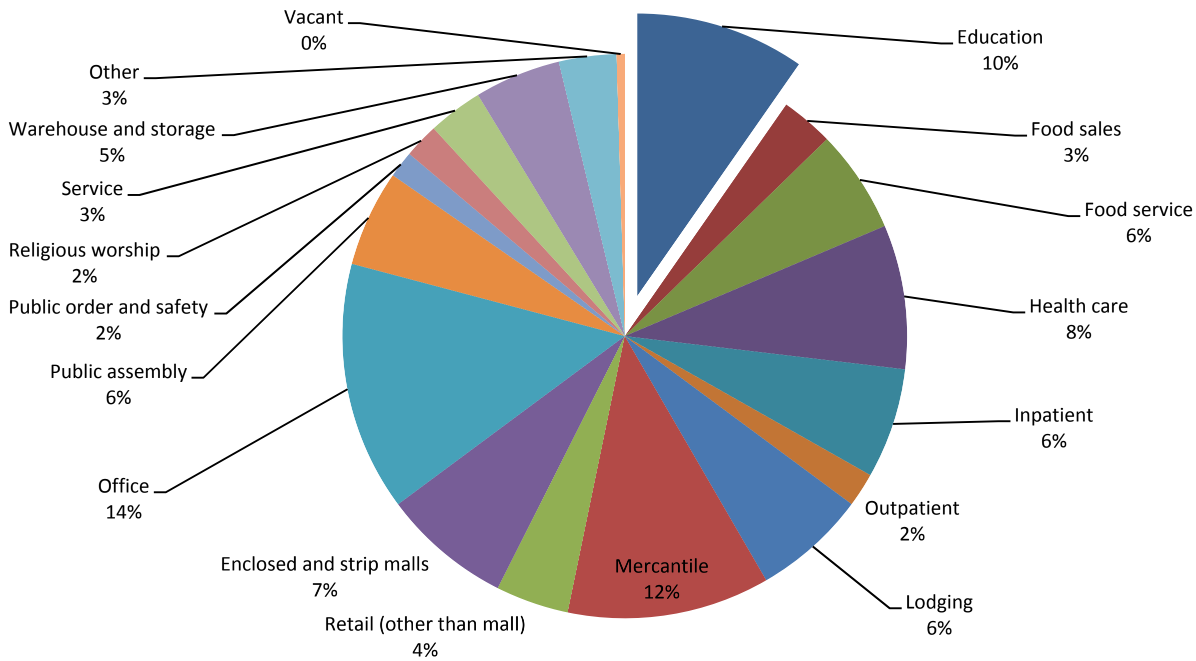


Figure1. U.S. energy use by building sector. *Source*: EIA 2016

The cost of energy is one of the few budget items that can be reduced without negatively affecting classroom instruction. For that reason, some school administrators are taking a long-term view and establishing long-term goals for facilities, including reducing energy impacts, showing the cost benefit of building zero energy or low-energy facilities, and justifying additional capital costs with long-term energy savings. Because many schools are purchased with publically issued bonds, raising funds for capital projects is often easier than increasing operational budgets to pay for ongoing energy bills.

Beyond producing energy savings, a ZE school creates the opportunity for a range of environmental, economic, and educational benefits. Many of these "soft" benefits are hard to measure, and the metrics are hard to quantify. Work should continue to more fully develop these metrics and provide their value to the educational system. Some of these include:

- Reduced greenhouse gas (GHG) emissions
- Increased economic benefits through job creation and market development
- Improved student performance
- Improved indoor air quality
- Increased attendance
- Enhanced educational opportunities

- Increased teacher retention rates
- Reduced insurance costs
- Reduced legal liability due to improved indoor environmental quality
- Demonstrated leadership
- More predictable future energy expenditures and stable budgets
- Lower maintenance costs with less complex mechanical, lighting, and electrical systems.

Given these benefits, DOE is working to accelerate the number of ZE schools in the United States by expanding the demand and the ability of the building design, construction, and operation industry to deliver buildings with very low energy loads. This paper focuses on identifying the challenges and DOE's strategies to drive the market adaption of ZE K-12 schools.

