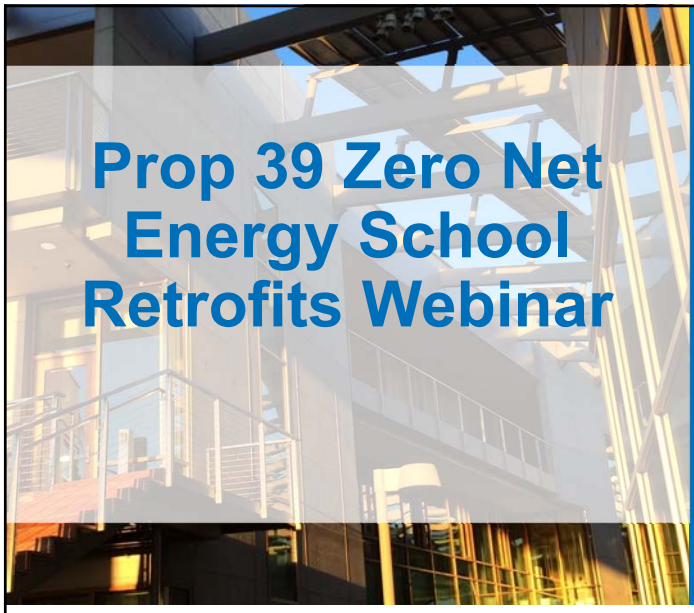

Prop 39 Zero Net Energy School Retrofits Webinar

Dreaming the Future: How Zero Net Energy Design Can Transform the School Environment

June 13, 2018

New Buildings Institute
Amy Cortese, Program Director
Reilly Loveland, Project Analyst

nbi new buildings institute | Pacific Gas and Electric Company | SDGE A Sempra Energy utility | Southern California Edison An Edison International Company | SoCalGas A Sempra Energy utility

Prop 39 ZNE School Retrofit Pilot Program Workshops

The Prop 39 ZNE Pilot Program s funded by California utility customers and administered by Pacific Gas and Electric Company, San Diego Gas & Electric Company, Southern California Edison Company, and Southern California Gas Company under the auspices of the California Public Utilities Commission. The California investor-owned utilities are not responsible for the preparation of this presentation, nor do any of them make any representation concerning the quality, accuracy or suitability of the information set forth herein. As the author of this presentation, the New Building Institute is solely responsible for this presentation and its contents.

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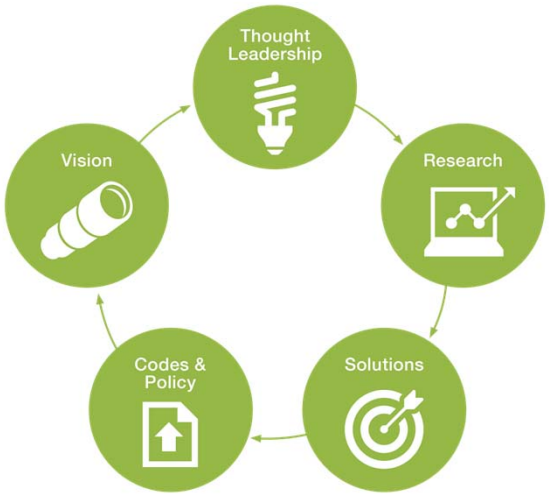
Redefining energy efficiency in the built environment

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.

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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

Sbrega Health & Science Building | Fall River, MA
Photo Courtesy of Edward Caruso

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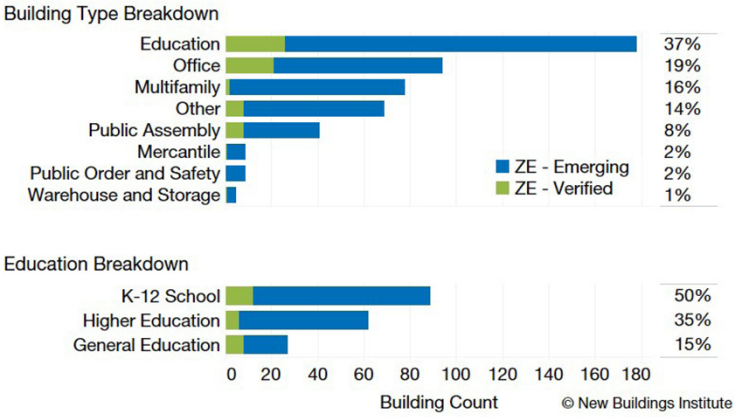
Schools are Leading in ZNE



