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Path to ZNE in K-14 Schools

Design for Education

VMDO Architects

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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

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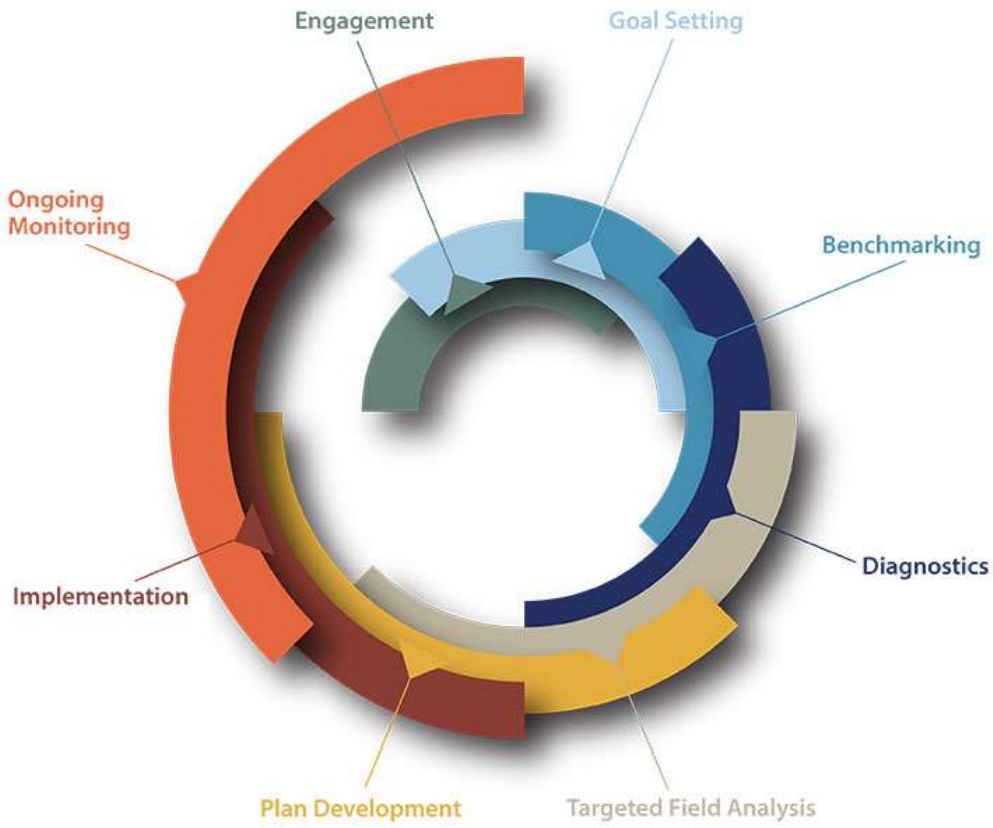
Portfolio Benchmarking



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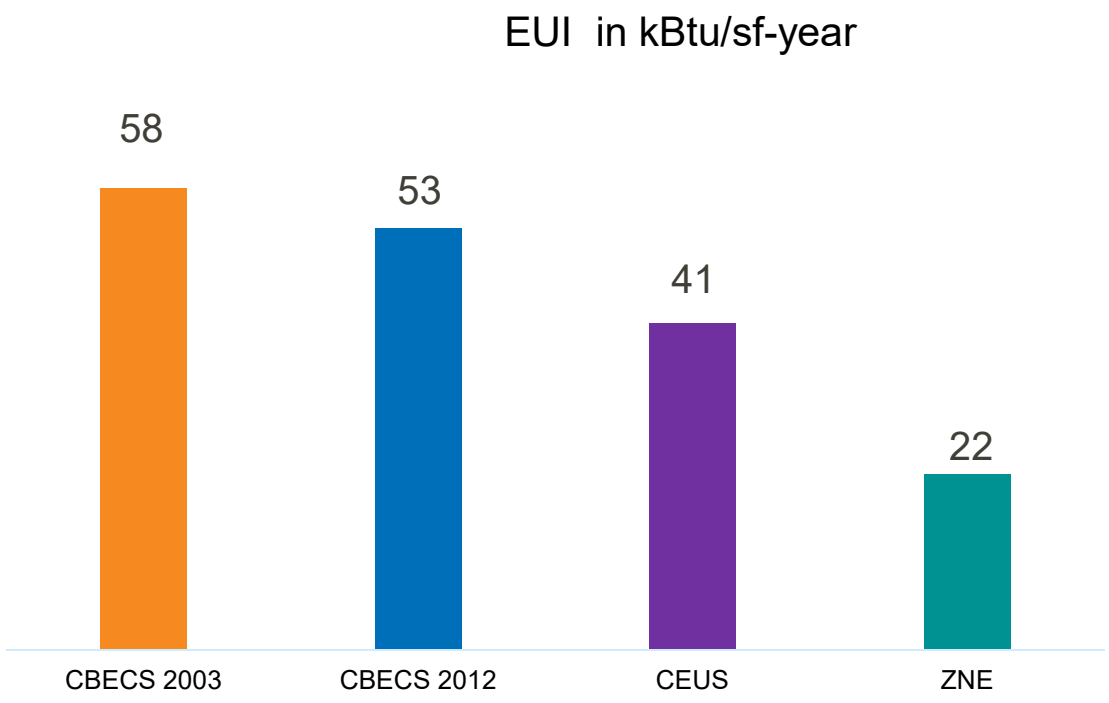
Energy Use Intensity

School data sources:

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



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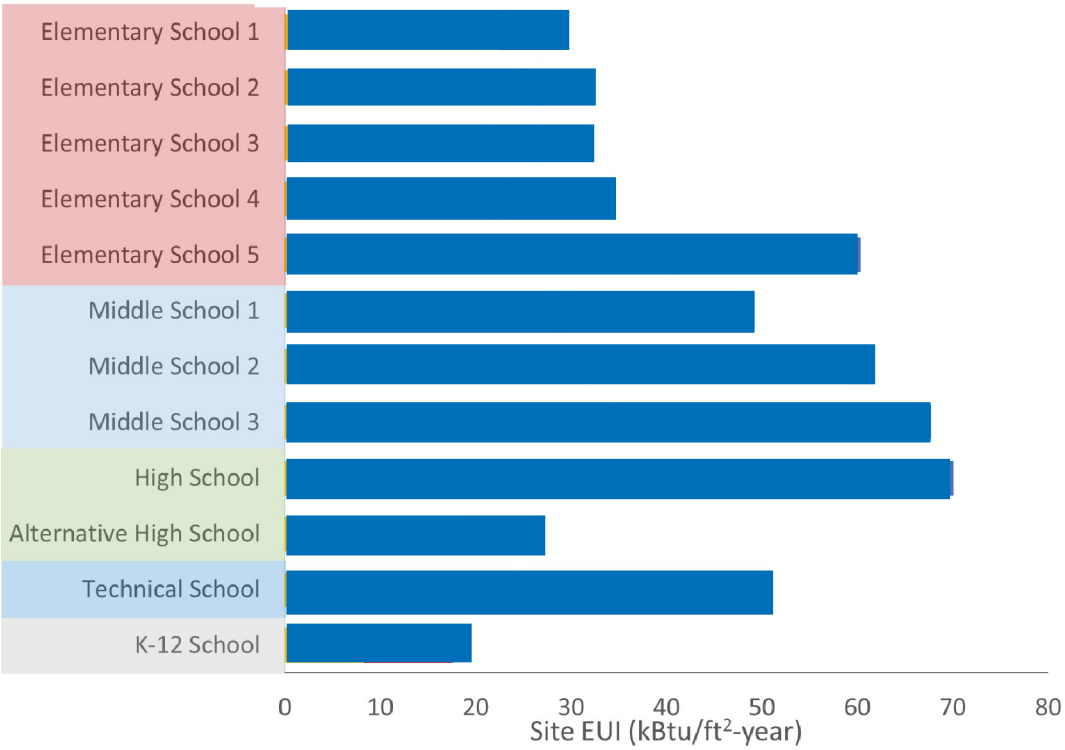
Portfolio-Level EUI