## The First Step: Defining a Zero Energy Building

The important first step in moving the building industry to a paradigm shift in which buildings become exporters of energy rather than consumers is to create a definition of a zero energy building (ZEB) to establish a common language. Conceptually, a building that generates as much renewable energy as it consumes is a ZEB. A broadly accepted definition of ZEB boundaries and metrics is foundational to efforts by governments, utilities, or private entities to recognize or incentivize ZEBs. Last year, DOE published a common definition for zero energy commercial buildings to bring the industry together and move the market in a unified direction (DOE 2015). This definition supports program and policy goals and encourages commercial new construction and major renovation projects to design, construct, and operate buildings that achieve a high level of energy efficiency while meeting remaining loads with on-site renewable energy sources.

Per the published definition, a ZEB 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. It is important to note that the foundation of a ZEB is achieving a low energy use intensity (EUI) via aggressive energy efficiency measures followed by the use of renewable energy to supplement the remaining load. Figure 2 shows that the balance is at the site and commoditized energy flows are measured at the site boundary. Typically, these are measured at the utility interface or, in the case of delivered fuels, at the point of delivery on the site. Only the energy flows that are purchased or could be sold are counted in the balance. The site measurements are converted to source numbers to put before the balance is determined as specified by the DOE definition. The DOE definition (DOE 2015) also includes a comprehensive nomenclature section so that all related terms are clear. Note that renewable energy generated on site is not measured, as the solar energy entering the site is "free" and not a commodity item.

## Step Two: Conducting a Feasibility Study

Two barriers are often identified in zero energy discussions. The first is whether the buildings are technically feasible. The second concerns whether there is a cost premium that makes it unrealistic to construct a ZEB. A feasibility study was completed for K-12 schools to determine what mix of technologies and efficiency strategies were needed to achieve a ZE school. This was a critical second step, as without a firm foundation of technical merit encouraging ZE schools would be fruitless. The feasibility study looked at what changes were needed in building design and operation to achieve the goal. The study was completed by the National Renewable Energy Laboratory (NREL) as an energy modeling based analysis, and it resulted in target EUIs and a technical pathway to meet or exceed the zero energy goal. Input for the study came from a panel of industry experts (Bonnema, et al. 2016). The specific objectives of the feasibility study were to:

- Document the energy modeling assumptions used to establish EUI targets that make zero energy goals possible
- Document the energy simulation school models
- Provide target EUIs by climate zone to achieve zero energy in schools.