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ZNE and Ultra-Low Energy in Education

K-12 Schools

Community Colleges

Higher Education

Libraries

Science Centers

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Steps to Success in Sustainable Design

Kathleen Grimm School, PS 62 | New York, NY
Photo Courtesy: James Ewing

- 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

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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.

Redding School for the Arts | Redding, CA
Photo Courtesy: TRILOGY Architecture

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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.

Discovery Elementary | Arlington. VA
Photo Courtesy: VMDO Architects

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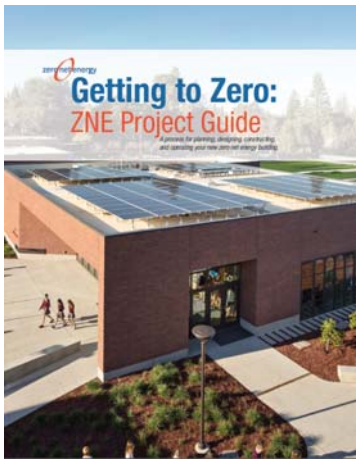
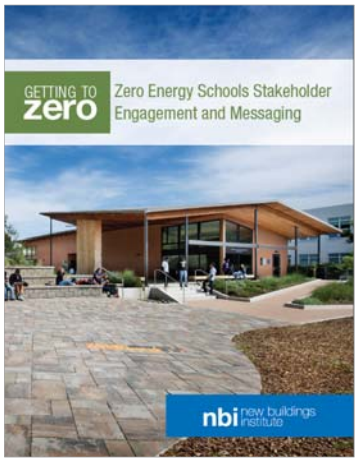
Tools for Zero Energy Schools





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NBI Prop 39 Retrofit Case Studies

COMMERCIAL

BUILDING TYPE: K-12 SCHOOL

LOS OSOS MIDDLE SCHOOL

LOS OSOS, CA

VIEW CASE STUDY

COMMERCIAL

BUILDING TYPE: K-12 SCHOOL

NEWCASTLE ELEMENTARY SCHOOL

NEWCASTLE, CA

VIEW CASE STUDY

COMMERCIAL

BUILDING TYPE: K-12 SCHOOL

GARDEN GROVE UNIFIED SCHOOL DISTRICT

GARDEN GROVE, CA

VIEW CASE STUDY

https://gettingtozeroforum.org/schools/

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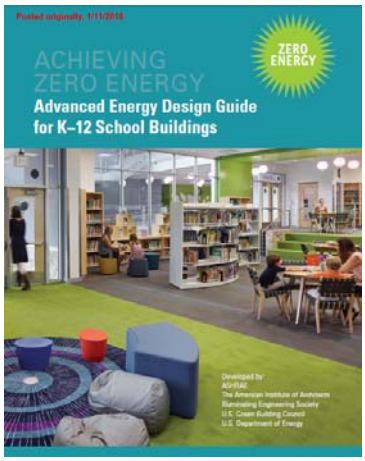
AEDG Zero Energy K-12 Schools Guide



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Getting to Zero Resources HUB

STATE POLICIES & PROGRAMS | SCHOOL & DISTRICT LEADERSHIP | RESEARCH & TOOLS

https://gettingtozeroforum.org/zero-energy-schools-resources/

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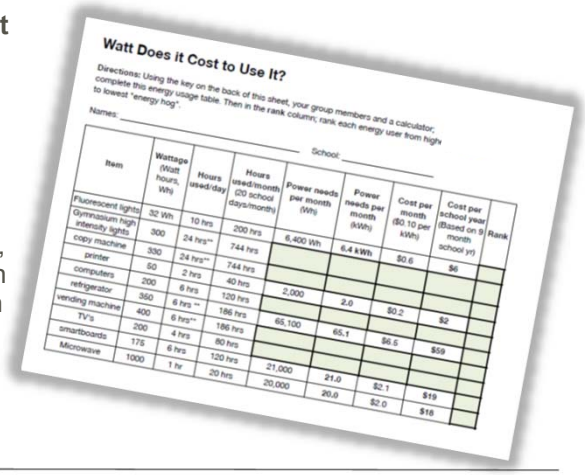
School buildings as a tool to enhance student learning

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**.



