Prop 39 ZNE School Retrofit Pilot Program Workshops

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NBI is a national nonprofit working to improve buildings for people and the environment.

Program Areas:
1. Best practices in new and existing buildings
2. Continuous code and policy innovation
3. Zero energy leadership and market development

Learning Objectives
1. Recognize zero-energy strategies for energy conservation, sustainable ecologies, health and safety, money savings, and project-based learning opportunities.
2. Learn how ZNE projects take an innovate approach to occupant engagement, transforming the energy use of the building into a teaching tool for students, teachers and administrators.
3. Participants will be given the tools needed to assist in effectively communicate the benefits of ZNE schools to their own school district stakeholders.
4. Participants will gain an understanding of the replicable and scalable energy efficiency measures and policies implemented by districts currently on the path to ZNE to apply in their own practice and districts.
Introduction to Zero Net Energy

What is a Zero Net Energy Building?

**ZNE Source Definition:**
A building that produces at least as much energy as it uses in a year when grid-supplied energy (including primary energy for generation, transmission and delivery to the site) is taken into account.

Sinema Health & Science Building | Fall River, MA
Photo Courtesy of Edward Caruso
Schools are Leading in ZNE

ZNE and Ultra-Low Energy in Education

K-12 Schools  Community Colleges  Higher Education

Libraries  Science Centers
Steps to Success in Sustainable Design

• Get Stakeholder Support
• Make a Commitment
• Use an Integrated Design Process
• Set Energy Targets
• Design and Construct To The Target
• Optimize Operations
• Measure and Verify

Six Key Messages for Communicating Zero Energy

1. ZERO ENERGY: Zero energy (ZE) schools are low energy buildings coupled with renewables that provide a ready generation resource.

2. LOWER OPERATING COSTS: Schools built to ZE performance avoid utility costs that can be spent on educating students or further improving facilities.

3. INCREASED STUDENT PERFORMANCE: Occupants of ZE schools benefit from heightened student performance, increased attendance, better occupant health and improved teacher satisfaction and retention.
Six Key Messages for Communicating Zero Energy

4. EDUCATIONAL BENEFITS: ZE schools are living laboratories, stimulating learning and innovation.

5. RESILIENCY: ZE 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.

6. GETTING TO ZERO: While ZE is the end game for building sustainably, it is a process and can take time to accomplish. School districts can start now on this path to zero.

Tools for Zero Energy Schools
NBI Prop 39 Retrofit Case Studies

https://gettingtozeroforum.org/schools/

AEDG Zero Energy K-12 Schools Guide
School buildings as a tool to enhance student learning
Use the Building as an Opportunity for Education

- **Hands on learning** opportunities increase **student performance** and **lesson retention**.
- Use daily building operations as educational opportunities.
- Adapts students to a knowledge-based technologically advanced society.
- Students grasp **21st century skills** like teamwork, research gathering, time management, information synthesizing, independence and utilizing high tech tools.
- Schools house the **next generation of environmental leaders**.

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**ZNE Supports Next Generation Science Standards & Skills**

- Analyzing and Interpreting Data
  - Engineering Design and Human Impacts
  - Energy
- Influence of Science, Engineering, and Technology on Society and the Natural World
  - Engineering Design
- **ESS3.C: Human Impacts on Earth Systems**
  - Human Impacts
- Science Addresses Questions About the Natural and Material World
  - Human Impacts
- Constructing Explanations and Designing Solutions
  - Energy
- Engaging in Argument from Evidence
  - Energy
- **ETS1.B: Developing Possible Solutions**
  - Energy

... among others!
Benefits of High Performance Schools

• Occupants in ventilated spaces with low CO2 and low volatile organic compounds (VOCs) had improved scores in crisis response, information usage, and strategy ranging from 100 to 300%.

• Students in daylit environments showed a 20-26% improvement on test scores compared to traditionally lit environments.

• Students with operable windows progressed 7-8% faster than those without operable windows.

• Students with the most daylighting performed 7-18% better in math and reading than those without.

• Students exposed to daylight attended school 3.2 to 3.8 more days per year.