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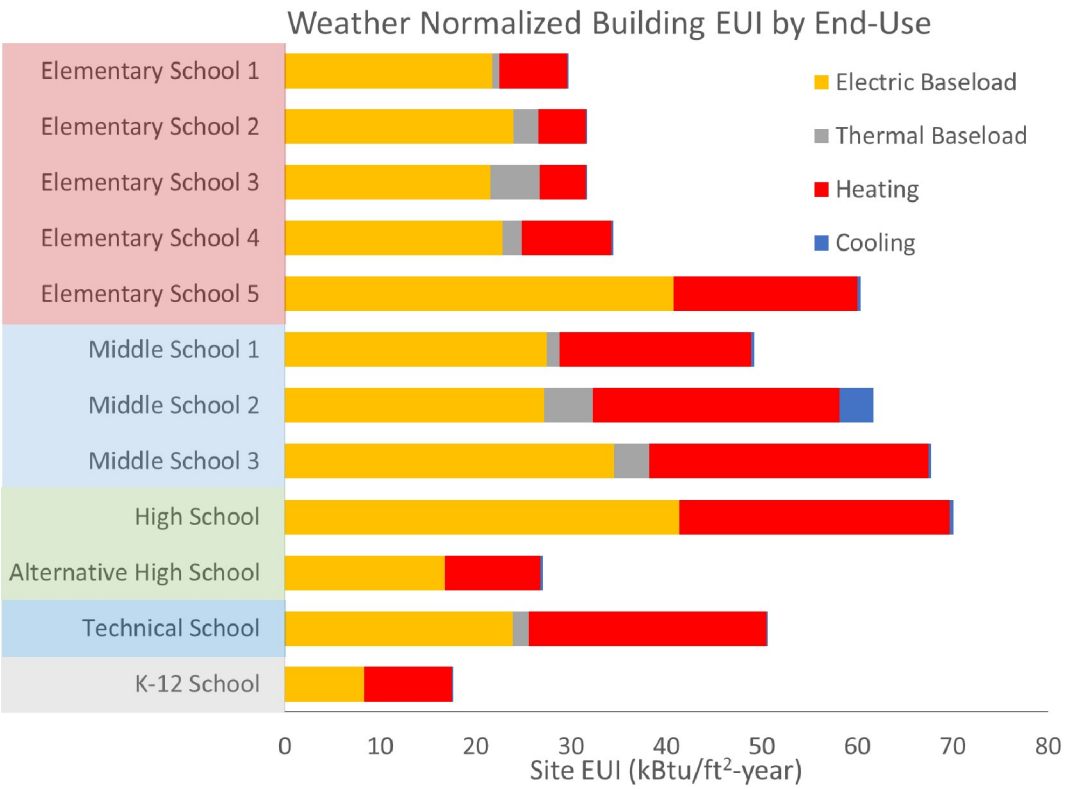
Portfolio-Level: Disaggregated Energy



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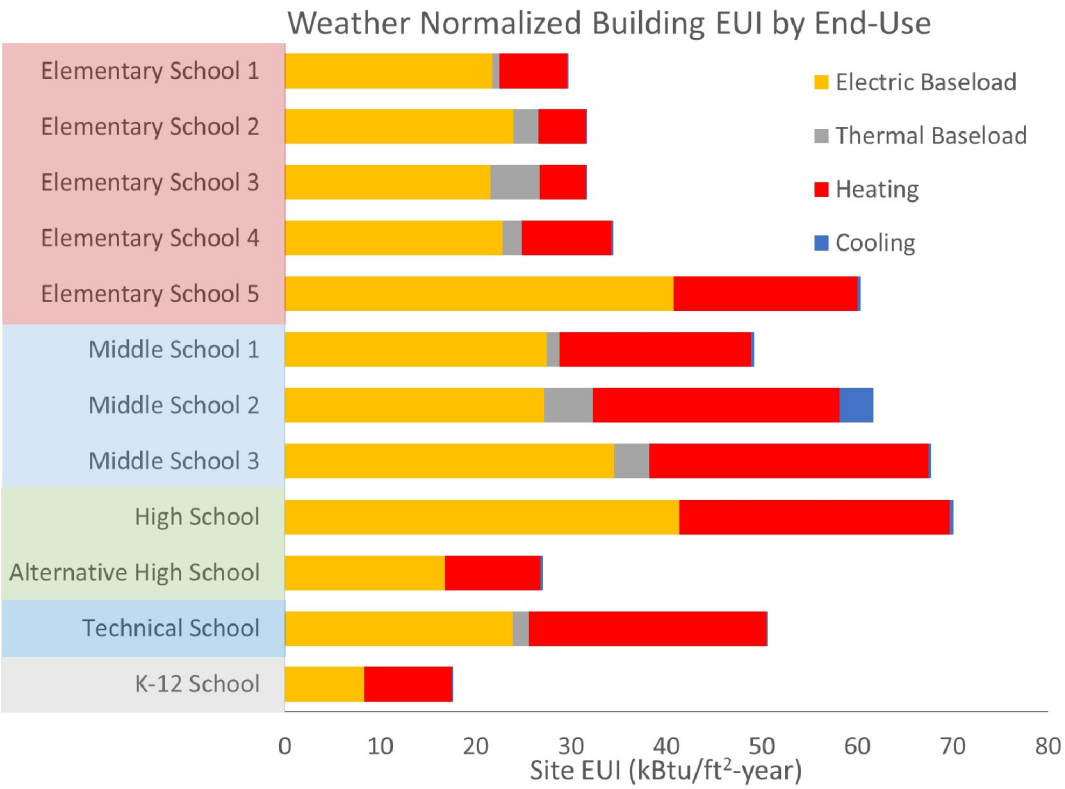
Portfolio-Level: Disaggregated Energy