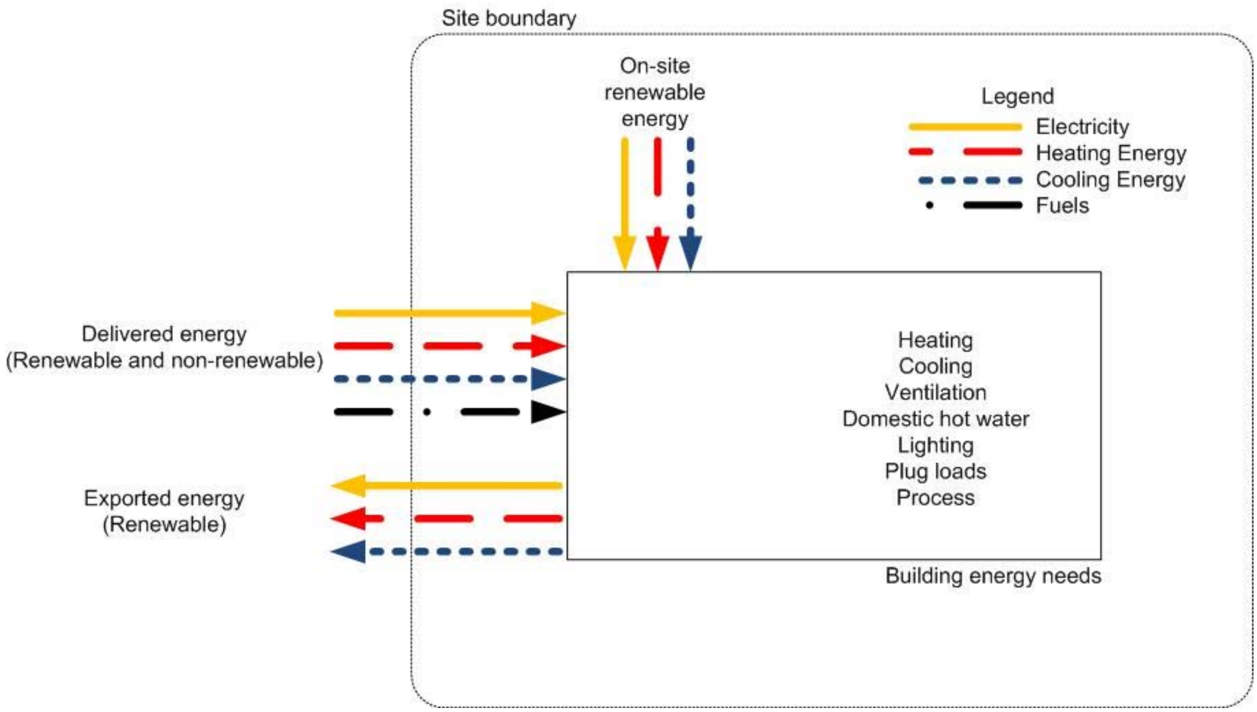


Figure 2. A common definition for zero energy buildings. *Source:* DOE 2015

The feasibility study focused on the energy consumption of the building, which was determined by two factors. The first was the amount of renewable energy on the site. For ease in the analysis, photovoltaic systems (PV) were the renewable energy source selected. PV is easily scaled, has widespread applicability, and is easy to analyze. This does not imply that in some areas, other on-site renewable resources should not be considered, such as wind and biomass. The second factor was consistency in technologies selected. For example, if plug load reduction was recommended in a cold climate and this strategy was easily implemented, this same strategy should be applied to mild climates. Consistency in applying strategies helped to prioritize efficiency and not create inefficient buildings where renewable systems could "solve" any energy problem.

Reducing the building load reduces the amount of PV required. The significant achievement of the feasibility study was to determine an appropriate energy target for ZE schools that was achievable based on climate. Detailed energy simulation analyses were performed across U.S. climate zones with a variety of systems and building parameters to arrive at a pathway that meets the zero energy goal. Table 1 summarizes the EUI targets to meet or exceed zero for a building in each climate zone. In Climate Zones 1–6, zero energy can be achieved with less than 50% of the rooftop dedicated to solar panels, which is an achievable objective for most K-12 schools. In the colder climates of Climate Zones 7 and 8, additional site space beyond the building footprint is needed due to larger heating loads as well as diminished solar availability. For reference, the climate zone map is included as Figure 3.

