Ventilation Verification Fundamentals

Jeremy Zeedyk (NEMIC)– Representative / Northeast Region

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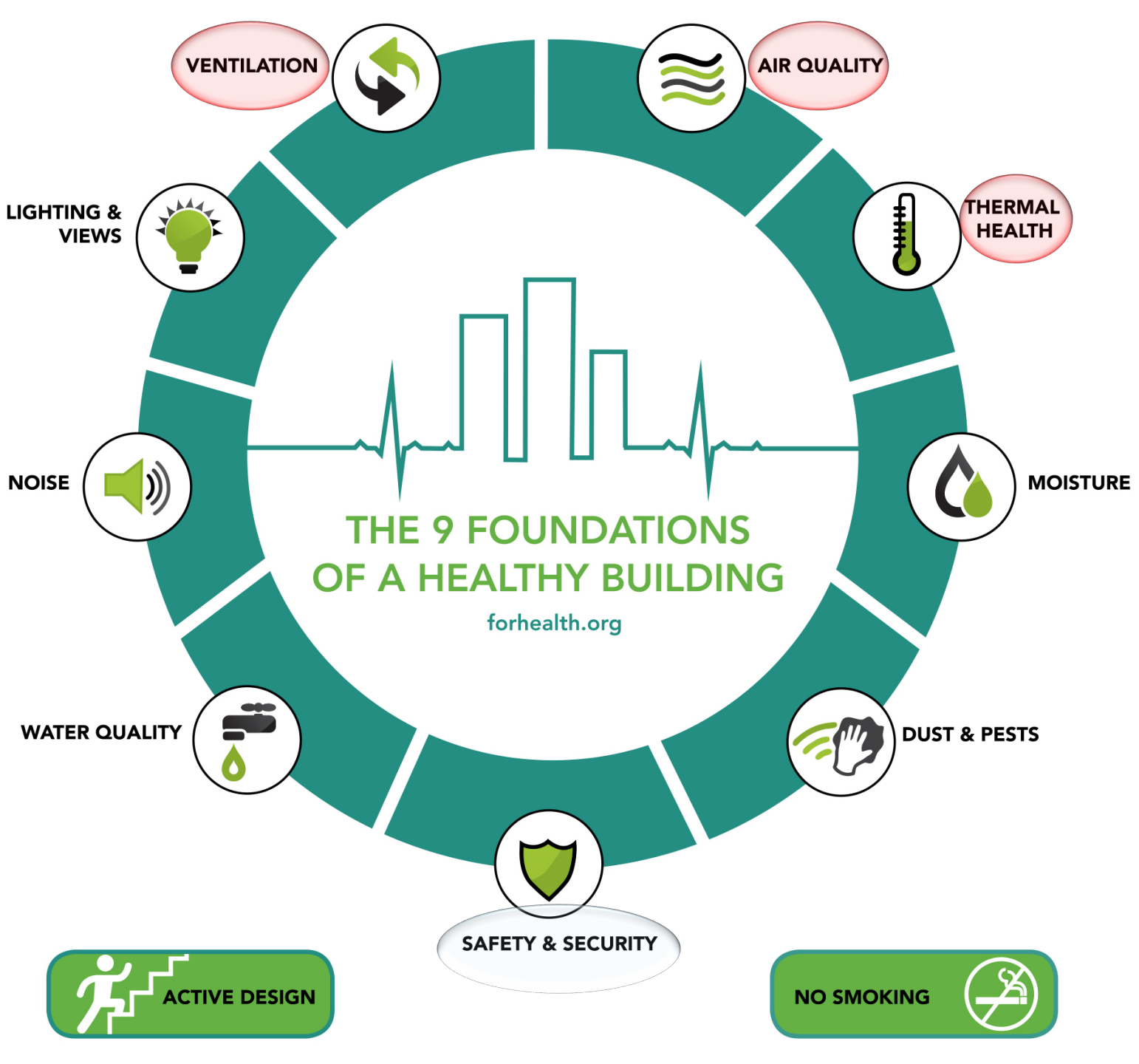

Source: forhealth.org
https://9foundations.forhealth.org/

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ASHRAE Core Recommendations

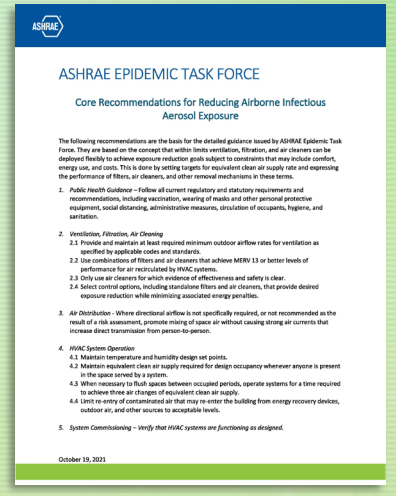
1. **Public Health Guidance** – Follow all current regulatory and statutory requirements and recommendations

2. **Ventilation, Filtration, Air Cleaning**

3. **Air Distribution**

4. **HVAC System Operation**

5. **System Commissioning** – Verify that HVAC systems are functioning as designed.



ASHRAE EPIDEMIC TASK FORCE

Core Recommendations for Reducing Airborne Infectious Aerosol Exposure

The following recommendations are the basis for the detailed guidance issued by ASHRAE Epidemic Task Force. They are based on the concept that within limits ventilation, filtration, and air cleaners can be deployed flexibly to achieve exposure reduction goals subject to constraints that may include comfort, energy use, and costs. This is done by setting targets for equivalent clean air supply rate and expressing the performance of filters, air cleaners, and other removal mechanisms in these terms.

1. *Public Health Guidance* – Follow all current regulatory and statutory requirements and recommendations, including vaccination, wearing of masks and other personal protective equipment, social distancing, administrative measures, circulation of occupants, hygiene, and sanitation.

2. *Ventilation, Filtration, Air Cleaning*
   - 2.1 Provide and maintain at least required minimum outdoor airflow rates for ventilation as specified by applicable codes and standards.
   - 2.2 Use combinations of filters and air cleaners that achieve MERV 13 or better levels of performance for air recirculated by HVAC systems.
   - 2.3 Only use air cleaners for which evidence of effectiveness and safety is clear.
   - 2.4 Select control options, including standalone filters and air cleaners, that provide desired exposure reduction while minimizing associated energy penalties.