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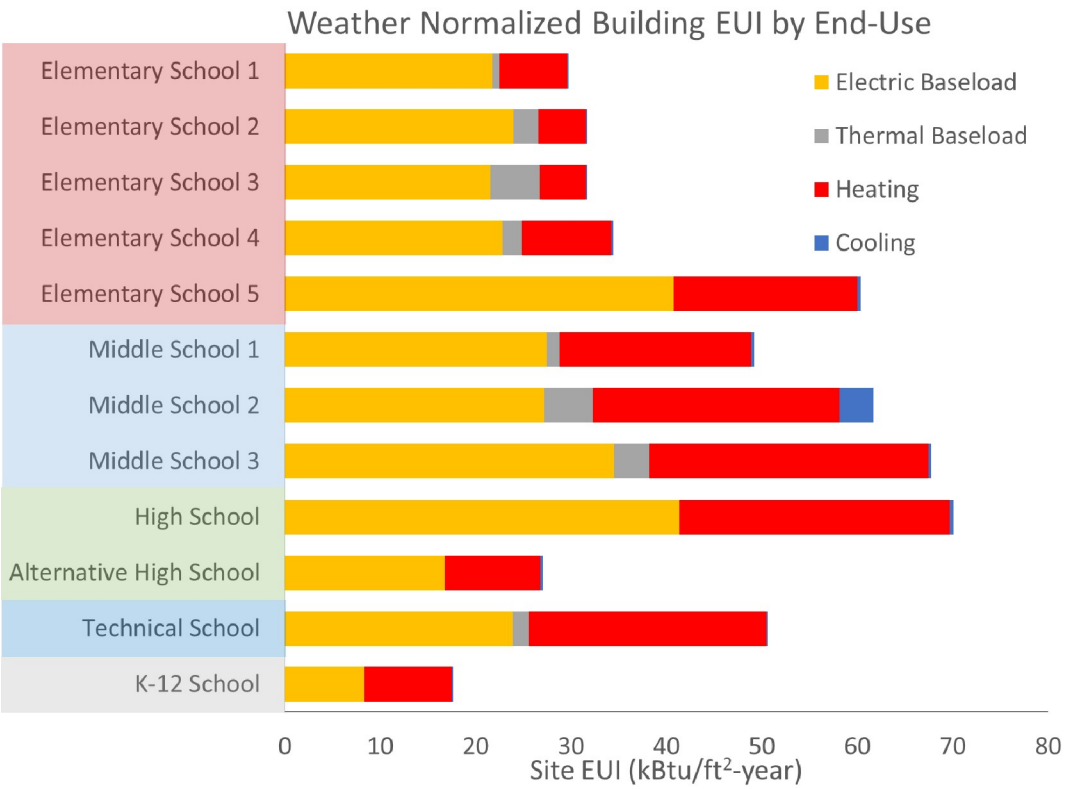
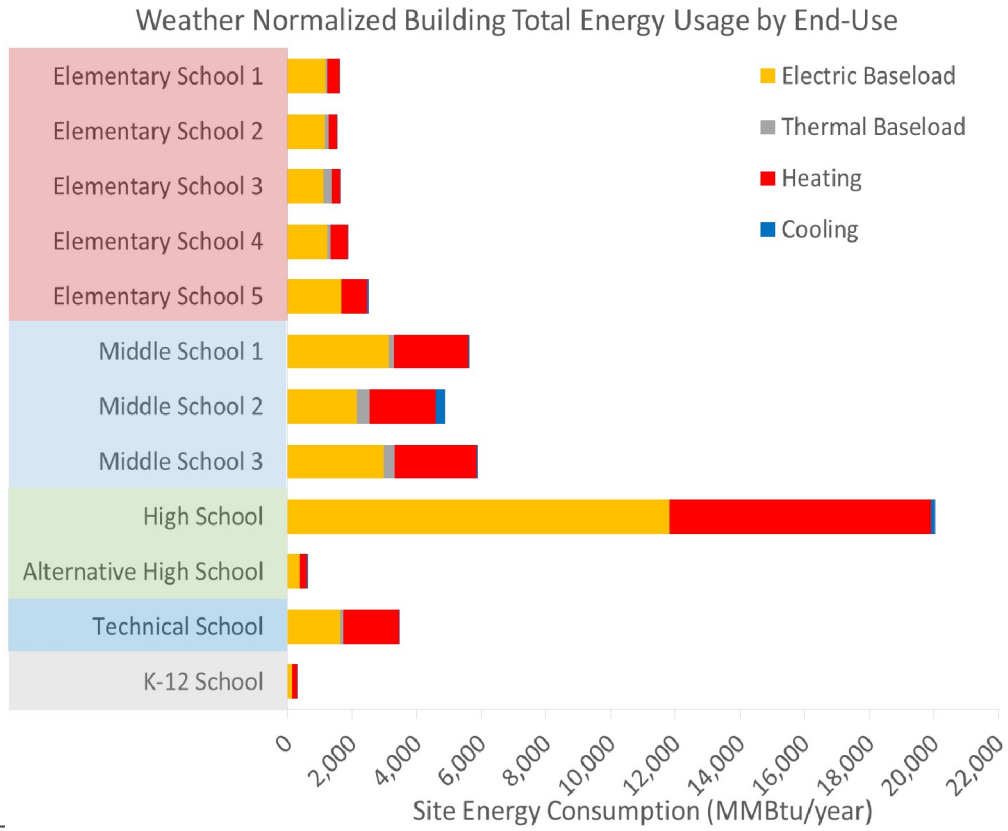
EUI



Total Consumption



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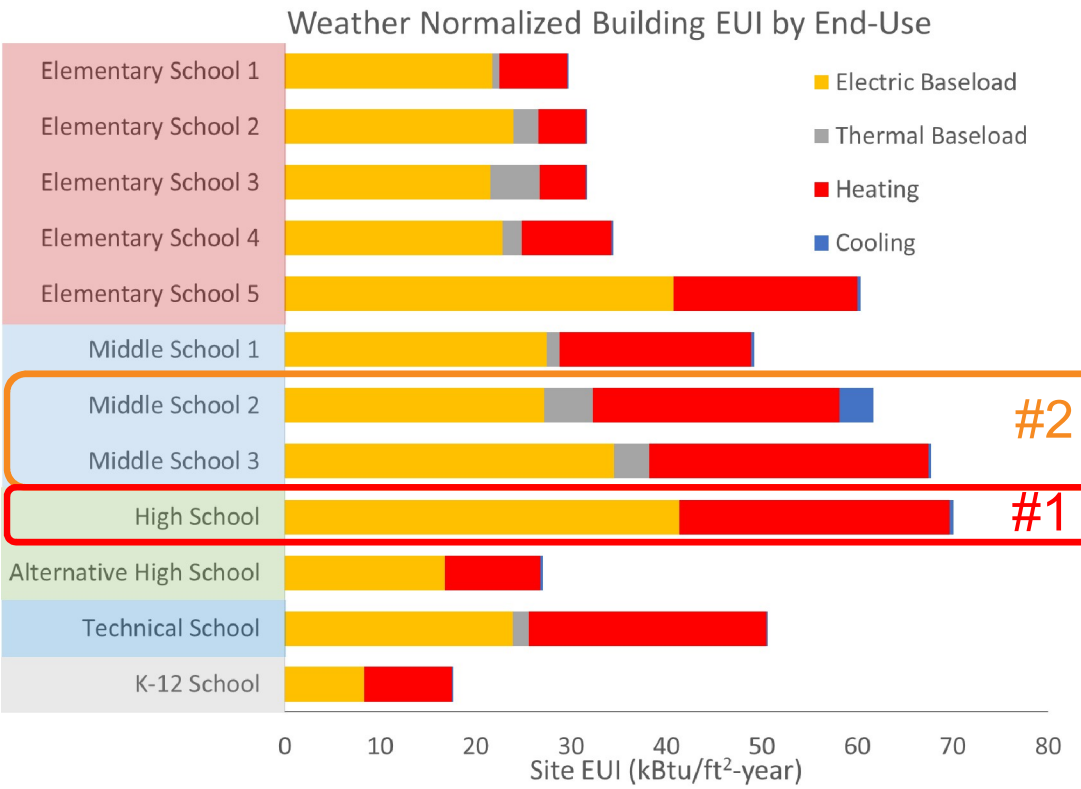
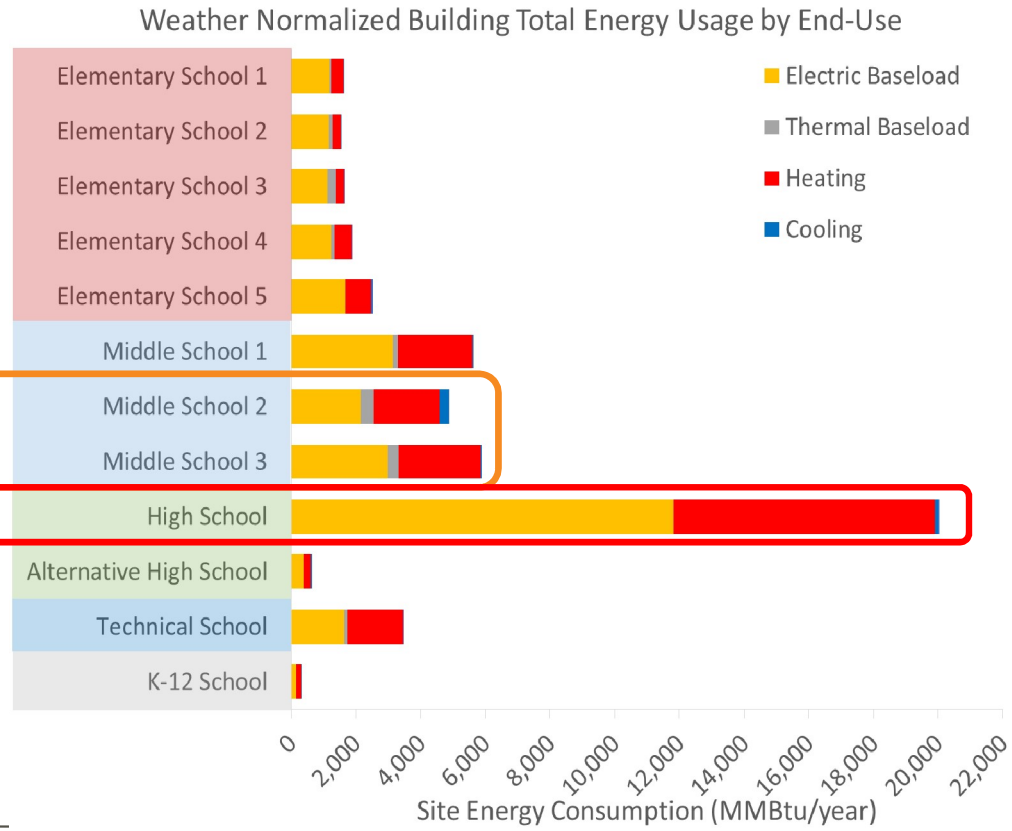
Strategic Approach to Retrofits & ZNE