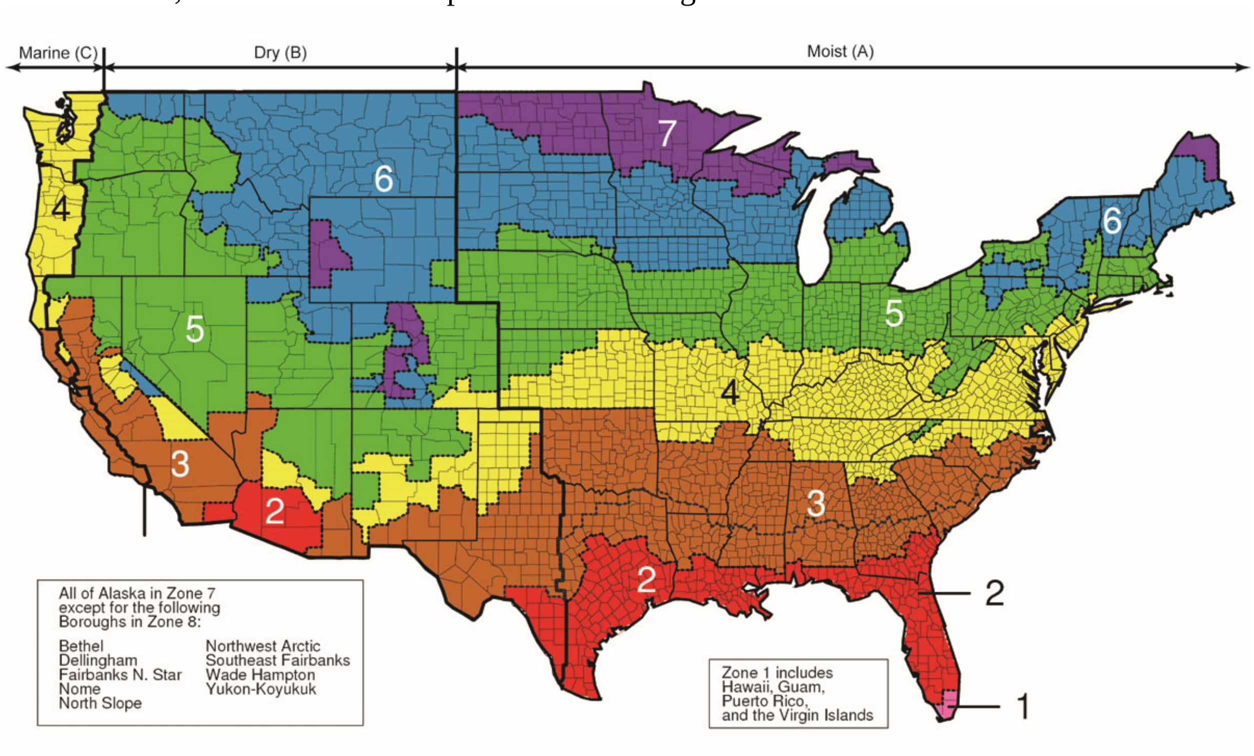


Figure 3. DOE climate zones and representative cities. *Source:* DOE 2003

The second question about financial feasibility is much more complex and was beyond the scope of the technical feasibility study. Boards of education, administrators, architects, and engineers understand the complexities and constraints of school finance and limited construction budgets. Schools are built to meet needs of students, educators, and other stakeholders. This functionality is critical to the success of the design. The complexities and demands on schools continue to increase including gymnasiums, libraries, kitchens, cafeterias, and classrooms. Schools are also changing dramatically with their information technology, which influences energy loads. To make an affordable ZEB, it is critical that the building form and architecture must be blended with energy efficiency strategies. In other words, efficiency strategies cannot be an add-on but must be carefully integrated such that the function and form are energy efficient. NREL has worked on addressing the cost issues in commercial buildings and has strategized how to build ZEBs at little or no cost premium (Pless 2012). There are school districts that have created zero energy schools. Another viewpoint is that these schools districts take the risk of being first, based on the theoretical analysis and mimicking design strategies of other commercial building sector early adopters. Case studies on these pioneers in the industry will be critical to move from a pilot stage of implementation to a broader demonstration stage. A limited number of school buildings with low energy use intensities has been identified (Bonnema, et al. 2016).

Ideally, the cost of a ZE school should be no more than the cost of a conventional code-compliant school. Other building types have documented cost data that show that zero energy is achievable at no additional cost. Some limited data for ZE schools show total cost of ownership has been substantially less than a conventional building (Torcellini 2016). This does make a strong business case for schools, as funding for schools is often by bond sales that are repaid over time. Having a positive cash flow for the bond repayment plus the (lack of) energy bills is a strong motivator, although it is not as strong as having no additional up-front costs. Those that have addressed the cost barrier have done so with highly integrated design and construction processes. Setting measureable energy performance objectives and selecting design and contractor teams to achieve these objectives enables these teams to make trade-offs to push down energy consumption without affecting cost. As an example, a well-designed thermal envelope that integrates daylighting can serve as a cooling mechanism, lighting system, and ventilation system, thereby reducing the size of conventional electrical and mechanical systems, which reduces those costs.

## Challenges in Building ZEB Schools

Ultimately, whether to create ZE schools will be the decision of school districts working with design professionals and contractors. Design and operation of buildings is about making decisions. To move the market, stakeholder engagement and input will identify the barriers, whether real or perceived, and help tune efforts to transition the market to a world of ZE schools. To date, only a few schools have attempted the lofty goal. Although the concept of building ZE schools has been around for a few years, the market uptake has been rather slow due to the many financial, technical, and social challenges. To best understand and break down these barriers, DOE assembled a group of diverse industry leaders with in-depth knowledge of the current market situation. These leaders represented school districts, design professionals, and market leaders. The following summarizes the business, technical, and other challenges.

### Technical Challenges

- Lack of qualified architects and engineers trained to design ZEBs
- Lack of skilled building operations and maintenance workforce
- Lack of integration of designers and school administrators
- Little or no culture of continuous commissioning post construction
- Complicated solar interconnection arrangements with utilities
- Limited access to (or knowledge of) latest technology advances.