High Performance Schools Fast Facts!


Source: World GBC
Meet our Presenters!

Theresa Pistochini
Engineering Manager | Western Cooling Efficiency Center
Energy and Efficiency Institute, UC Davis

Rengie Chan
Research Scientist
Lawrence Berkeley National Laboratory

Join us!
2018 Proposition 39 ZNE School Trainings

Workshops
Delivering The Winning Pitch: Making the Business Case for ZNE Schools
June 26, 9 AM-12 PM
East Bay AIA, Oakland, CA
Inefficiency is Old School: A Technical Deep Dive Into ZNE School Retrofits
October 30, 1-5 PM
Pasadena, CA

Webinars
More webinars scheduled for September 27, 2018 and November 29, 2018!
Check back for details at: https://newbuildings.org/proposition-39-trainings/
Additional Resources

- 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
- U.S. DOE Zero Energy School Accelerator: www.zeroenergy.org
Ensuring Proper Installation and Commissioning of HVAC Systems for Energy Efficiency and Indoor Air Quality

• Current research sponsored by the California Energy Commission's EPIC Program
• Partnership between University of California, Davis and Lawrence Berkeley National Laboratory

Agenda

• The Importance of Ventilation in Classrooms
• Ensuring Ventilation Compliance in HVAC Replacements
  • Title 24, Part 6 – California Energy Code
• Opportunities for carbon dioxide (CO₂) Sensing and Demand Control Ventilation Systems
The Importance of Ventilation in Classrooms

Building Ventilation

- Ventilation is the supply of outdoor air to a building
Why is building ventilation needed?

• Ensure comfort and satisfaction
  • Remove odor
  • Avoid stuffiness
• Maintain overall indoor air quality
  • Remove indoor air pollutants (e.g., formaldehyde emitted from building materials, furnishings)
• Support health and productivity of occupants

REVIEW

The ventilation problem in schools: literature review

W. J. Fisk ©

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Abstract
Based on a review of literature published in refereed archival journals, ventilation rates in classrooms often fall far short of the minimum ventilation rates specified in standards. There is compelling evidence, from both cross-sectional and intervention studies, of an association of increased student performance with increased ventilation rates. There is evidence that reduced respiratory health effects and reduced student absence are associated with increased ventilation rates. Increasing ventilation rates in schools imposes energy costs and can increase heating, ventilating, and air-conditioning system capital costs. The net annual costs, ranging from a few dollars to about 10 dollars per person, are less than 0.1% of typical public spending on elementary and secondary education in the United States. Such expenditures seem like a small price to pay given the evidence of health and performance benefits.

KEYWORDS
carbon dioxide, costs, health, performance, schools, ventilation
CO₂ Concentrations Measured in a Classroom

CO₂ data suggested this classroom does NOT have sufficient ventilation

CO₂ Concentrations Measured in Classrooms

- CO₂ data from research studies worldwide (including US) indicate a widespread failure to provide the minimum amount of ventilation specified in standards for classrooms.

Associations of Ventilation Rates with Student Performance

8 of 11 studies reported statistically significant (p<0.05) improvements in some measure(s) of student performance with increased ventilation rates or lower CO₂ concentrations.

5 studies measured students’ scores on standard academic achievement tests used by school districts to assess student performance.

6 studies used special tests by researchers to measure student performance.

Results on Student Performance from Intervention Studies

5 of 5 intervention* studies found statistically significant increases in some aspects of performance with increased ventilation rate.

Examples of special tests to measure student performance

- Speed and accuracy in number addition, multiplication
- Logical thinking
- Reading and comprehension

* Ventilation rates were increased, and changes in performance within students were measured.
An Intervention Study to Increase Ventilation Rates in 12 Elementary School Classrooms

- Ventilation rate increased from 1 L/s per person to 8 L/s per person using a custom-built system
- Average CO₂ reduced from 3,000 to 1,000 ppm
- Performance index measured students’ error-free reaction time using computerized tests


Associations of Ventilation Rates with Health Symptoms

8 of 11 studies report statistically significant (p<0.05) improvements in some health symptom(s) with increased ventilation rates.
- Questionnaires
- Measured signs of respiratory health (e.g., indicators of inflammation in nasal passages)

"research suggests improvements in measures of respiratory health with increased ventilation rates, but the evidence of improvement in health is not as compelling as the evidence of improvements in student performance."