EUI



Total Consumption



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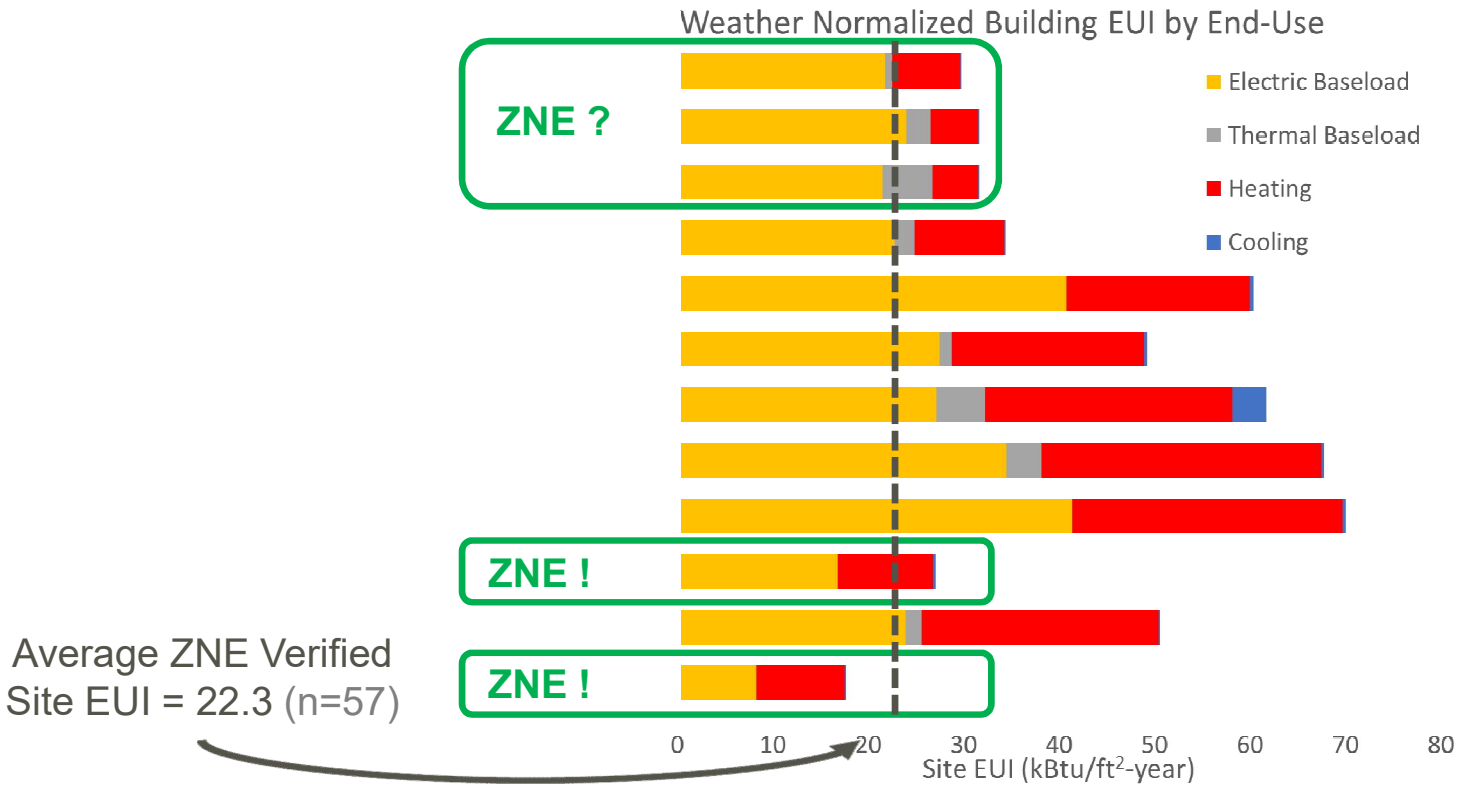
Other ZNE Pilot Candidates