### Business Challenges

- Tight construction budgets
- Perception that ZE schools are significantly more costly

- Firewall between construction and operations budget in planning schools
- Unbalanced equity, as new ZE schools tend to receive more attention and resources and may divert resources from other schools
- Lack of incentives from utilities
- Inability of decision makers to see beyond the first cost of building
- Lack of ZEB knowledge by school decision makers
- Low utility rates resulting in longer pay back in efficiency investments
- Lack of innovative financial models.

**Other Challenges**

- Lack of state/local partnerships
- Lack of community engagement
- Lack of public awareness of ZE schools and their overall impact in students' well being
- Net metering policies.

Table 1. Energy use intensity targets to meet or exceed zero energy

| Climate Zone | Representative City | Primary School | | Secondary School | |
|---|---|---|---|---|---|
| | | Site Energy (kBtu/ft²·yr) | Source Energy (kBtu/ft²·yr) | Site Energy (kBtu/ft²·yr) | Source Energy (kBtu/ft²·yr) |
| 1A | Miami, FL | 25.9 | 76.4 | 23.1 | 68.5 |
| 2A | Houston, TX | 24.3 | 71.1 | 21.7 | 63.5 |
| 2B | Phoenix, AZ | 24.7 | 72.5 | 21.9 | 64.3 |
| 3A | Memphis, TN | 23.8 | 69.0 | 21.2 | 61.6 |
| 3B | El Paso, TX | 23.4 | 67.8 | 20.7 | 60.2 |
| 3C | San Francisco, CA | 21.6 | 61.9 | 19.0 | 54.3 |
| 4A | Baltimore, MD | 23.5 | 67.6 | 20.9 | 60.1 |
| 4B | Albuquerque, NM | 23.1 | 66.6 | 20.4 | 58.8 |
| 4C | Salem, OR | 22.4 | 64.2 | 19.7 | 56.4 |
| 5A | Chicago, IL | 24.3 | 69.9 | 21.6 | 62.2 |
| 5B | Boise, ID | 23.2 | 66.7 | 20.4 | 58.4 |
| 6A | Burlington, VT | 24.5 | 70.1 | 21.6 | 61.9 |
| 6B | Helena, MT | 23.5 | 66.9 | 20.5 | 58.4 |
| 7 | Duluth, MN | 25.9 | 74.1 | 22.8 | 65.1 |
| 8 | Fairbanks, AL | 28.7 | 82.5 | 25.0 | 71.5 |

*Source:* NREL 2016

## Resources and Market Outreach

With the solid technical foundation described above, planning is underway to move toward market outreach for ZE schools as shown in Figure 4. The keys to delivering ZE school projects at a competitive cost are careful management of the procurement process from the outset, community engagement, and the integration of architecture, engineering, and construction practices. To this end, DOE is preliminarily providing the following resources and market outreach efforts.