3. *Air Distribution* – Where directional airflow is not specifically required, or not recommended as the result of a risk assessment, promote mixing of space air without causing strong air currents that increase direct transmission from person-to-person.

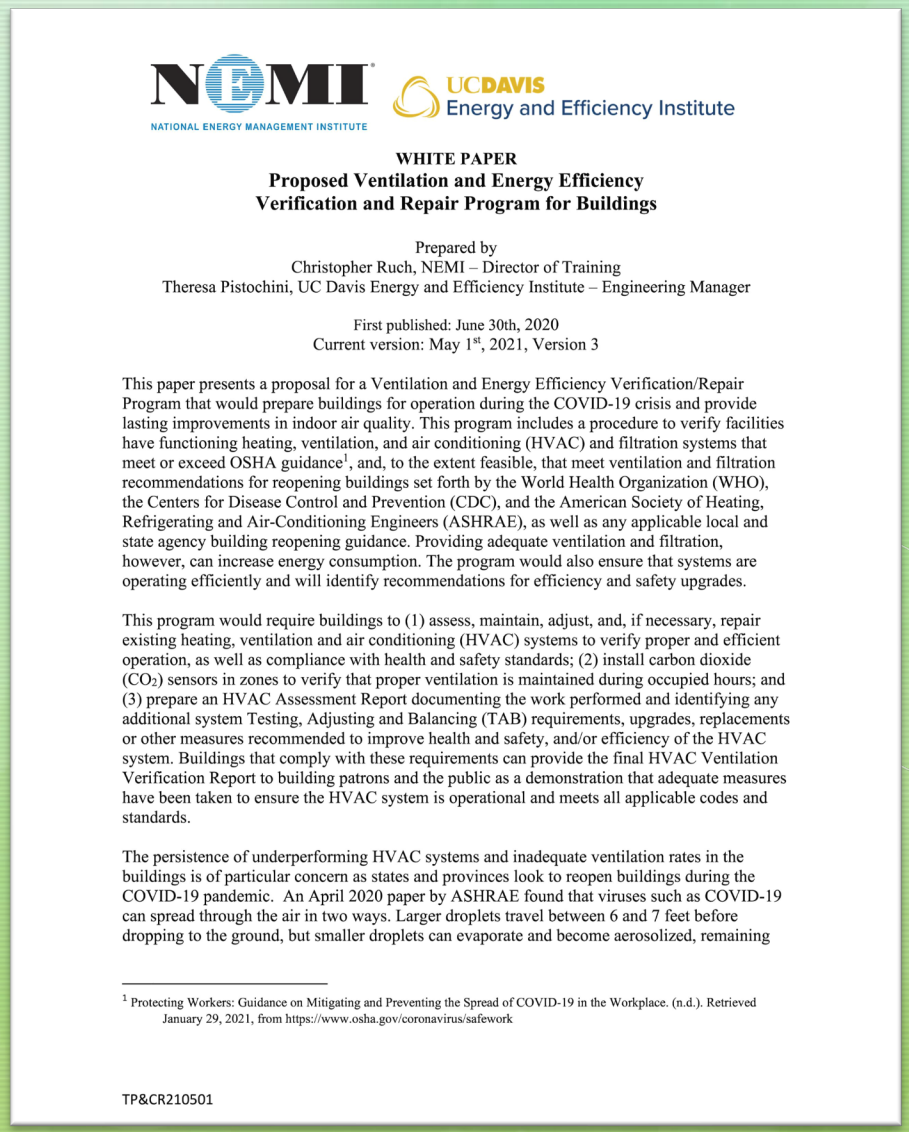
4. *HVAC System Operation*
   - 4.1 Maintain temperature and humidity design set points.
   - 4.2 Maintain equivalent clean air supply required for design occupancy whenever anyone is present in the space served by a system.
   - 4.3 When necessary to flush spaces between occupied periods, operate systems for a time required to achieve three air changes of equivalent clean air supply.
   - 4.4 Limit re-entry of contaminated air that may re-enter the building from energy recovery devices, outdoor air, and other sources to acceptable levels.

5. *System Commissioning – Verify that HVAC systems are functioning as designed.*

October 19, 2021

ASHRAE Epidemic Task Force - Core Recommendations for Reducing Airborne Infectious Aerosol Exposure. 19 Oct. 2021, https://www.ashrae.org/file%20library/technical%20resources/covid-19/core-recommendations-for-reducing-airborne-infectious-aerosol-exposure.pdf .

Ventilation Verification & Energy Optimization White Paper



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WHITE PAPER
Proposed Ventilation and Energy Efficiency Verification and Repair Program for Buildings

Prepared by
Christopher Ruch, NEMI – Director of Training
Theresa Pistochini, UC Davis Energy and Efficiency Institute – Engineering Manager

First published: June 30th, 2020
Current version: May 1st, 2021, Version 3

This paper presents a proposal for a Ventilation and Energy Efficiency Verification/Repair Program that would prepare buildings for operation during the COVID-19 crisis and provide lasting improvements in indoor air quality. This program includes a procedure to verify facilities have functioning heating, ventilation, and air conditioning (HVAC) and filtration systems that meet or exceed OSHA guidance[1], and, to the extent feasible, that meet ventilation and filtration recommendations for reopening buildings set forth by the World Health Organization (WHO), the Centers for Disease Control and Prevention (CDC), and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), as well as any applicable local and state agency building reopening guidance. Providing adequate ventilation and filtration, however, can increase energy consumption. The program would also ensure that systems are operating efficiently and will identify recommendations for efficiency and safety upgrades.

