Path to ZNE in K-14 Schools
Design for Education
Getting to Zero Portfolio Strategy

• Continuous energy improvement on the path to zero energy
• Leverage projects as they naturally occur
• Benchmark and prioritize to identify opportunities for:
  • Operational improvements
  • Deep energy retrofits
  • ZE pilot projects
• Energy planning incorporated into Facilities Master Plan
  • EUI Energy targets (20-30 kBtu/SF-year)
  • 50% savings goal for deep retrofits
  • 20% goal for equipment replacement
  • ZNE or at least solar ready
Portfolio Benchmarking
Energy Use Intensity

School data sources:

- CBECS – National survey median
- CEUS – California survey average
- ZNE – NBI Getting to Zero Database average

<table>
<thead>
<tr>
<th>Source</th>
<th>EUI in kBtu/sf-year</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBECS 2003</td>
<td>58</td>
</tr>
<tr>
<td>CBECS 2012</td>
<td>53</td>
</tr>
<tr>
<td>CEUS</td>
<td>41</td>
</tr>
<tr>
<td>ZNE</td>
<td>22</td>
</tr>
</tbody>
</table>
Portfolio-Level EUI
Portfolio-Level: Disaggregated Energy

Weather Normalized Building EUI by End-Use

- Elementary School 1
- Elementary School 2
- Elementary School 3
- Elementary School 4
- Elementary School 5
- Middle School 1
- Middle School 2
- Middle School 3
- High School
- Alternative High School
- Technical School
- K-12 School

Site EUI (kBtu/ft²-year)
Portfolio-Level: Disaggregated Energy

Weather Normalized Building EUI by End-Use

- Elementary School 1
- Elementary School 2
- Elementary School 3
- Elementary School 4
- Elementary School 5
- Middle School 1
- Middle School 2
- Middle School 3
- High School
- Alternative High School
- Technical School
- K-12 School

Legend:
- Electric Baseload
- Thermal Baseload
- Heating
- Cooling

Site EUI (kBtu/ft²-year)
Strategic Approach to Retrofits & ZNE

EUI

Weather Normalized Building EUI by End-Use

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Electric Baseload</th>
<th>Thermal Baseload</th>
<th>Heating</th>
<th>Cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elementary School 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elementary School 2</td>
<td></td>
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<tr>
<td>Elementary School 3</td>
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<tr>
<td>Elementary School 4</td>
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<tr>
<td>Elementary School 5</td>
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<tr>
<td>Middle School 1</td>
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<td>Middle School 2</td>
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<td>Middle School 3</td>
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<tr>
<td>High School</td>
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<tr>
<td>Alternative High School</td>
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<tr>
<td>Technical School</td>
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<tr>
<td>K-12 School</td>
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<td></td>
</tr>
</tbody>
</table>

Site EUI (kBTU/ft²-year)

Total Consumption

Weather Normalized Building Total Energy Usage by End-Use

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Electric Baseload</th>
<th>Thermal Baseload</th>
<th>Heating</th>
<th>Cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elementary School 1</td>
<td></td>
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<tr>
<td>Elementary School 2</td>
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<tr>
<td>Elementary School 3</td>
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<tr>
<td>Elementary School 4</td>
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<tr>
<td>Elementary School 5</td>
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<tr>
<td>Middle School 1</td>
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<td>Middle School 2</td>
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<tr>
<td>Middle School 3</td>
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<tr>
<td>Alternative High School</td>
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<tr>
<td>Technical School</td>
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</tr>
<tr>
<td>K-12 School</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Site Energy Consumption (MMBTU/year)

©2017, New Buildings Institute
Other ZNE Pilot Candidates

Weather Normalized Building EUI by End-Use

- ZNE ?
- ZNE !
- ZNE !