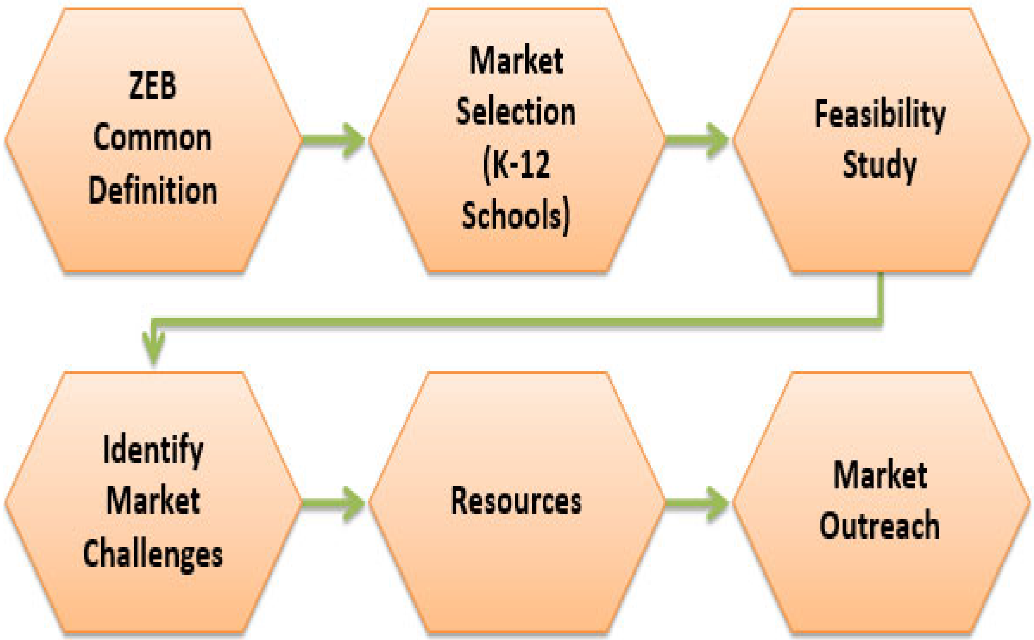


Figure 4. Pathway to zero energy buildings

### Resources

1. Common Definition of ZEB — As mentioned above, the common definition published by DOE (2015) delivers the much-needed uniformity in the ZEB market. The definition provides effective and accepted descriptions of ZEBs in clear and concise language. In addition, metrics and measurement guidelines are defined to allow verification of the achievement of the key elements of the definition while addressing how energy consumption is measured and what energy uses and types to include in its determination.
2. Accessibility to Feasibility Study — The technical feasibility study completed by NREL (Bonnema, et al. 2016) shows that ZE schools are achievable using typical construction techniques. The study documents pathways and directions that could lead to widespread deployment of ZE schools. Therefore, DOE and NREL will make this study available to all interested stakeholders.
3. Technical Design Guide — A market-facing technical guide or a "cookbook" that will create a strong foundation for deployment channels is essential to consistently and cost-effectively delivering ZEBs. To this end, DOE is deploying industry-based technical

know-how as a comprehensive *Zero Energy Design Guide* (to be developed Fall 2016) that addresses best practices to achieve low levels of EUIs and plausible renewable energy options for all regions of the United States.

4. Resource Hub — Providing an easy-access online platform for all content related to building ZE schools is essential. Recognizing this need, DOE is establishing a ZEB commercial resource hub. DOE acknowledges supports and amplifies the work of many credible organizations working toward the same goal of accelerating the uptake of ZE schools. Hence, the ZEB Solution Center will serve to connect these organizations, school stakeholders, and networks of architectural and engineering communities.
5. Case Studies —The concept of zero energy is relatively new. Therefore, case studies serve as a springboard to show the viability of ZE schools. Using the above-mentioned ZEB Solution Center, DOE will document success stories from around the United States that demonstrate best practices of achieving EUIs that are so low that renewable energy could meet the remaining load. These case studies will be in static form as well as short videos.

**Market Outreach**

1. Adoption of Common ZEB Definition — DOE, in conjunction with NREL, will provide assistance to states or organizations that would like to formally adopt the common definition of ZEB. This investment is necessary to establish uniformity.
2. ZE Schools Accelerator — The Zero Energy Schools Accelerator is designed to expand the uptake of ZE K-12 schools by state and local governments. It aims to catalyze public-sector ZE schools investments in the upcoming years using innovative and best-practice approaches to enhance ZEB programs. States that become partners will work together to develop their approaches and implement them for the long term. Additionally, the accelerator compels member states and local officials to make substantial commitments to increase the number of ZE schools by encouraging and recognizing this national leadership initiative.
3. Technical Exchange — Peer-to-peer exchange and training will take place in the form of webinars, conferences, and in-person trainings.
4. Recognition or Certificate Program — As part of the Zero Energy Schools Accelerator, DOE will certify and recognize states demonstrating investment in ZE schools with successful implementation models and innovative solutions. Such healthy competition is meant to spur creativity and bring the best programs to the forefront.

## Conclusion

With the strong community involvement that surrounds them, K-12 school buildings can be a catalyst for change in the built environment. They are "public" buildings and make excellent case studies for the entire construction industry. ZE schools are feasible and they have a proven record of producing substantial energy, and environmental and economic benefits. Moreover, the cost of energy is one of the few things that can be reduced without negatively affecting classroom instruction. Operational budgets of states and school districts are restricted, while technologies around energy efficiency and renewable energy have advanced. It is an opportune time to engage the market in changing schools from consumers of energy to producers of energy.

Conceivably, the prevalent impact a ZE school has is on its occupants. A new generation of students is being raised for whom "going zero" is a default concept. School buildings represent ongoing hands-on lesson plans for millions of students. The Department of Energy's ZE schools program will provide technical guidance, a common platform for industry leaders to share ideas and motivational force to make ZE schools routine rather than the occasional novelty they are today. A successful market uptake in ZE schools affords a good initial pathway into other zero energy commercial buildings industry.

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