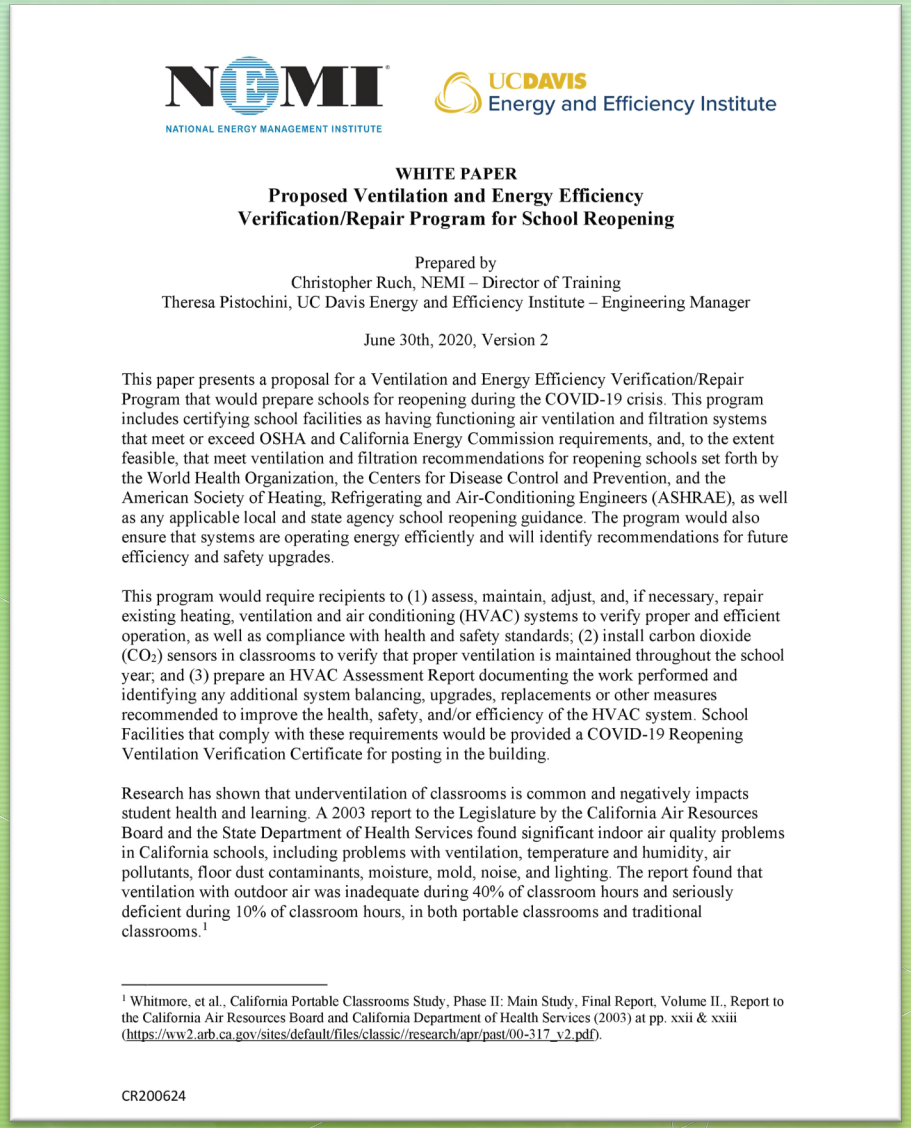
This program would require buildings to (1) assess, maintain, adjust, and, if necessary, repair existing heating, ventilation and air conditioning (HVAC) systems to verify proper and efficient operation, as well as compliance with health and safety standards; (2) install carbon dioxide (CO_2) sensors in zones to verify that proper ventilation is maintained during occupied hours; and (3) prepare an HVAC Assessment Report documenting the work performed and identifying any additional system Testing, Adjusting and Balancing (TAB) requirements, upgrades, replacements or other measures recommended to improve health and safety, and/or efficiency of the HVAC system. Buildings that comply with these requirements can provide the final HVAC Ventilation Verification Report to building patrons and the public as a demonstration that adequate measures have been taken to ensure the HVAC system is operational and meets all applicable codes and standards.

The persistence of underperforming HVAC systems and inadequate ventilation rates in the buildings is of particular concern as states and provinces look to reopen buildings during the COVID-19 pandemic. An April 2020 paper by ASHRAE found that viruses such as COVID-19 can spread through the air in two ways. Larger droplets travel between 6 and 7 feet before dropping to the ground, but smaller droplets can evaporate and become aerosolized, remaining

[1] Protecting Workers: Guidance on Mitigating and Preventing the Spread of COVID-19 in the Workplace. (n.d.). Retrieved January 29, 2021, from https://www.osha.gov/coronavirus/safework

TP&CR210501

https://www.nemionline.org/ProposedVentilationProgramforBuildings



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WHITE PAPER
Proposed Ventilation and Energy Efficiency Verification/Repair Program for School Reopening

Prepared by
Christopher Ruch, NEMI – Director of Training
Theresa Pistochini, UC Davis Energy and Efficiency Institute – Engineering Manager

June 30th, 2020, Version 2

This paper presents a proposal for a Ventilation and Energy Efficiency Verification/Repair Program that would prepare schools for reopening during the COVID-19 crisis. This program includes certifying school facilities as having functioning air ventilation and filtration systems that meet or exceed OSHA and California Energy Commission requirements, and, to the extent feasible, that meet ventilation and filtration recommendations for reopening schools set forth by the World Health Organization, the Centers for Disease Control and Prevention, and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), as well as any applicable local and state agency school reopening guidance. The program would also ensure that systems are operating energy efficiently and will identify recommendations for future efficiency and safety upgrades.

This program would require recipients to (1) assess, maintain, adjust, and, if necessary, repair existing heating, ventilation and air conditioning (HVAC) systems to verify proper and efficient operation, as well as compliance with health and safety standards; (2) install carbon dioxide (CO_2) sensors in classrooms to verify that proper ventilation is maintained throughout the school year; and (3) prepare an HVAC Assessment Report documenting the work performed and identifying any additional system balancing, upgrades, replacements or other measures recommended to improve the health, safety, and/or efficiency of the HVAC system. School Facilities that comply with these requirements would be provided a COVID-19 Reopening Ventilation Verification Certificate for posting in the building.

Research has shown that underventilation of classrooms is common and negatively impacts student health and learning. A 2003 report to the Legislature by the California Air Resources Board and the State Department of Health Services found significant indoor air quality problems in California schools, including problems with ventilation, temperature and humidity, air pollutants, floor dust contaminants, moisture, mold, noise, and lighting. The report found that ventilation with outdoor air was inadequate during 40% of classroom hours and seriously deficient during 10% of classroom hours, in both portable classrooms and traditional classrooms.[1]

[1] Whitmore, et al., California Portable Classrooms Study, Phase II: Main Study, Final Report, Volume II., Report to the California Air Resources Board and California Department of Health Services (2003) at pp. xxii & xxiii (https://ww2.arb.ca.gov/sites/default/files/classic//research/apr/past/00-317_v2.pdf).