Average ZNE Verified Site EUI = 22.3 (n=57)
Energy Modeling Analysis

• Start with standard practice baseline building (DEER assumptions)
• Special look at the impact of operations
• Packages of “good,” “better” and “best” options analyzed
EUI from Primary School (CZ3)

Baseline EUI = 47.2 kBtu/ft²-year

Poor Operations

Result EUI = 54.8 kBtu/ft²-year

<table>
<thead>
<tr>
<th>EUI (kBtu/sf-year)</th>
<th>54.8</th>
<th>47.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Square Foot</td>
<td>125,000</td>
<td>125,000</td>
</tr>
<tr>
<td>kBtu per year</td>
<td>6,850,000</td>
<td>5,900,000</td>
</tr>
<tr>
<td>kWh per year</td>
<td>2,007,620</td>
<td>1,729,191</td>
</tr>
<tr>
<td>Utility Cost*</td>
<td>$0.15</td>
<td>$0.15</td>
</tr>
<tr>
<td>Total Annual Cost</td>
<td>$303,753</td>
<td>$261,627</td>
</tr>
</tbody>
</table>

* Based on National Average over all Sectors. 2017 EIA: https://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a

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HVAC Retrofit Packages

1. High Performance VAV
   • Hydronic reheat with condensing gas boiler (98% efficient)
   • High performance multistage chiller with magnetic bearing compressor (two stage, COP-5)
   • Demand controlled ventilation
   • Air economizer
   • Low supply and return fan power (0.9W/cfm)
   • Static pressure reset

2. Ground Source Heat Pump
   • GSHP (EER-18 and COP-3.7) with a water loop equipped with a variable speed pump aided by natural ventilation for cooling operations
   • Heat recovery on outside air ventilation ducts

3. High Performance Units
   • High Performance Single Zone Units with gas heat and DX cooling (EER-13, IEER-15.1) with air economizer
   • Variable speed supply fan (0.4W/cfm)
Lighting & Controls Retrofit Packages

1. Lighting Power Density
   • Complete LED retrofit
   • LPD from 2011 DEER vintage level by 50%

2. Daylighting, Interior Lighting and Plug Load Control
   • Side and top daylighting control with continuous dimming
   • Advanced lighting and plug load controls (vacancy sensors)

3. Daylight, LED and Improved Controls
   • Both packages together
Envelope Retrofit Packages

1. Opaque Surfaces and Infiltration Reduction
   • Opaque surfaces
     Roof U-0.028, Wall U-0.037, Slab F-0.434;
   • Reduced from 0.038 cfm/sf to 0.019 cfm/sf

2. Fenestration
   • High performance glazing coupled to a thermally broken frame applied to all windows

3. Opaque, Infiltration and Fenestration
   • Both packages together
EUI from Best Packages: Primary School (CZ3)

Baseline EUI = 47.2 kBtu/ft²-year

HVAC Savings

Lighting Savings

Envelope Savings

Best EUI = 23.2 kBtu/ft²-year
Primary School Comparison

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>EUI: 23.3 kBtu/ft²</th>
<th>Baseline EUI: 47.2 kBtu/ft²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Zone 7</td>
<td>EUI: 19.8 kBtu/ft²</td>
<td>Baseline EUI: 38.6 kBtu/ft²</td>
</tr>
<tr>
<td>Climate Zone 10</td>
<td>EUI: 22.3 kBtu/ft²</td>
<td>Baseline EUI: 45.9 kBtu/ft²</td>
</tr>
<tr>
<td>Climate Zone 13</td>
<td>EUI: 25.5 kBtu/ft²</td>
<td>Baseline EUI: 53.7 kBtu/ft²</td>
</tr>
</tbody>
</table>

- Savings fraction: HVAC
- Savings fraction: Internal Gains
- Savings fraction: Envelope
- Energy Use
Key Take Aways

The Energy Loading Order
Retrofit Impact on End Use Breakdown
Primary School (CZ3)

Baseline EUI = 47.2 kBtu/ft²-year
Best EUI = 23.2 kBtu/ft²-year
Manage Plug Loads
Range of Energy Performance Outcome

OCCUPANT BEHAVIOR
SCHEDULE AND USE
ACTUAL SYSTEM OPERATION
MODELED SYSTEM OPERATION

Energy Use

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THE PATH TO NET ZERO: A SHOUT OUT TO BUILDING OPERATORS


Like they don't have enough to do already, facility managers and building operators are now working to manage both sides of the electrical meter. The evolution of buildings incorporating advanced systems, highly integrated controls and distributed generation (typically photovoltaics) is growing and driving a dramatic leap in the skills needed to operate and maintain both comfort and energy efficiency.