Associations of Ventilation Rates with Student Illness Absence

4 of 5 studies report statistically significant (p<0.05) decreases in absence rates with more ventilation or lower CO₂ concentrations.

1 study followed 162 classrooms in California for 2 years, found a 1.6% decrease in absence for each 1 L/s (or 2 cfm) per person increase in ventilation rate.


Two-Year Study of Illness Absence in 162 California Elementary School Classrooms

- Study included 28 schools in three districts: South Coast, Bay Area, Central Valley
- Data collected on daily illness absence count, demographic data, and CO₂ levels
- Ventilation effects on long-term susceptibility to infections??

Economic Benefits of Bringing California Classroom Ventilation Rates

If Current Average of 4 L/s per person was raised to Meet Code Requirement of 7 L/s per person

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Costs</th>
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<td>$33 million increase in school district revenue</td>
<td>$6 million increase in energy cost</td>
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<tr>
<td>$80 million reduction in caregiver costs</td>
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Recommendation (1): Provide Adequate Ventilation

Fresh Air

Students more alert and focus; Fewer respiratory symptoms and illness absence

Students tired, loss of concentration; Increase respiratory symptoms and illness absence
Health Burden of PM$_{2.5}$

- USEPA estimated 130,000 PM$_{2.5}$-related deaths (4,700 ozone-related deaths) using risk coefficients from long-term American Cancer Society cohort study and National Mortality and Morbidity Air Pollution Study.

Recommendation (2): Use High Efficiency Air Filters

- Providing adequate outdoor air will increase student exposure to outdoor pollutants if adequate filtration is not provided.
- Substantial health benefits from reducing exposure to airborne particles (PM$_{2.5}$), especially if school is located near a busy roadway.

<table>
<thead>
<tr>
<th>Filter</th>
<th>CALGreen</th>
<th>Removal Efficiency</th>
<th>Cost</th>
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<tbody>
<tr>
<td>MERV 8</td>
<td>Tier 1</td>
<td>25%</td>
<td>$10</td>
</tr>
<tr>
<td>MERV 11</td>
<td>Tier 2</td>
<td>40%</td>
<td>$12</td>
</tr>
<tr>
<td>MERV 13</td>
<td>Tier 2</td>
<td>65%</td>
<td>$15</td>
</tr>
</tbody>
</table>
Ensuring Ventilation Compliance in HVAC Replacements

Single-zone HVAC Replacements

This presentation covers ventilation requirements for single-zone HVAC replacements, including wall-mount and roof-top-units (RTU) (majority of CA classrooms).
Ventilation Compliance

• California’s 2016 Building Energy Efficiency Standards (Title 24, Part 6) specifies ventilation requirements
• HVAC Replacements must comply
  • Even when replacements are “like-for-like”
  • Even when project is DSA exempt
    • School board assumes responsibility for exempt projects*


Do I really need to worry about this?

• YES! In our recent study of 104 California classrooms with single-zone HVAC replacements between 2013-2016, 65% of classrooms had elevated CO₂ levels, defined as average daily high CO₂ concentration above 1100 ppm

Example School from Recent UC Davis Study at 11 Schools combining CO₂ measurements with HVAC inspections

Colors indicate ventilation is:
- As required by Code
- Half of that required by Code
- Less than half of that required by Code
Steps for HVAC Replacement (and where ventilation goes wrong)

- **Design and Equipment Selection**
  - Equipment must be capable of providing ventilation rates for high occupant density classrooms

- **Installation**
  - Ventilation equipment must be installed correctly and accurately connected to control system

- **Commissioning and Acceptance Testing**
  - Ventilation system settings must be configured
  - Control system must be programmed correctly

- **Maintenance and Operation**
  - Filters must be changed regularly
  - Teachers need instruction on system operation