CR200624

https://ucdavis.app.box.com/v/ProposedVentilationProgramforSchools

Educational Facility Opportunity
Existing Infrastructure

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- ✓ **53%** of public-school districts report the need to update or replace multiple building systems, including HVAC systems (1)
- ✓ Government Accountability Office (GAO) estimates that **41%** of school districts need to update or replace the HVAC systems in **at least half** of their schools. (2)

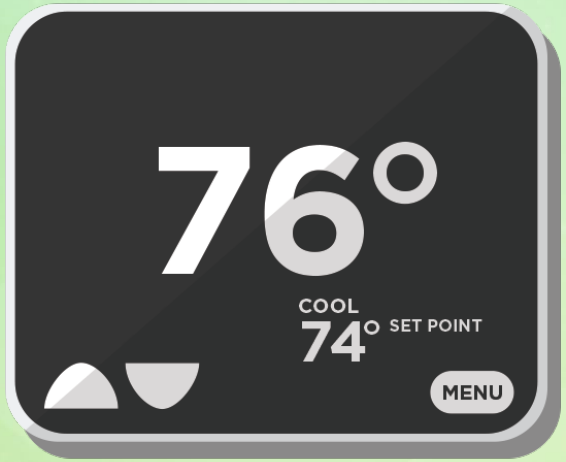
(1) Schools. ASCE's 2021 Infrastructure Report Card |. (2021, March 25). Retrieved May 8, 2022, from https://infrastructurereportcard.org/cat-item/schools/

(2) K-12 Education School Districts Frequently Identified Multiple Building Systems Needing Updates or Replacement (Rep. No. GAO-20-494). (June 4th, 2020). United States Government Accountability Office. https://www.gao.gov/assets/710/707374.pdf

Educational Benefits

Adequate Ventilation and Thermal Health

- ✓ **A study of 70 elementary schools in southwestern US showed schools with proper indoor temperatures and higher ventilation rates resulted in 13–14% higher percentage of students scoring satisfactory in the mathematics and reading tests compared to schools with higher temperatures and lower ventilation rates.(1)**



(1) U. Haverinen-Shaughnessy, R.J. Shaughnessy, E.C. Cole, O. Toyinbo, D. J. Moschandreas, An assessment of indoor environmental quality in schools and its association with health and performance, Build. Environ. 93 (2015) 35–40. https://www.semanticscholar.org/paper/An-assessment-of-indoor-environmental-quality-in-Haverinen-Shaughnessy-Shaughnessy/d8ce5901edcd7401e118bf43d4bce436a77cb82e

WILDFIRE IAQ CONCERNS

STANFORD CENTER FOR INNOVATION AND GLOBAL HEALTH

- **"Every year, about 7.4 million children across the United States are affected by wildfire smoke."**

- **"Wildfire smoke contains fine, inhalable particles called PM2.5, as well as dangerous levels heavy metals and other toxins. It may be as much as 10 times more dangerous for kids than other forms of air pollution."**

- **"Wildfire smoke can increase emergency room visits for asthma and upper respiratory infections in kids. It can also reduce immune function, lead to cardiovascular and lung diseases later in life, and create long-term cancer risks."**

- **"Since air pollution levels are also associated with reduced school performance, improving schools' air quality doesn't just help protect kids' health – it also safeguards their learning."**

Stanford Center for Innovation in Global Health. "Wildfires and Health." *Global Health*, 21 July 2022, https://globalhealth.stanford.edu/planetary-health/wildfires-and-health.html/.

Wildfire IAQ Solutions

Stanford Center for Innovation and Global Health

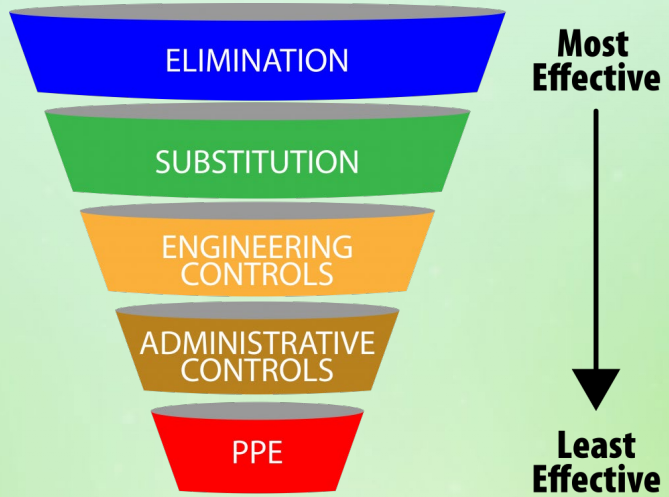
- **Measure your Indoor Air Quality**
- **Conduct baseline assessment**
- **Improve HVAC Systems**

Stanford Center for Innovation in Global Health. “Wildfires and Health.” *Global Health*, 21 July 2022, https://globalhealth.stanford.edu/planetary-health/wildfires-and-health.html/.

ASTHMA CONCERNS

EPA – MANAGING ASTHMA IN THE SCHOOL ENVIRONMENT

Provide a safe and healthy school environment to reduce asthma triggers.



Hierarchy of Controls

IAQ is only one component of effective asthma management

- Administrative Controls - Education and awareness programs for students and school staff.
- Elimination - Reduce individual sources (*dust, mold, pests, smoke*)

Poor Indoor Air Quality can trigger or exacerbate Asthma Symptoms.

- Action Plan to develop an Indoor Air Quality program to identify, solve, and prevent IAQ problems.