Building operators have responsibilities today that were rarely imagined just a decade ago. Two that were spotlighted in our study “Zero Net Energy Building Controls” were 1) the Internet of Things (I o T) – a shorthand name for sensors now being in everything from cooling systems to copiers to the coffee maker within buildings, and 2) Distributed Generation whereby the building operator ensures not only the building’s operational energy use but also the generation and distribution of energy back to the grid. This is a whole new world and ground ‘zero’ is in the hands of the operator.

Zero is a key concept for hundreds of today’s operators who have performance-based targets for the final energy outcomes of the building systems and its distributed generation. To get to zero net energy the operator must take (ideally) very well designed building and systems and run them real time with all the nuances and variables that were only modeling hypothesis for the design team. For the Operator the needle is always moving and there is no static point of ‘zero’ net energy. Comfort and safety override energy as do resource and time constraints. Experience and training on new HVAC or lighting systems, and in particular controls and monitoring systems, are rare. Many operators cited feeling isolated from the design assumptions and abandoned regarding the hand off of operational and commissioning needs.
Arch of Continuity

Design Team  Construction Team  Operations & Maintenance Team
Engage Students

Discovery Elementary

Location: Arlington, VA
Construction Type: New Construction
Design Team: VMDO Architects, CMTA Engineers, Oculus, Heery, Fox + Associates
School Type: Elementary School
Building Size: 97,588 ft²
Building Completed: 2016
Cost: $33.5 Million
Modeled EUI: 21.2 kBtu/ft²
Actual EUI: 16.2 (Building total EUI) – 11 (RPI) = **-0.65** (Net EUI)

Photos Courtesy of CMTA Engineers
Verify Performance
• What are the educational goals of the proposed project?
• What are the assets and liabilities of the existing facility?
• Among the liabilities, what systems (plumbing, heating, glazing, etc.) are nearing the end of their useful life?
• How much can the energy and water needs be reduced before designing systems to supply those needs?
• What are the most efficient current alternatives to those systems?
• What are reasonably foreseeable advances in such systems, and what could be done now to make it possible to take advantage of future advances at the least cost?
Lincoln High School in Oakland, CA  
Team: WRNS Studio, Integral Group, Interface Engineering, Bellinger Foster Steinmetz Landscape Architecture, Sherwood Design Engineers, Loisos+ Ubbelohde

<table>
<thead>
<tr>
<th>Measure</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add trees to street</td>
<td>$77,266</td>
</tr>
<tr>
<td>Envelope Glazing</td>
<td>$380,169</td>
</tr>
<tr>
<td>Landscape Courtyard</td>
<td>$112,825</td>
</tr>
<tr>
<td>Play Structure</td>
<td>$29,699</td>
</tr>
<tr>
<td>Roof &amp; Insulation</td>
<td>$234,296</td>
</tr>
<tr>
<td>Roof mounted PV</td>
<td>$184,512</td>
</tr>
</tbody>
</table>
### San Diego High School in San Diego, CA
Team: Aedis Architects

<table>
<thead>
<tr>
<th>Measure</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling Fans</td>
<td>$2,198 each</td>
</tr>
<tr>
<td>New operable windows</td>
<td>$123,280 per classroom</td>
</tr>
<tr>
<td>Passive ventilation system</td>
<td>$232,125 per classroom</td>
</tr>
<tr>
<td>Skylight between classrooms</td>
<td>$792,118</td>
</tr>
<tr>
<td>Tubular skylights</td>
<td>$20,592 per classroom</td>
</tr>
</tbody>
</table>
Los Angeles Technical Trade College
Team: Hamilton + Aitken Architects / Capital Engineering Consultants, Inc.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Window Replacement</td>
<td>$2,425,228</td>
</tr>
<tr>
<td>Change Chiller to VRF for 100% water savings on HVAC</td>
<td>$6,337,500</td>
</tr>
<tr>
<td>3000 PV panels</td>
<td>$10,140,000</td>
</tr>
<tr>
<td>Rainwater storage system</td>
<td>$315,159</td>
</tr>
<tr>
<td>Drought tolerant landscaping</td>
<td>$228,800</td>
</tr>
</tbody>
</table>
nbi new buildings institute

ZNE Resources
Coming November 2017: The Second Annual ZNE Recognition Awards!