Watt Does it Cost to Use It?

Directions: Using the key on the back of this sheet, your group members and a calculator, complete this energy usage table. Then in the rank column, rank each energy user from high to lowest "energy hog".

Names: _____ School: _____

Item	Wattage (Watt hours, Wh)	Hours used/day	Hours used/month (20 school days/month)	Power needs per month (Wh)	Power needs per month (kWh)	Cost per month ($0.10 per kWh)	Cost per school year (Based on 9 month school yr)	Rank
Fluorescent lights	32 Wh	10 hrs	200 hrs	6,400 Wh	6.4 kWh	$0.6	$6	
Gymnasium high intensity lights	300	24 hrs**	744 hrs					
copy machine	330	24 hrs**	744 hrs					
printer	50	2 hrs	40 hrs	2,000	2.0	$0.2	$2	
computers	200	6 hrs	120 hrs					
refrigerator	350	6 hrs **	186 hrs	65,100	65.1	$6.5	$59	
vending machine	400	6 hrs**	186 hrs					
TV's	200	4 hrs	80 hrs	21,000	21.0	$2.1	$19	
smartboards	175	6 hrs	120 hrs	20,000	20.0	$2.0	$18	
Microwave	1000	1 hr	20 hrs					

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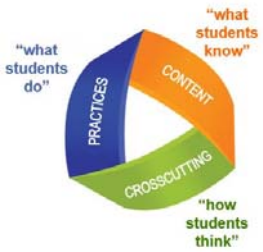
ZNE Supports Next Generation Science Standards & Skills

- **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!

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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%.[1]
- Students in daylit environments showed a 20-26% improvement on test scores compared to traditionally lit environments[2].
- Students with operable windows progressed 7-8% faster than those without operable windows[2].
- Students with the most daylighting performed 7-18% better in math and reading than those without[2].
- Students exposed to daylight attended school 3.2 to 3.810 more days per year[3]

Discovery Elementary School | Arlington, VA
Photo Courtesy of VMDO Architects

1. Bakó-Biró, Zs., Kochhar, N., Clements-Croome, D.J., Awbi, H.B. & Williams, M. (2007, January). Ventilation Rates in Schools and Learning Performance. https://www.researchgate.net/publication
2. Heshong Mahone Group. (1999, August 20). Daylighting in Schools: An Investigation into the Relationship Between Daylighting and Human Performance. http://h-m-g.com/downloads/Daylighting/schoolc.pdf
3. Healthy Schools Network, Inc. (2012) Daylighting. http://www.healthyschools.org/downloads/Daylighting.pdf

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High Performance Schools Fast Facts!

Did you know that the classroom environment can affect a child's academic progress over a year by as much as **25%**[1]

65% Reduction in asthma cases among elementary students when school indoor environment quality improves.[2]

3% Reduction in teacher turnover in green schools - saving US$4 per square foot over a 20 year period.[3]

20% Faster progression in math in schools with good daylighting.[4]

26% Faster progression in reading in schools with good daylighting.[4]

10% Increase in overall performance in schools with good daylighting.[4]

Source: World GBC

1. Barett, P., Zhang, Y., Moffat, J., & Kobbacy, K. (2012, October 03). A holistic, multi-level analysis identifying the impact of classroom design on pupils' learning.
2. Meng, Y., Babey, S. H., & Wolstein, J. (2012). Asthma-Related School Absenteeism and School Concentration of Low-Income Students in California.
3. Katz, G. (2006). Greening America's Schools: Costs and Benefits.
4. Heschong Mahone Group. (1999). Daylighting in Schools: An Investigation into the Relationship Between Daylighting and Human Performance.