(1) EPA, Environmental Protection Agency, https://www.epa.gov/iaq-schools/managing-asthma-school-environment.
(2) Centers for Disease Control and Prevention. (2022, August 11). Hierarchy of controls. Centers for Disease Control and Prevention. Retrieved September 17, 2022, from https://www.cdc.gov/niosh/topics/hierarchy/default.html

Ventilation Verification and Energy Optimization Process

HVAC Assessment Report Template

Section 1: Overview

Section 2: Filtration

Section 3: Ventilation Rate

Section 4: Economizer Operation

Section 5: DCV Operation

Section 6: Air Distribution and Building Controls

Section 7: General Maintenance

Section 8: Operational Controls

Section 9: CO_2 Monitoring

Section 10: Limited or No Existing Mechanical Ventilation

Source: UC Davis WCEC

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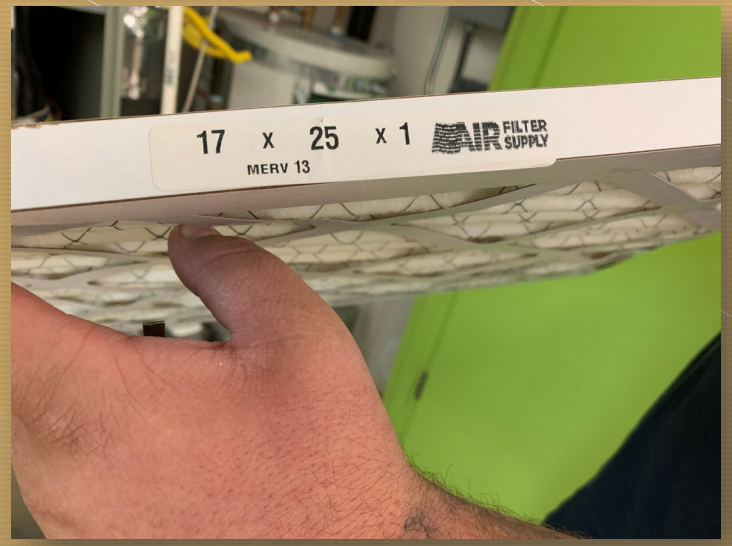
Filtration

- Verify filters are installed correctly and replace if needed.
- Apply the highest Minimum Efficiency Reporting Value (MERV) applicable for the HVAC units considering airflow and conditioning capabilities. MERV 13 or better is recommended.



Filtration – Field Results

- *"A review of manufacturer specifications of existing filters and of available MERV-13 filters found that almost all buildings had options to upgrade with similar or even lower initial pressure drops." [1]*
  - *Only one of the 95 buildings were mechanically unable to upgrade to MERV 13*

- *MERV 13 filters typically cost more and will need to be replaced more often. However, MERV 13 filters provide the highest infection risk reduction at the lowest cost of all filtration levels and various ventilation rates.[2]*

(1) McNulty, M. K., Kono, J., & Abramson, B. (2022 ASHRAE Winter Conference). From Guidance to Implementation: Applying ASHRAE Epidemic Task Force Building Readiness Strategies in 95 Commercial Office Buildings. https://www.thefreelibrary.com/_/print/PrintArticle.aspx?id=713048616

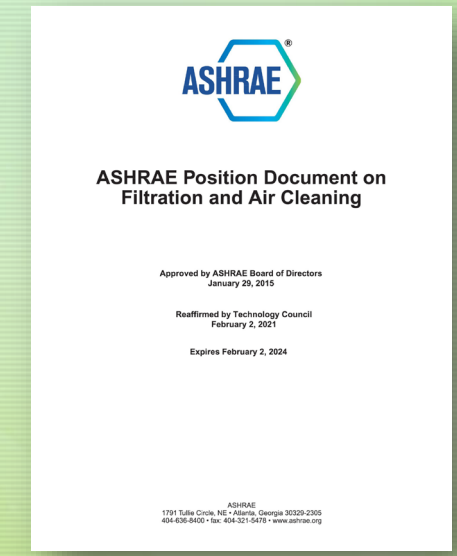
(2) Azimi P, Stephens B, 2013. HVAC filtration for controlling infectious airborne disease transmission in indoor environments: Predicting risk reductions and operational costs. Build Environ. 2013(70):150-160. doi:10.1016/j.buildenv.2013.08.025 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7127325/

Portable Air Cleaners

Air cleaners installed within the space as stand-alone component (generally portable, plugged in) separate from the central air system.

May Contain:

- High Efficiency Particulate Air (HEPA) filter media
- Ultraviolet Germicidal Irradiation (UVGI)
- Emerging Technology such as Ionizers **
- ASHRAE Position Document on Filtration and Air Cleaning
  - Reaffirmed February 2nd, 2021
- Convincing scientifically rigorous, peer-reviewed studies do not currently exist on this emerging technology; manufacturer data should be carefully considered.



ASHRAE . (2021). *ASHRAE Position Document on Filtration and Air Cleaning - Developed by the Society's Filtration and Air Cleaning Position Document Committee* . https://www.ashrae.org/file%20library/about/position%20documents/filtration-and-air-cleaning-pd-feb.2.2021.pdf

Case Study – Portable Classroom Level Air Cleaning

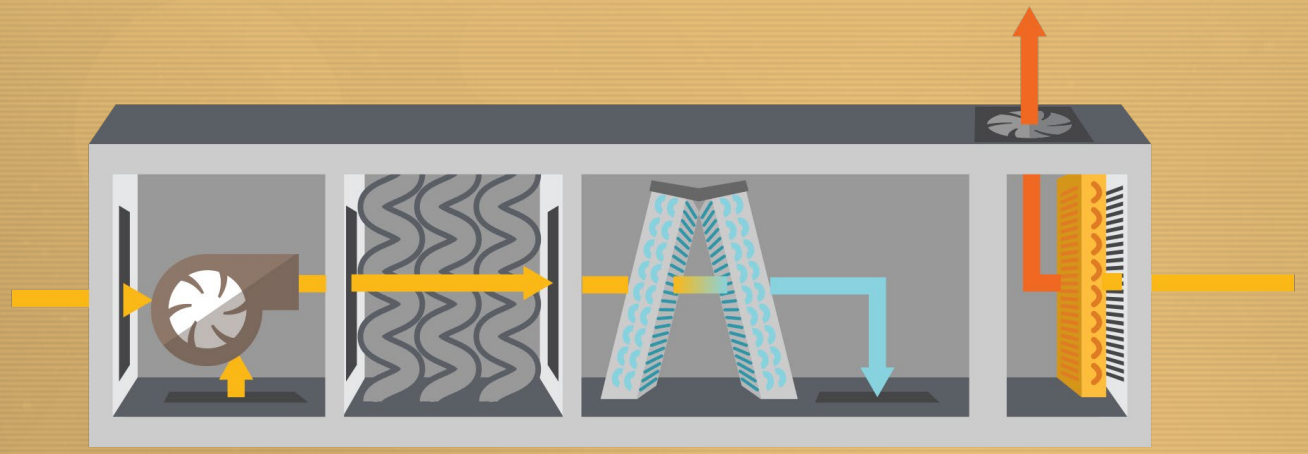
- According to Sacramento Bee (Article 1/24/21)[1]
- Local Sacramento City Unified School District paid over $6 million for classroom air cleaners at $688 per device.
- District was under the impression at the time of purchase the units could purify the space for up to 1000 sq ft
- Actual Clean Air Delivery Rate (CADR) showed the units would be sufficient for 130 sq ft.
- That would mean the district would need 8 devices per 1000 sq feet, not 1
- The school district had begun removing the devices. (Article 2/5/21)[2]