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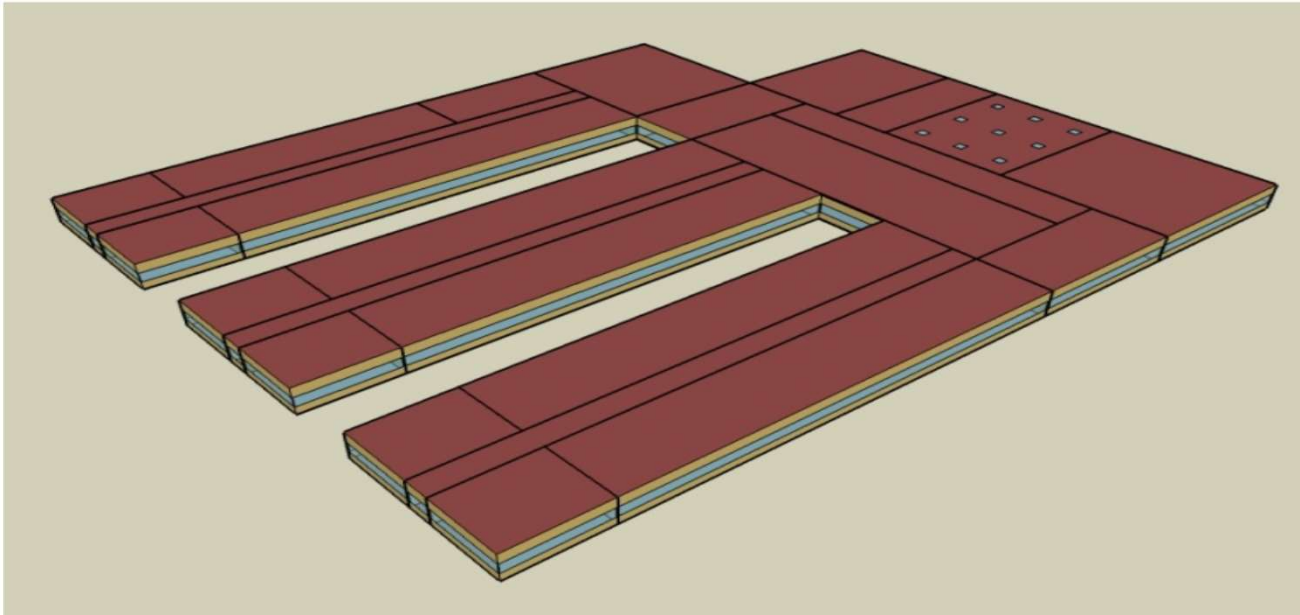
ZNE Retrofit Approaches

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



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EUI from Primary School (CZ3)

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

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* 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)

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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

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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

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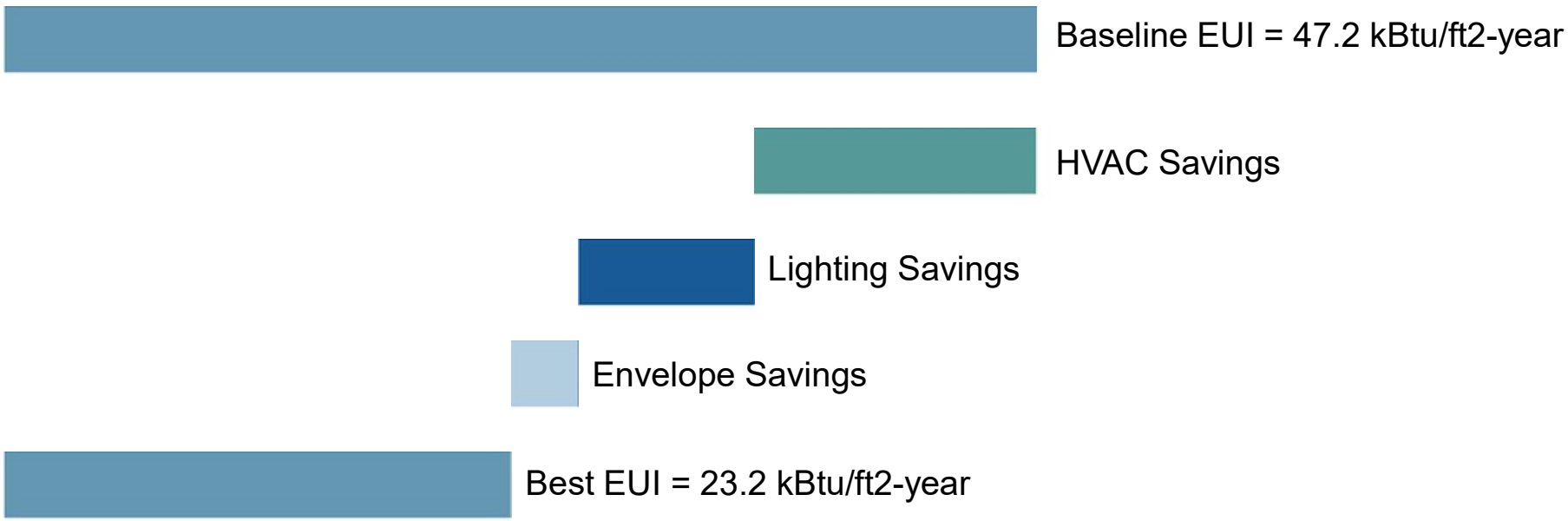
EUI from Best Packages: Primary School (CZ3)



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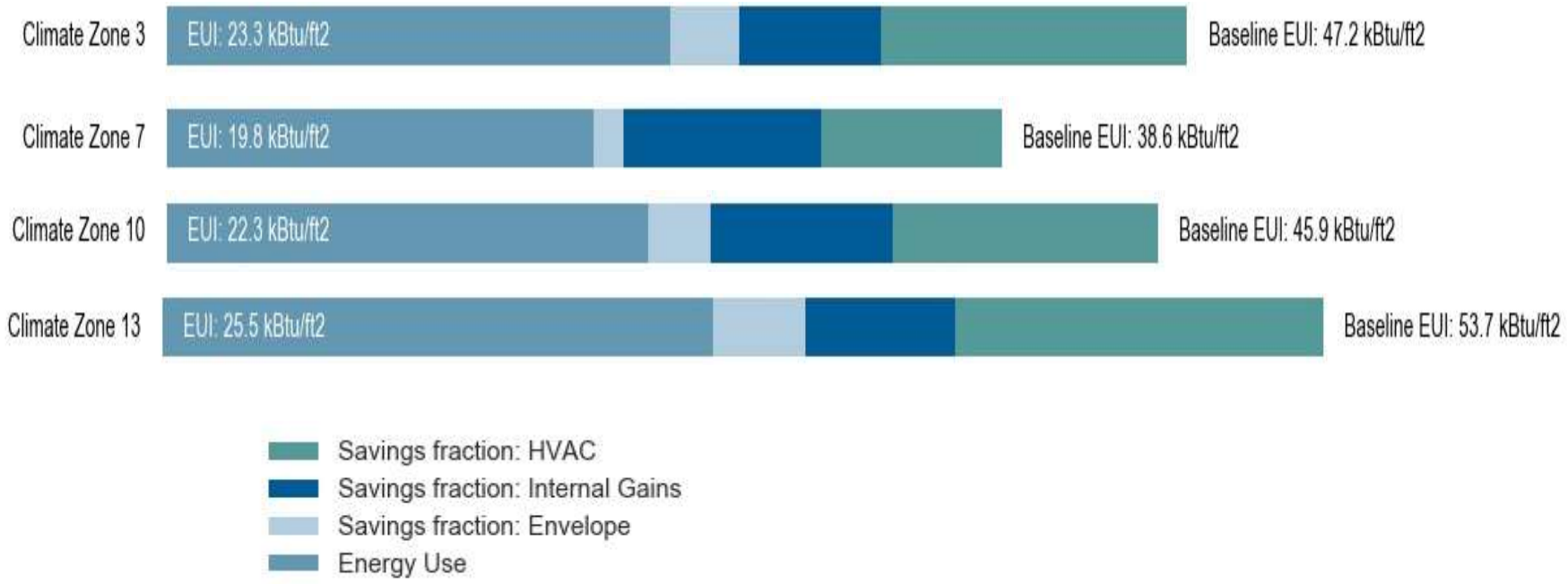
Primary School Comparison