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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

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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/

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Additional 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
- **U.S. DOE Zero Energy School Accelerator:** www.zeroenergy.org
- **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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Thank You!

New Buildings Institute
Reilly Loveland, Project Analyst, reilly@newbuildings.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**





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Agenda

- The Importance of Ventilation in Classrooms
- Ensuring Ventilation Compliance in HVAC Replacements
  - *Title 24, Part 6 – California Energy Code*
- Opportunities for carbon dioxide (CO_2) Sensing and Demand Control Ventilation Systems

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The Importance of Ventilation in Classrooms

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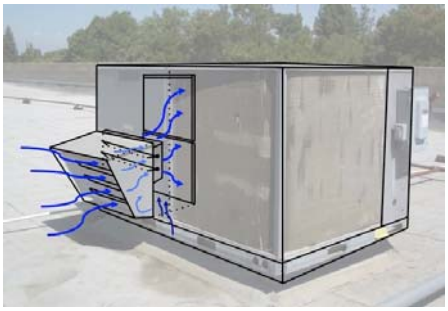
Building Ventilation

- Ventilation is the supply of outdoor air to a building



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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

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REVIEW

WILEY

The ventilation problem in schools: literature review

W. J. Fisk

Indoor Environment Group, Lawrence Berkeley National Laboratory, Berkeley, CA, USA

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First published: 6 July 2017
https://doi.org/10.1111/ina.12403

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

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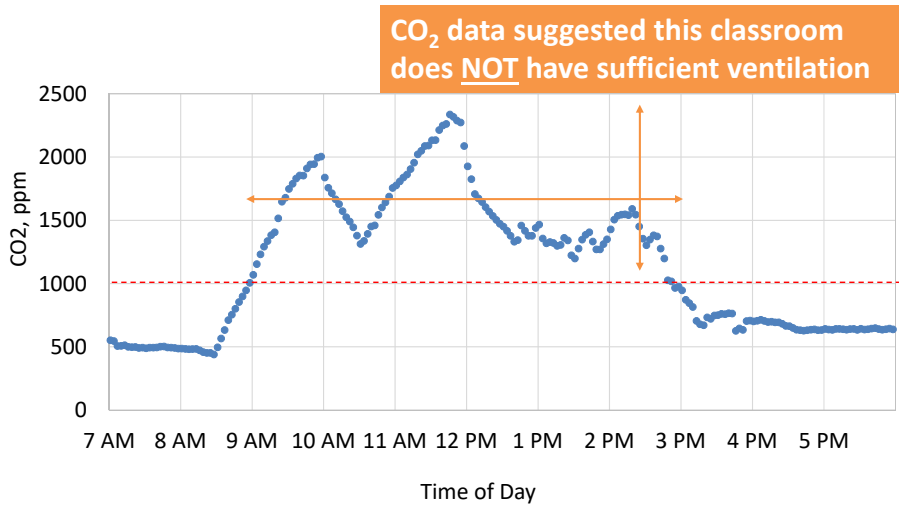
CO_2 Concentrations Measured in a Classroom



CO_2 Concentrations Measured in Classrooms

- CO_2 data from research studies worldwide (including US) indicate a widespread failure to provide the minimum amount of ventilation specified in standards for classrooms.

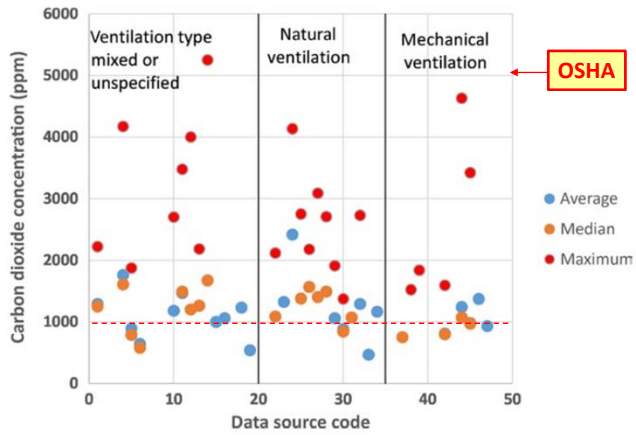


FIGURE 2 Time-average carbon dioxide concentrations in classrooms

Fisk (2017) Indoor Air, 27(6): 1039–1051.