(1) Yoon-Hendricks, A. (2021, January 24). Sac City schools paid $6 million for costly air cleaners with unnecessary features. Sacramento Bee www.sacbee.com/news/local/article248431190.html

(2) Yoon-Hendricks, A. (2021, February 5). Sacramento Schools remove controversial air cleaners after experts, teachers raise concerns. Sacramento Bee. www.sacbee.com/news/local/article248965569.html

Ventilation

- Minimum Outside Air
- Can Outside Air be increased?
- Exhaust airflow



Source: UC Davis WCEC

Health Benefits

- ✓ **CDC study of 3,000 individuals across 40 buildings found that 57% of sickness can be attributed to poor ventilation. (1)**
- ✓ **Adequately sized Mechanical Ventilation with air changes of 6 or more has the ability to reduce Sars-COV-2 infection risk by over 80%. (2)**

(1) Allen, Joseph and Macomber, John. “What Makes an Office Building “Healthy””. Harvard Business Review. April 2020. https://hbr.org/2020/04/what-makes-an-office-building-healthy
(2) Marche Region Italy. (n.d.). Controlled Mechanical Ventilation (CMV) works. https://www.fondazionehume.it/data-analysis/controlled-mechanical-ventilation-cmv-works/

Ventilation – Minimum Ventilation

Sample requirement for a 900 square foot classroom

Standard	Method	15 People	25 People	35 People
ASHRAE 62.1 2022	$10\ CFM/person + 0.12\ CFM/ft^2$	258 CFM	358 CFM	458 CFM

CFM = Cubic Feet per Minute

American Society of Heating, Refrigerating and Air-Conditioning Engineers. (2022). Ventilation for acceptable indoor air quality: ASHRAE Standard 62.1 - 2022. https://ashrae.iwrapper.com/ASHRAE_PREVIEW_ONLY_STANDARDS/STD_62.1_2022

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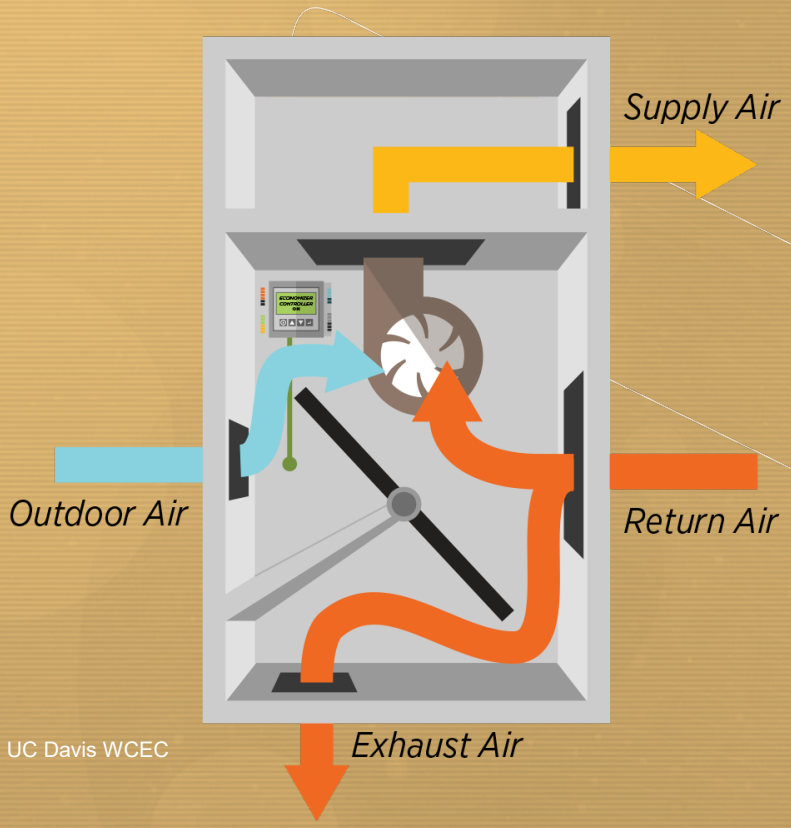
Ventilation – Field Results

- ***Only 44% of the buildings were in compliance with the minimum adequate ventilation rate as defined by ASHRAE 62.1***
- ***33% of the buildings were initially under ventilated but could be adjusted by a skilled, trained, and certified technician.***
- ***23% of the buildings were initially under ventilated but required mechanical improvements to achieve the minimum adequate ventilation rate.***

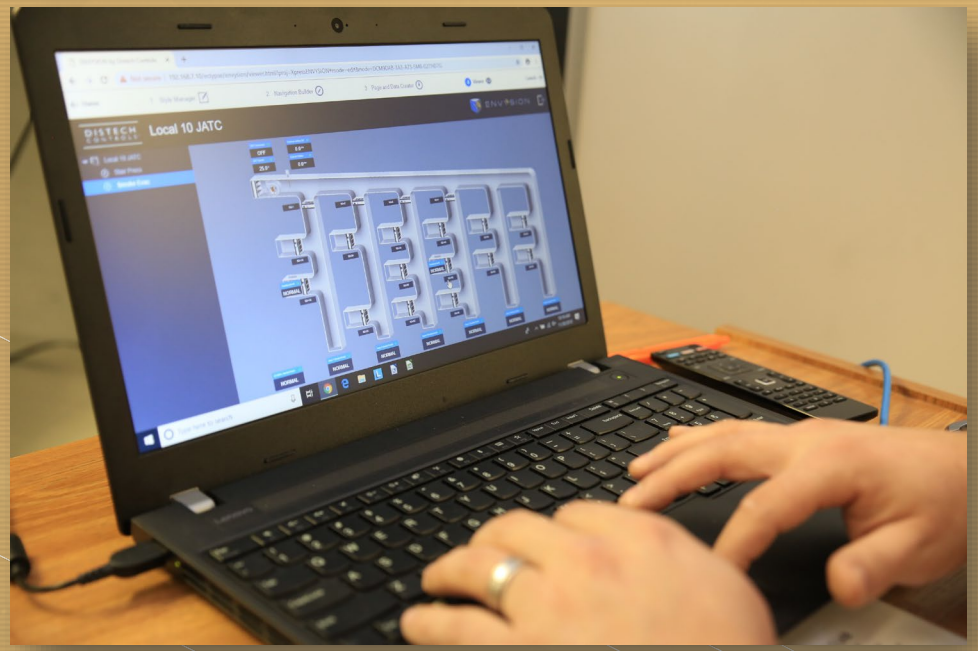
McNulty, M. K., Kono, J., & Abramson, B. (2022 ASHRAE Winter Conference). From Guidance to Implementation: Applying ASHRAE Epidemic Task Force Building Readiness Strategies in 95 Commercial Office Buildings. https://www.thefreelibrary.com/_/print/PrintArticle.aspx?id=713048616