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Key Take Aways

The Energy Loading Order

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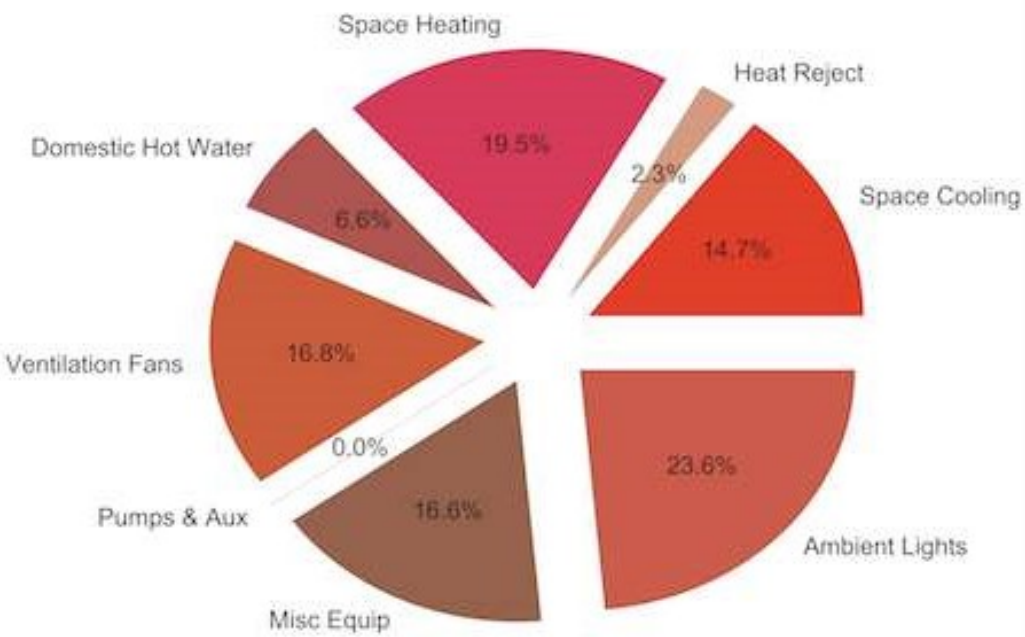
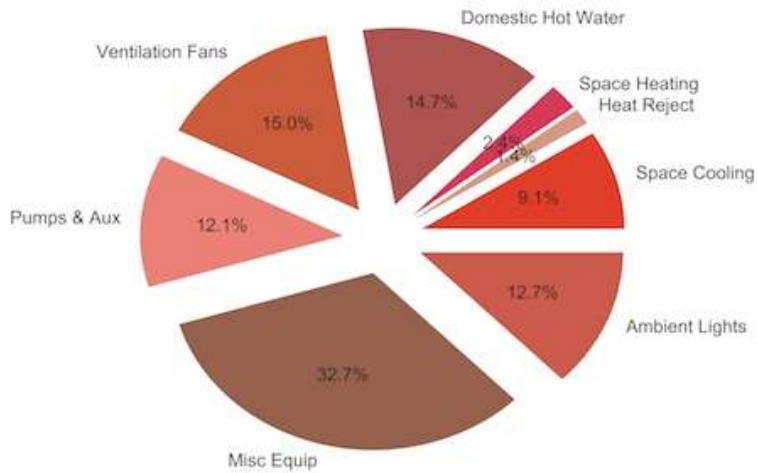
Retrofit Impact on End Use Breakdown Primary School (CZ3)



Baseline EUI = 47.2 kBtu/ft2-year



Best EUI = 23.2 kBtu/ft2-year

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Manage Plug Loads

Image: St Lucie K-12 Schools https://schools.stlucie.k12.fl.us/fks/programs/technology/

Image: Shorewood K-12 Schools
http://www.shorewood.k12.wi.us/page.cfm?id=1642&noticeid=42&isnewsletter=YES&sitechoice=0

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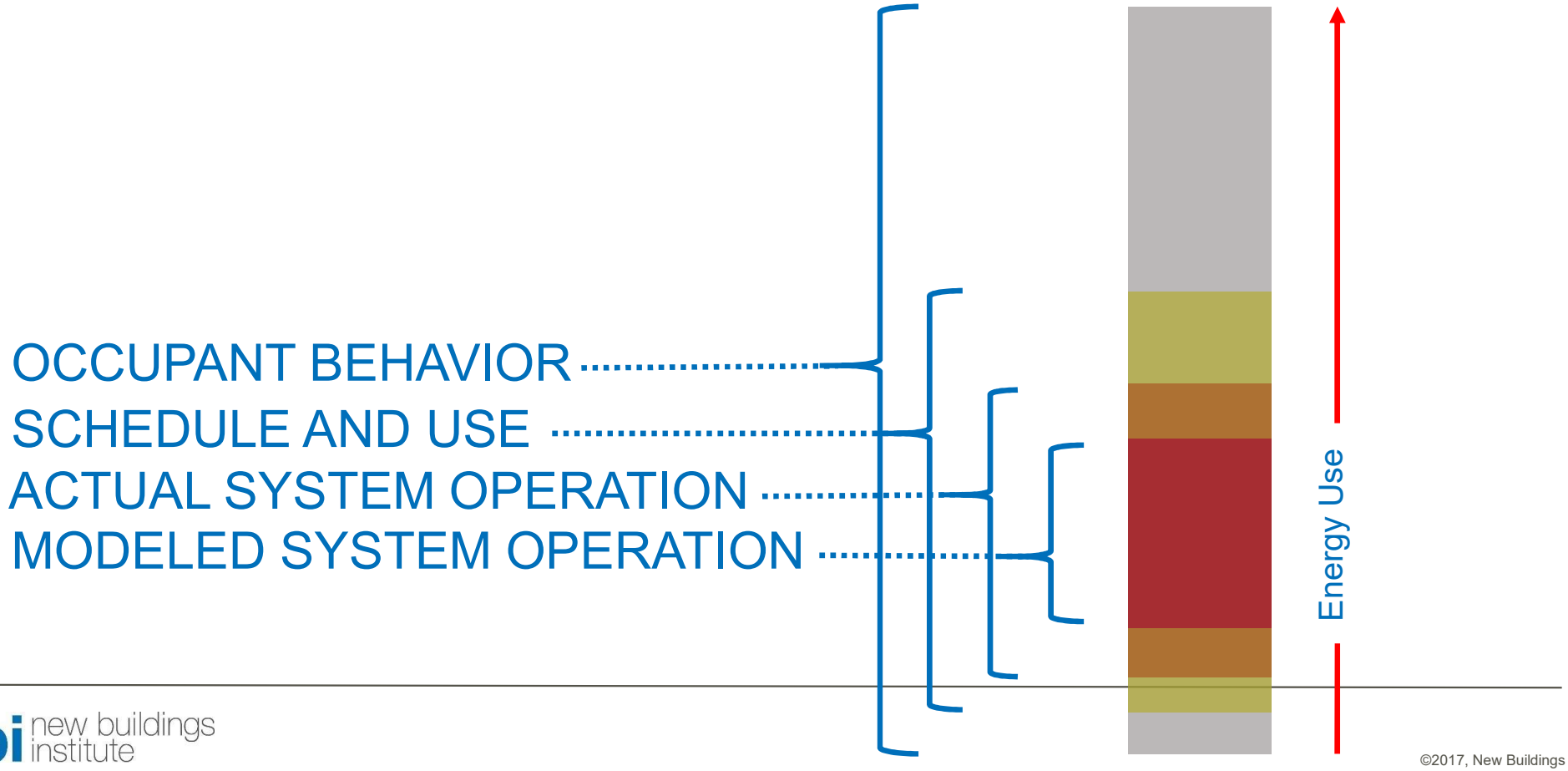
Range of Energy Performance Outcome



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

June 21, 2016 / Zero Net Energy / Controls, Operations & Maintenance, Zero Net Energy (ZNE)

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) a 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.