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 CO_2 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.

Fisk (2017) Indoor Air, 27(6): 1039–1051.

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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.

Fisk (2017) Indoor Air, 27(6): 1039–1051.

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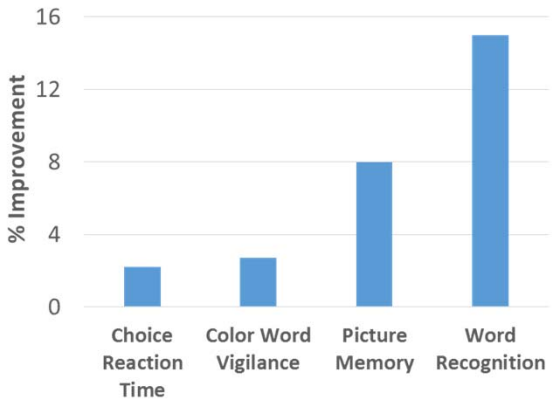
An Intervention Study to Increase Ventilation Rates in 12 Elementary School Classrooms

- Ventilation rate increased from 1 L/s per person to 8 L/s per person using a custom-built system
- Average CO_2 reduced from 3,000 to 1,000 ppm
- Performance index measured students' error-free reaction time using computerized tests



Bako-Biro et al. (2012) Build Environ., 48: 215–223.

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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."

Fisk (2017) Indoor Air, 27(6): 1039–1051.

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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 CO_2 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.

Fisk (2017) Indoor Air, 27(6): 1039–1051.

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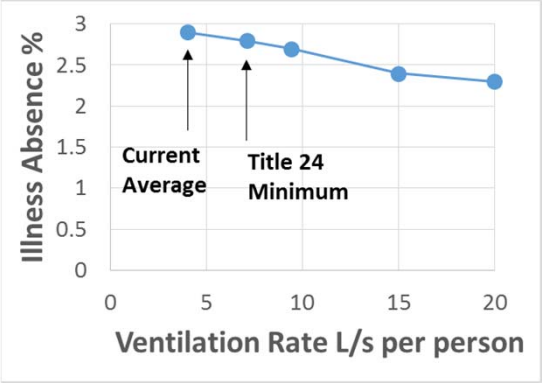
Two-Year Study of Illness Absence in 162 California Elementary School Classrooms

- Study included 28 schools in three districts: South Coast, Bay Area, Central Valley
- Data collected on daily illness absence count, demographic data, and CO_2 levels
- Ventilation effects on long-term susceptibility to infections???



Mendell et al. (2016) Indoor Air, 26: 546–557.

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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

Benefits *Costs*

$33 million increase in school district revenue

$80 million reduction in care-giver costs

$$$$$ $$$$$ $$$$$ $$$

$ **$6 million** increase in energy cost

Mendell et al. (2016) Indoor Air, 26: 546–557.

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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***

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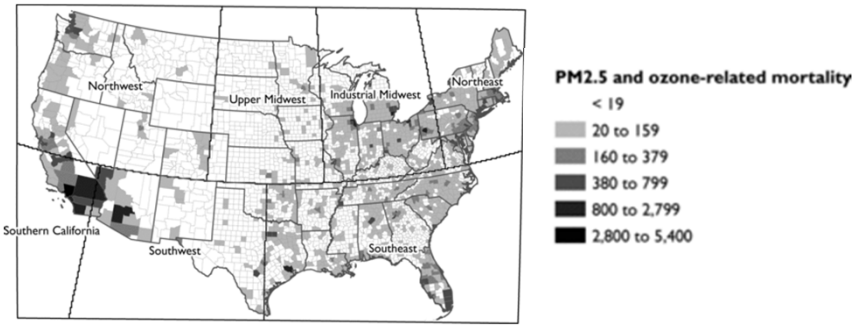
Health Burden of $PM_{2.5}$

- 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



PM2.5 and ozone-related excess mortalities estimated at county level.

Fann et al. (2012) Risk Analysis, 32: 81–95.