Economizer/DCV Operation

Operational Controls



Source: UC Davis WCEC



Energy Benefits

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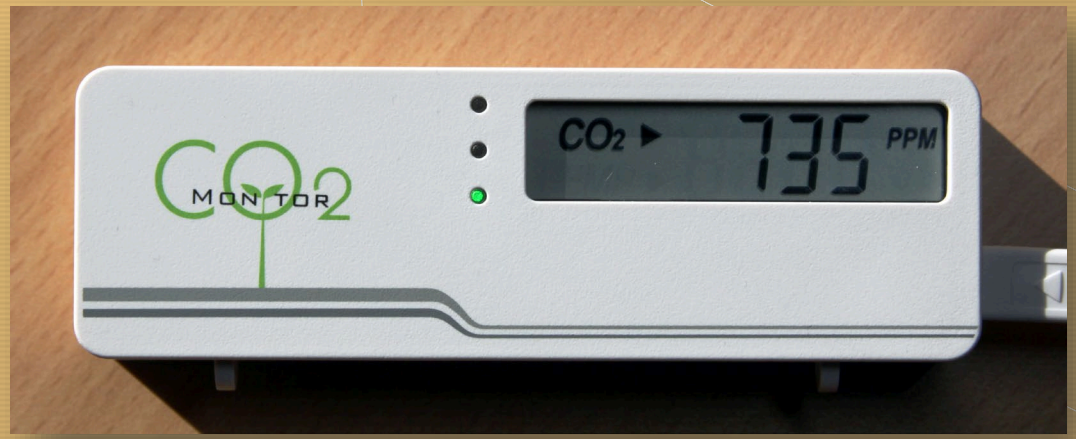
- ✓ **Buildings account for about 40% of total US energy use. (1)**
  - **35%+ of the US energy is used to operate buildings Heating, Ventilation, and Air Conditioning (HVAC). (2)**
  - **Compared to 11% for lighting**
  - **Ductwork**
    - **Estimates of Efficiency Reductions caused by improper ductwork installations range from 10 to 40 %.**

(1) U.S. Energy Information Administration May 14th 2019, How much energy is consumed in U.S. residential and commercial buildings?, https://www.eia.gov/tools/faqs/faq.php?id=86&t=1
(2) Department of Energy September 2015, An Assessment of Energy Technologies and Research Opportunities, Ch.5: Increasing Efficiency of Building Systems and Technologies, https://www.energy.gov/sites/prod/files/2017/03/f34/qtr-2015-chapter5.pdf

Airflow & Pressure

- Ensure airflow patterns are measured, verified, and documented to provide maximize distribution and mixing but minimize occupant exposure to particles.
- Room pressure differentials and directional airflow help control airflow between zones.

CO_2 Monitoring



Section 9 – CO_2 Monitoring

Ventilation Verification and Energy Optimization Assessment

☐	**Verify installation or install a CO_2 monitor.** • All classrooms shall be equipped with a CO_2 monitor. • General Buildings – At least one CO2 monitor shall per installed in each zone of the building (where a zone is defined by an area of the building with temperature controlled by a thermostat). The number of CO2 monitor must also meet or exceed at least one CO_2 monitor per 10,000 square feet of occupied floor space. **CO_2 monitors shall**:
☐	Be hard-wired or plugged-in and mounted to the wall between 3 – 6 feet above the floor and at least 5 feet away from the door and operable windows.
☐	Display the CO_2 readings to the occupants through a display on the device or other means such as a web-based application or cell-phone application.
☐	Notify the building operator through visual indicator on the monitor (e.g. indicator light) or other alert such as e-mail, text, or cell phone application, when the CO2 levels have exceeded 1,100 ppm.
☐	Maintain a record of previous data which includes at least the maximum CO2 concentration measured.
☐	Have a range of 400 ppm to 2000 ppm or greater;
☐	Be certified by the manufacturer to be accurate within 75 ppm at 1,000 ppm CO2 concentration and is certified by the manufacturer to require calibration no more frequently than once every five years.

Y/N	**Is a CO_2 monitor installed that meets the required features listed above?**	
☐	If installed but lacking required features, what features are missing?	
☐	If installed, document CO_2 monitor nameplate data.	
Manufacturer:		Model:
Serial:		
☐	Include relevant photographic documentation	

Educational Benefits

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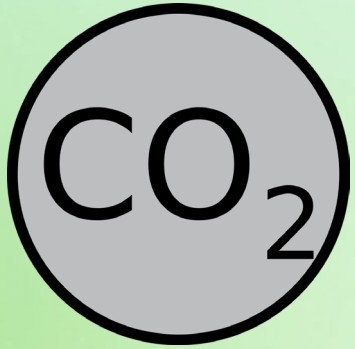
- ✓ 8 studies reported statistically **significant improvements** in some measures of **student performance** associated with increased ventilation rates or lower CO2 concentrations, with performance increases up to **15%.** (1)



(1) Fisk, W. J., The ventilation problem in schools: literature review, Indoor Air. 2017;27:1039–1051 https://onlinelibrary.wiley.com/doi/epdf/10.1111/ina.12403