Newsletter

Sign up to receive updates from NBI.

Email

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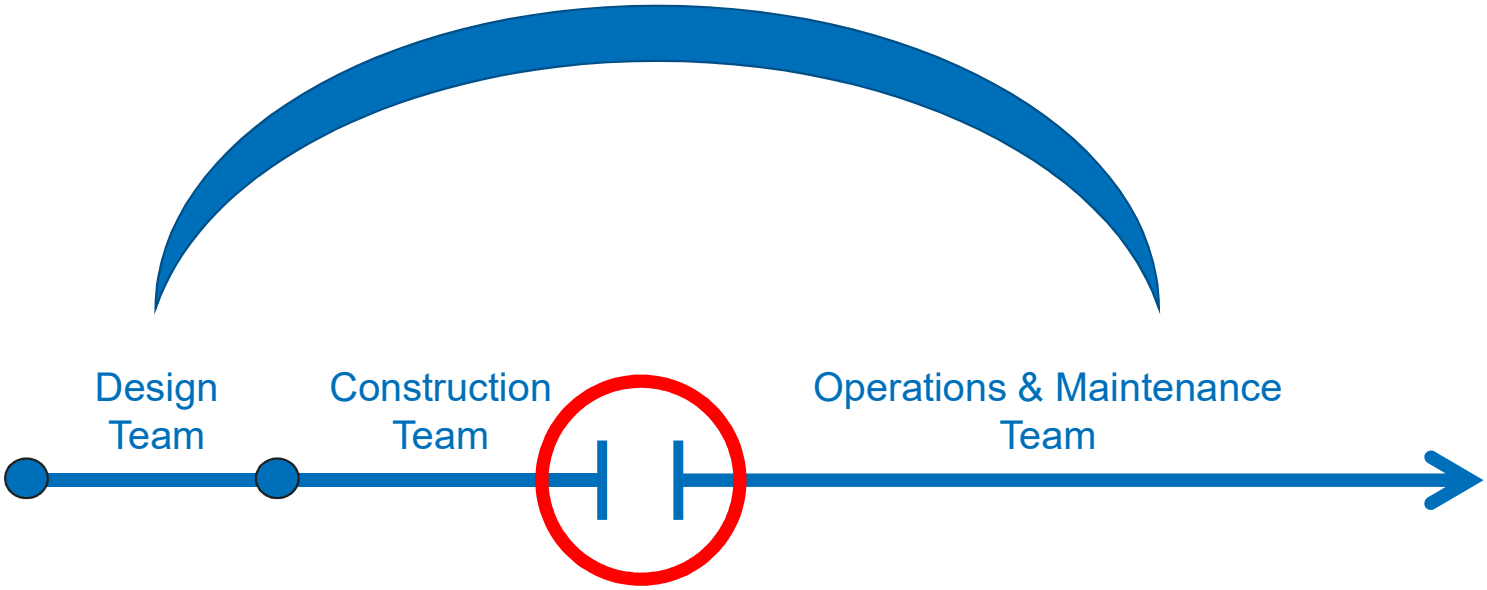
Arch of Continuity



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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 ft^2

Building Completed: 2016

Cost: $33.5 Million

Modeled EUI: 21.2 $kBtu/ft^2$

Actual EUI: 16.2 (Building total EUI) – 11 (RPI) = **-0.65** (Net EUI)

VMDO Architects

Verify Performance

7x7x7 | DESIGN ENERGY WATER
7 ARCHITECTS 7 SCHOOLS 7 INNOVATIONS

- 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?

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Lincoln High School in Oakland, CA

Team: WRNS Studio, Integral Group, Interface Engineering, Bellinger Foster Steinmetz Landscape Architecture, Sherwood Design Engineers, Loisos+ Ubbelohde

Measure	Estimated Cost
Add trees to street	$77,266
Envelope Glazing	$380,169
Landscape Courtyard	$112,825
Play Structure	$29,699
Roof & Insulation	$234,296
Roof mounted PV	$184,512

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San Diego High School in San Diego , CA

Team: Aedis Architects

Measure	Estimated Cost
Ceiling Fans	$2,198 each
New operable windows	$123,280 per classroom
Passive ventilation system	$232,125 per classroom
Skylight between classrooms	$792,118
Tubular skylights	$20,592 per classroom

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Los Angeles Technical Trade College

Team: Hamilton + Aitken Architects / Capital Engineering Consultants, Inc.

Measure	Estimated Cost
Window Replacement	$2,425,228
Change Chiller to VRF for 100% water savings on HVAC	$6,337,500
3000 PV panels	$10,140,000
Rainwater storage system	$315,159
Drought tolerant landscaping	$228,800

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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.

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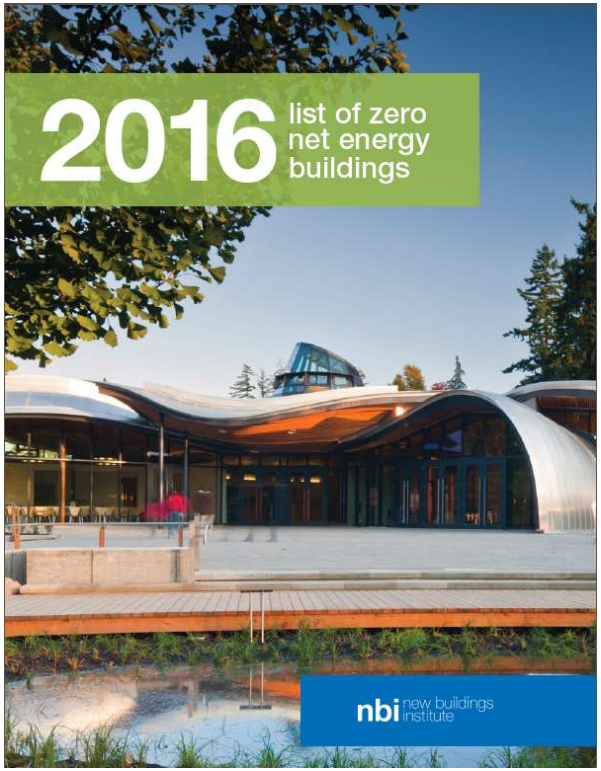
2016 Getting to Zero List

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



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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
  http://energydesignresources.com/resources/publications/case-studies/case-studies-ZE-non-residential-buildings.aspx
- NBI Registry http://newbuildings.org/share
- Getting to Zero Database
  http://newbuildings.org/getting-to-zero-buildings-database

1955

Zero Net Energy Project Profile

Small Office Retrofit

Photos: ARCHITECTS hannah gabriel wells

OVERVIEW

Site Details

Building Size: 4,500 SF

Location: San Diego, California

Construction Type: Retrofit

Construction Year: 1955, 2009

Building Type: Small Office

CA Climate Zone: 7

Measured Energy Stats

13 - 22 = -9

BUILDING'S TOTAL EUI | RENEWABLE PRODUCTION EUI | BUILDING'S NET EUI

Site Energy Use Index (EUI) kBtu/SF/year

The Energy Equation: **the building energy use** *minus* **the renewables production** *equals* **the net energy of the building.** Buildings may be 'Getting to Zero' and have a net EUI

BACON STREET OFFICES

The Bacon Street Office project is a 4,500 SF retrofit of a single-story, 1950's-era auto repair shop into a high performance office for the firm ARCHITECTS hannah gabriel wells. Through creative design strategies, renewable energy generation and with support from local utilities, including the Savings by Design program, the project has achieved zero net energy goals. In fact, this project is so energy efficient it returns power to the grid.