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.

MERV 8	MERV 11	MERV 13
• CALGreen Mandatory • 25% removal efficiency • $10 each	• CALGreen Tier 1 • 40% removal efficiency • $12 each	• CALGreen Tier 2 • 65% removal efficiency • $15 each

Ensuring Ventilation Compliance in HVAC Replacements

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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).

Roof Top Units (RTU)

Vertical Wall Mount Units
(“Bard” Units)

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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*

DSA PR 14-02

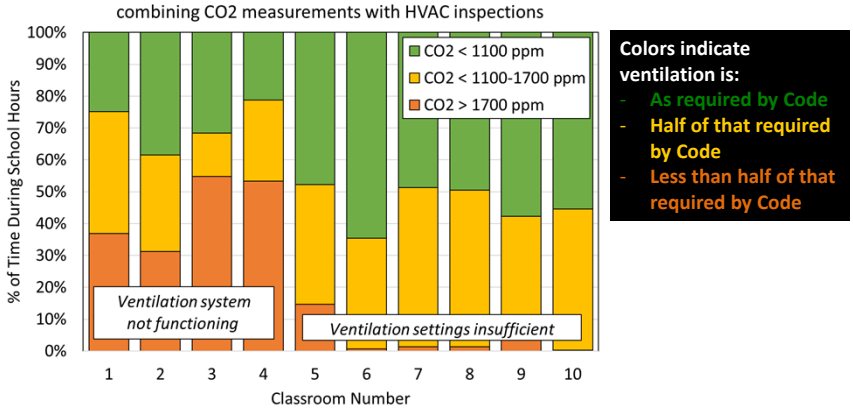
PROCEDURE: EXEMPT CONCURRENCE

*https://www.documents.dgs.ca.gov/dsa/pubs/PR_14-02.pdf

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 CO_2 levels**, defined as average daily high CO_2 concentration above 1100 ppm

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



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 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.

$$30\ occupants\ x\ 15\ \frac{CFM}{occupant} = 450\ CFM$$

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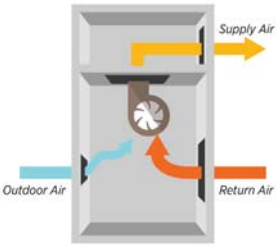
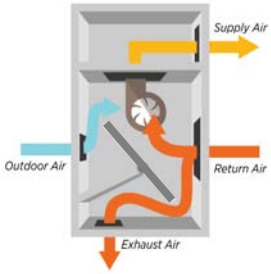
Ventilation Equipment Types

Spring-based damper

Fixed Inlet

Motorized Damper





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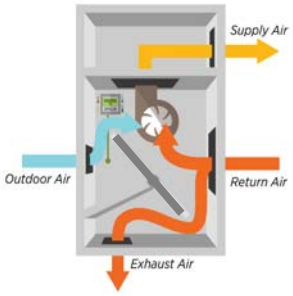
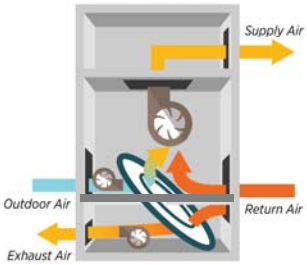
Ventilation Equipment Types

Motorized Damper with Economizer

Energy Recovery Ventilator





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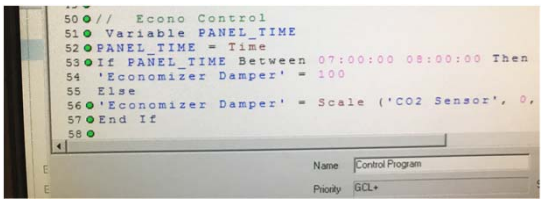
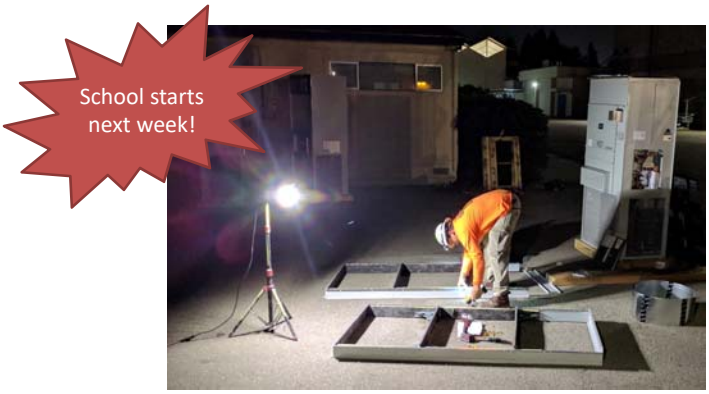
Control System Equipment Types