The first ever ZNE awards program in the country will have a call for submissions in September 2017. Know a project or leader? Nominate them!

Recognition Categories

**ZNE Leadership Award**
Honoring the leaders, both individuals who inspire others on the path to ZNE and project teams that work effectively together to achieve ZNE goals.

**Outstanding Buildings Award**
Spotlighting ZNE verified, ZNE emerging and ultra-low projects at K-12 schools and community college campuses.

**Visionary School District Award**
Recognizing both large and small districts that have utilized policies, programs or plans that results in larger scale advancement of zero energy buildings.
2016 Getting to Zero List

The ZE buildings on this list have either achieved or committed to the goal of producing as much renewable energy onsite as they consume over the course of a year.

Have a project to share?
Please email: info@newbuildings.org
Existing ZE & Ultra-Low Energy Case Studies

• NBI Case Study Briefs & ZE Case Studies
  http://newbuildings.org/case-studies-ZE-projects

• PG&E Case Studies

• NBI Registry
  http://newbuildings.org/share

• Getting to Zero Database
  http://newbuildings.org/getting-to-zero-buildings-database
GREAT NEW TOOLS FOR ZNE BUILDINGS

1. **ZNE Message Platform**
   Key messages for target audiences on the what and why of ZNE.

2. **“Intro to ZNE” Presentation**
   Customizable powerpoint presentation provides an overview of California’s goals and policies for ZNE, key strategies, and case study examples.

3. **ZNE Companion Guide/Fact Sheets**
   Collection of FAQs, resources, design strategies, and key messages for designers, commercial building owners, policymakers, and decisionmakers of schools and public buildings.

   Read about ZNE and ultra-low energy building examples, including design strategies, costs, and lessons learned.

5. **ZNE Action Bulletin**
   Sign up for our quarterly e-newsletter for updates on ZNE news, events, trainings, case studies, planning, policy, and research. To sign up, or to get more info about the toolkit, email heather@newbuilding.org.

---

**ZNE Communications Toolkit**

**ZNE Design Fundamentals**

A ZNE building produces as much energy as it consumes over the course of a year

The traditional approach, where the architect designs the building shape, orientation and envelope and then transmits the drawings to the mechanical and electrical engineers for their design, is a sequential approach that misses the rich opportunities for optimizing building performance through a collaborative approach throughout the design process.

Integrated Design and Advanced Technologies = High Performance

Achieving a zero net energy (ZNE) goal for any new commercial construction or deep renovation project requires a commitment by the design team to a full integrated process where the interrelationships between the building and its systems, surroundings and occupants make efficient and effective use of all resources. For example, many of the completed ZNE buildings located in the coastal marine areas of California are able to greatly reduce or even eliminate the need for mechanical cooling by prioritizing natural ventilation as part of their design schema.

Integrated project delivery involves making all members of the design team aware of the project goals and outcomes including setting energy performance targets such as EUI (Energy Use Intensity) at the outset. It also requires engaging project participants early in the design process, so each member can understand how their role contributes to the greater design of the whole project.

**The Four Major Components of Integrated Design**

- **Sync**
- **Simplify**
- **Streamline**
- **Scale back

---

**ZNE Schools**

A ZNE building produces as much energy as it consumes over the course of a year

K-12 schools and community colleges represent key opportunities to advance zero net energy (ZNE) policies and practices. Schools can serve as examples of the feasibility and benefits of ZNE building and as hubs to educate the broader community about ZNE buildings.