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Design/Equipment for Ventilation

- **Title 24, Part 6 (§141.0 and §120.1(b))**: Requires at least 15 cubic feet per minute (CFM) of outdoor air per expected occupant.

\[
\frac{30 \text{ occupants} \times 15 \text{ CFM}}{\text{occupant}} = 450 \text{ CFM}
\]
Ventilation Equipment Types

- Spring-based damper
- Fixed Inlet
- Motorized Damper

Motorized Damper with Economizer

Energy Recovery Ventilator
Control System Equipment Types

- **Title 24, Part 6 §120.1(c):** Requires minimum outdoor air rate when occupied and one hour before occupancy.
- Can be provided with local control (programmable thermostat) or Energy Management Control Systems (EMCS) to schedule ventilation system operation district wide.
- EMCS was very common in recent study (10 out of 11 schools).

Installation Considerations for Ventilation

- Ventilation Equipment must
  - Be installed, powered, and connected correctly to control system
  - Have the correct damper settings programmed
  - Have the correct thermostat or EMCS settings

School starts next week!
Commissioning and Acceptance Testing Ventilation

- Title 24, Part 6 §120.5(a) Required Nonresidential Mechanical System Acceptance
  - NA 7.5.1 Outdoor Air
  - NA 7.5.2 Constant-volume, single-zone, AC and HPs
  - Also: Duct leakage (<15%), Economizers, Demand Control Ventilation Systems

Highlights of acceptance testing
- **MEASURE** Outdoor air rate for each unit and confirm it’s within ±10% of design
- Confirm control system is programmed correctly
- Ventilation, heating, and cooling are all functioning
- Teachers know when heating or cooling is broken. Teachers perceptions of IAQ do not correlate to measured data. Teachers can not detect broken ventilation systems.
Demand Control Ventilation Systems

- Monitors and DISPLAYS CO₂ levels in the classroom. Ventilation problems are easy to detect.
- Control outdoor air damper to maintain CO₂ levels
  - Outdoor air rate based on classroom size always needed (150 CFM per 1000 ft²)
  - Up to design outdoor air rate (450 CFM)
  - Save energy ($$$) when ventilation is not needed
- Report CO₂ levels to EMCS

Comparison of CO₂ for classrooms with and without Demand Control Ventilation (DCV)

- Demand Control Ventilation (DCV) was very effective at managing CO₂ levels, and no hardware or control problems were identified in these installations
Maintenance/Filters

• Dirty filters reduce may airflow and ventilation rates and reduce system operating efficiencies

Educating Teachers

• One-third of teachers surveyed said that HVAC noise interfered with learning environment.
  • Consider fan noise ratings in HVAC purchases
  • Educate teachers on the importance of running the fan during occupied hours.
    • Report fans that are not running
    • Use the “override” outside of scheduled hours to provide ventilation, even when temperature is okay
  • UC Davis to create educational materials to share with teachers
Summary of Recommendations

• Equipment Selection
  • Select ventilation equipment appropriate for classrooms (MUST)
  • Consider EMCS system to manage system wide schedules (ensure fans are running, save energy)
  • Consider quieter fans (reduce noise for teachers)
  • Consider CO₂ sensing thermostats (detect ventilation problems)
  • Consider demand control ventilation systems (save energy)

• Installation/Commissioning
  • Ensure that contractor bids include acceptance testing*
  • Ensure that contractor performs the acceptance tests, and collect and review completed forms

• Maintenance/Operations
  • Educate teachers on necessity of fans running
  • Use MERV 13 filters and change them regularly

*https://www.cacx.org/resources/title24/PIER_T24_BidSheet.pdf

How do I check a previous installation?

• Request acceptance test reports from contractor (especially if your contract specified Title 24 compliance)
• Perform your own outdoor air measurements (flow hood)
• Spot check classroom CO₂ levels using inexpensive sensors ($200-$300 each).
  Log a classroom’s CO₂ concentration for a few days. “OK” classrooms should peak at less than 1100 PPM.
Questions?

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