- **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

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**

STATE OF CALIFORNIA
OUTDOOR AIR ACCEPTANCE
CEC-NRCA-MCH-02-A (Revised 07/16)

CERTIFICATE OF ACCEPTANCE	
Outdoor Air Acceptance	
Project Name:	Enforceme
Project Address:	City:
System Name or Identification/Tag:	System Lo

Note: Submit one Certificate of Acceptance for each system that must demonstrate compliance.

STATE OF CALIFORNIA
CONSTANT VOLUME, SINGLE ZONE, UNITARY AIR CONDITIONER AND HEAT PUMP SYSTEMS
CEC-NRCA-MCH-03-A (Revised 07/16)

CERTIFICATE OF ACCEPTANCE	
Constant Volume, Single Zone, Unitary (Packaged and Split) Air Co	
Project Name:	Enforcement A
Project Address:	City:
System Name or Identification/Tag:	System Locatio

Note: Submit one Certificate of Acceptance for each system that must demonstrate compliance.

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Commissioning and Acceptance Testing Ventilation

- 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.

Flow capture hood to measure outdoor air rate

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Demand Control Ventilation Systems

- Monitors and DISPLAYS $C0_2$ levels in the classroom. Ventilation problems are easy to detect.
- Control outdoor air damper to maintain CO_2 levels
  - Outdoor air rate based on classroom size always needed (150 CFM per 1000 ft^2)
  - Up to design outdoor air rate (450 CFM)
  - Save energy ($$$) when ventilation is not needed
- Report CO_2 levels to EMCS

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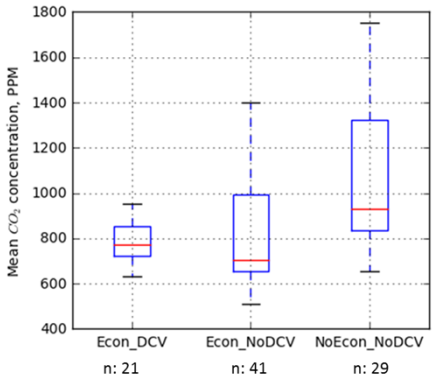
Comparison of CO_2 for classrooms with and without Demand Control Ventilation (DCV)



- Demand Control Ventilation (DCV) was very effective at managing CO_2 levels, and no hardware or control problems were identified in these installations

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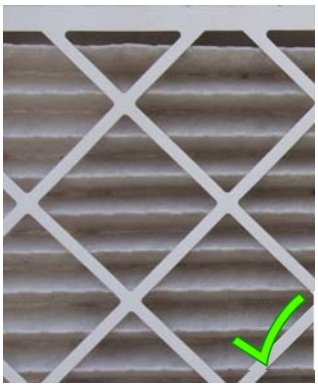
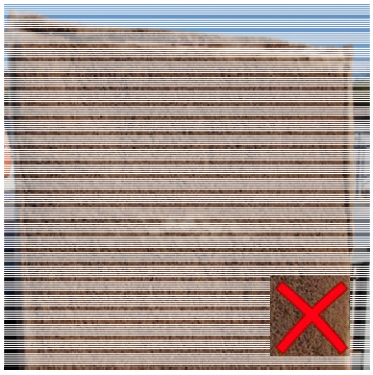
Maintenance/Filters

- 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 CO_2 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

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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 $C0_2$ levels using inexpensive sensors ($200-$300 each). Log a classroom's CO_2 concentration for a few days. "OK" classrooms should peak at less than 1100 PPM.

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  Title24@energy.ca.gov

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