Planning & Design Approach

The project demonstrates the difference between typical projects and ZNE projects. The following steps were critical to success:

- Start early and use an integrated design process
- Outline goals and benefits
- Structure fees to provide more research and design iterations
- Stay flexible and inclusive with the design process

Energy Efficiency Strategies and Features

Daylighting: A wall of windows along the public street side of the building provides daylight and views of a new landscaped parking court with native vegetation and canopy trees. This light is balanced with toplighting from diffuse skylights at the back of the space. Illuminating walls, ceilings and balancing

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5 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.

4 Case Studies: ZNE & Ultra-Low Energy 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

zero net energy

ZNE Design Fundamentals

zero net energy

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

Integrated Design and Advanced Technologies = High Performance

National Renewable Energy Laboratory | Golden, CO
Photo:: Dennis Schroeder, courtesy of NREL/DOE

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 fully 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 scheme.

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 onset. 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.

This team-oriented approach ensures the proper design strategies and high performance technologies that are so critical to the outcome of ZNE buildings are selected and implemented in a way that maximizes effectiveness and efficiency.

"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."

Lynn G. Bellenger, P.E. ASHRAE Fellow
2010-2011 ASHRAE President

The Four Major Components of Integrated Design

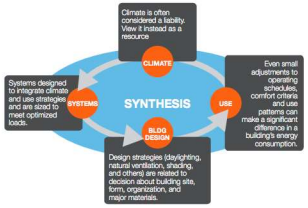


Image courtesy of BetterBricks/NEEA

ZNE Schools

zero net energy

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 buildings 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:

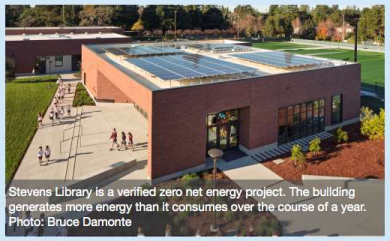
- **Lower Operating Costs:** K-12 schools spend $8 billion on energy, more than is spent on computers and textbooks combined. Schools built to ZNE performance have lower operating costs and over time, save money on energy bills that can be spent on educating students. ZNE also reduces exposure of school budgets to the volatility of shifting energy prices.
- **Increased Student Performance:** Occupants of ZNE schools benefit from heightened student performance, increased average attendance, better occupant health and improved teacher satisfaction and retention.

LA Harbor College, Science Complex, Emerging ZNE Building

- **Innovation:** ZNE schools are living laboratories, stimulating learning and innovation. Occupant engagement in ZNE schools can provide additional energy savings and serve as a teaching tool for students, STEM programs and the larger community.
- **Resiliency:** ZNE schools are also more resilient in severe weather events. They can create safe havens for the community during emergencies since the building energy generation systems can be islanded and remain functional continuing to provide light and space conditioning during an outage, they also use daylighting and natural ventilation.

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 6,800-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. The Stevens Library has a total energy use intensity (EUI) of 16.9,



Stevens Library is a verified zero net energy project. The building generates more energy than it consumes over the course of a year.
Photo: Bruce Damonte

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www.newbuildings.org/ZE-communications-toolkit

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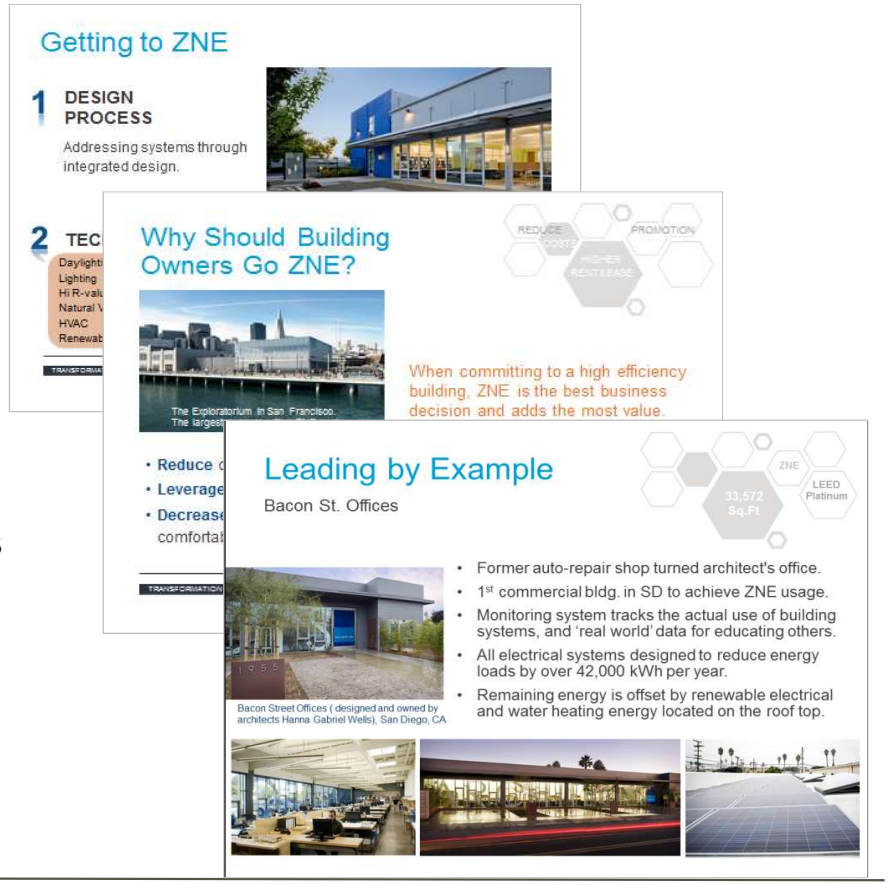
ZE Presentation Templates

- 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

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Other Resources

- **Energy Star Portfolio Manager:** https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager
- **NEEP 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
- **Green Ribbon Schools:** https://www2.ed.gov/programs/green-ribbon-schools/index.html
- **NCEF School Buildings Assessment Methods:** http://www.ncef.org/pubs/sanoffassess.pdf
- **San Diego Unified School District Energy Management Plan:** https://www.sandiegounified.org/sites/default/files_link/district/files/special-projects/2014%20Energy%20Management%20Plan%20EnviroSusCommitteeMeeting_V2.pdf
- **NREL Technical Feasibility for K-12 Schools:** http://www.nrel.gov/docs/fy17osti/67233.pdf
- **DOE Toolkit: K-12 Solutions for Building Energy Excellence:** https://betterbuildingsinitiative.energy.gov/toolkits/k-12-solutions-building-energy-excellence

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Santa Barbara High School in Santa Barbara, CA

Team: Hamilton + Aitken Architects / Capital Engineering Consultants, Inc.

Measure	Estimated Cost
Window Replacement	$2,395,250
Radiant heating / cooling piped system	$9,115,600
Solar thermal pre-heat for radiant & PV equip	$3,510,000
Rain/greywater storage & treatment	$797,420
Reclaimed sink water to flush toilets	$1,378,00

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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**!

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Thank You!

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Reilly Loveland, Project Analyst, reilly@newbuildings.org

Marin Country Day School
Photo Courtesy: EHDD Architects