Educational facilities have been some of the earliest models of sustainable, high performance buildings and many school districts participate in certifications such as LEED or the Collaborative for High Performance Schools (CHPS) to improve building energy performance. ZNE is the next step in this evolution of high performance schools, healthier learning environments and a commitment to mitigating climate impacts.

Some of the benefits of schools pursuing ZNE include:

- **Lower Operating Costs:** K-12 schools spend $8 billion on energy, more than is spent on computers and textbooks combined. Schools built to ZNE performance have lower operating costs and over time, save money on energy bills that can be spent on educating students. ZNE also reduces exposure of school budgets to the volatility of shifting energy prices.

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**PROJECT PROFILE: Stevens Library, Sacred Heart Elementary | Atherton, CA**

The Stevens Library at Sacred Heart Elementary School is the first verified zero net energy school building in California and an innovative model for zero net energy schools everywhere. Built in 2012, the 9,000-square-foot library is certified LEED Platinum by the USGBC and as a Net Zero Energy Building by the International Living Future Institute. The building features natural ventilation and daylighting augmented by high performance lighting, high efficiency mechanical systems and a 42.5-kW, low-profile photovoltaic system. The project includes an energy monitoring system dashboard for public education and was designed and constructed at 20% below standard industry prices.

Stevens Library is a verified net zero energy project. The building generates enough energy for its use and consumes zero energy over the course of a year.

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ZE Presentation Templates

• Primarily commercial
• Carries general messages
• Goals for ZE
• ZE building examples
• Open source platform! Slide collection will grow as champions and others develop their own ZE presentations
• Agendas/Presentations from Previous NBI Workshops

Users of the Presentations:
• Champions & Early Adopters
• Sustainability, Energy and Facility Managers
• Communications staff
Other Resources

- **NEEP High Performance Schools:** [http://www.neep.org/initiatives/energy-efficient-buildings/high-performance-schools](http://www.neep.org/initiatives/energy-efficient-buildings/high-performance-schools)
- **Collaborative for High Performance Schools (CHPS) Criteria:** [http://www.chps.net/dev/Drupal/node/212](http://www.chps.net/dev/Drupal/node/212)
- **Green Ribbon Schools:** [https://www2.ed.gov/programs/green-ribbon-schools/index.html](https://www2.ed.gov/programs/green-ribbon-schools/index.html)
- **DOE Toolkit: K-12 Solutions for Building Energy Excellence:** [https://betterbuildingsinitiative.energy.gov/toolkits/k-12-solutions-building-energy-excellence](https://betterbuildingsinitiative.energy.gov/toolkits/k-12-solutions-building-energy-excellence)
Santa Barbara High School in Santa Barbara, CA  
Team: Hamilton + Aitken Architects / Capital Engineering Consultants, Inc.

<table>
<thead>
<tr>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Window Replacement</td>
</tr>
<tr>
<td>Radiant heating / cooling piped system</td>
</tr>
<tr>
<td>Solar thermal pre-heat for radiant &amp; PV equip</td>
</tr>
<tr>
<td>Rain/greywater storage &amp; treatment</td>
</tr>
<tr>
<td>Reclaimed sink water to flush toilets</td>
</tr>
</tbody>
</table>
Activity: Prioritizing Your Project Pipeline for ZNE Retrofits

**Purpose:** To consider how you might add energy and ZNE to the list of considerations in the Facility Master Plan. **How do you make the case for one project over the other?**

**Using the benchmarking analysis for a small portfolio of schools in your district consider:**

**Group discussion:** What are the Important Considerations in your decision making? What process do you use you begin prioritizing which schools to retrofit.

**On your Worksheet:**
1. List any unique factors for these buildings that might affect facilities planning and potential ZNE outcome. You can use own experiences that influenced your retrofit prioritization or just speculate based on the data provided.

2. Rank each building from mostly likely to retrofit to ZNE to least likely (1 being the most likely, 10 being the least likely).

**Be sure to take into consideration the “Things to Note” on your sheet!**
Thank You!

New Buildings Institute
Amy Cortese, Associate Director, amy@newbuildings.org
Reilly Loveland, Project Analyst, reilly@newbuildings.org