Limited or No Existing Mechanical Ventilation

Source: UC DAVIS WCES

Section 10 – Limited or No Existing Mechanical Ventilation

Ventilation Verification and Energy Optimization Assessment

Collect and document existing HVAC infrastructure to assist the Design Professional in determining ventilation options.	
☐	**Existing HVAC Infrastructure –** Verify the functionality and document nameplate data on any existing HVAC equipment (i.e., heating only units, exhaust fans, etc.)
☐	Verify and document the location of windows and doors that can be opened. • Verify if windows have any switches or controls that initiate exhaust fans, motorized dampers or other devices that operate to provide free cooling.
☐	Verification or installation of the CO^2 sensor as detailed in Section 9.
☐	**Collection the following information, in addition to any information requested by a design professional to evaluate options for adding mechanical ventilation.** ☐ Verify existing mechanical, architectural, structural drawings match current conditions. ☐ Provide a sketch of actual roof penetrations, penetration type (i.e., vent pipe) and approximate locations if different from drawings. ☐ Document locations of any vents could contaminate Outside Air (OSA) intake locations. ☐ Photograph existing building, existing mechanical equipment (if applicable) and potential locations for mechanical ventilation equipment. ☐ Document roof and wall type/material to the best of the technician's ability. ☐ Document if existing mechanical equipment can be altered to provide outside air (OSA) or if a Dedicated Outside Air System (DOAS) is required. ☐ Obtain information on central plant capacity (if applicable) ☐ Document whether outside air conditions may make reliance on windows or other sources of non-filtered outside air potentially hazardous to occupants. ☐ Document recommendations for adding mechanical ventilation and filtration where none currently exists or for replacing a mechanical ventilation system where the current system is non-operational or is unable to provide recommended levels of ventilation and filtration.
☐	Include relevant screenshots and photographic documentation. • Include existing building and potential locations for mechanical ventilation equipment.

Mechanical Engineer
Ventilation and Energy Evaluation

Upon completion of the **HVAC Assessment Report**, a Mechanical Engineer shall review and determine if adjustments, repairs, or upgrades can be made to the HVAC system to increase energy efficiency, filtration, disinfection and ventilation.

Repairs, Adjustments, and Upgrades

If installed HVAC systems or system components are broken, fail to meet minimum ventilation requirements, or are unable to operate to the original design and intent, corrective work must be completed.

- Upgrades, as determined by the licensed professional, to increase ventilation, filtration, disinfection, or increase energy efficiency.
- All work completed by **Skilled, Trained, and Certified Workforce**.

Workforce Standards

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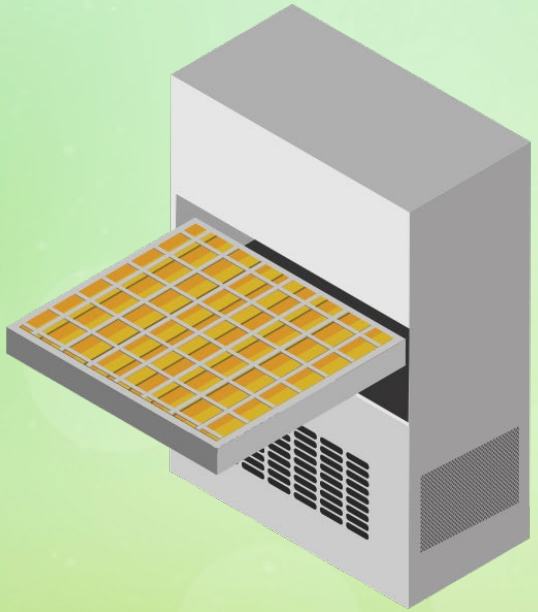
- ✓ **Poor Quality Installation Is Pervasive.** **A Study By The California Energy Commission Found That Over 50% Of New HVAC Systems And 85% Of Replacement HVAC Systems That They Evaluated Were Not Performing Correctly Due To Poor Quality Installation.** (1)(2)



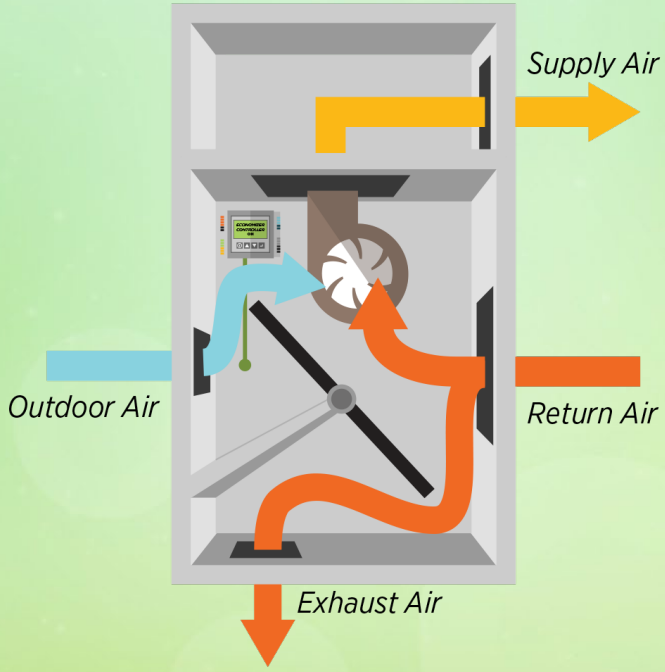
UC Davis WCEC

(1) California Energy Commission, *Strategic Plan to Reduce the Energy Impact of Air Conditioners* (June 2008), CEC-400-2008-010, at p. (v) (https://docplayer.net/6285926-Staff-report-strategic-plan-to-reduce-the-energy-impact-of-air-conditioners-california-energy-commission-june-2008-cec-400-2008-010.html);

(2) Zabin, et. al, Workforce Issues and Energy Efficiency Programs: A Plan for California's Utilities, Don Vial Center for Employment in the Green Economy (2014), at pp. 32-34 and Appendix 2B (http://laborcenter.berkeley.edu/workforce-issues-and-energy-efficiency-programs-a-plan-for-californias-utilities/).

Workforce Standards

- ✓ **2019 Report by UC Davis and Lawrence Berkely National Labs reviewed HVAC system replaced within the last 3 years.** [1]
  - **Only around 15% of the classrooms had a median Ventilation rate of 15 CFM per person**



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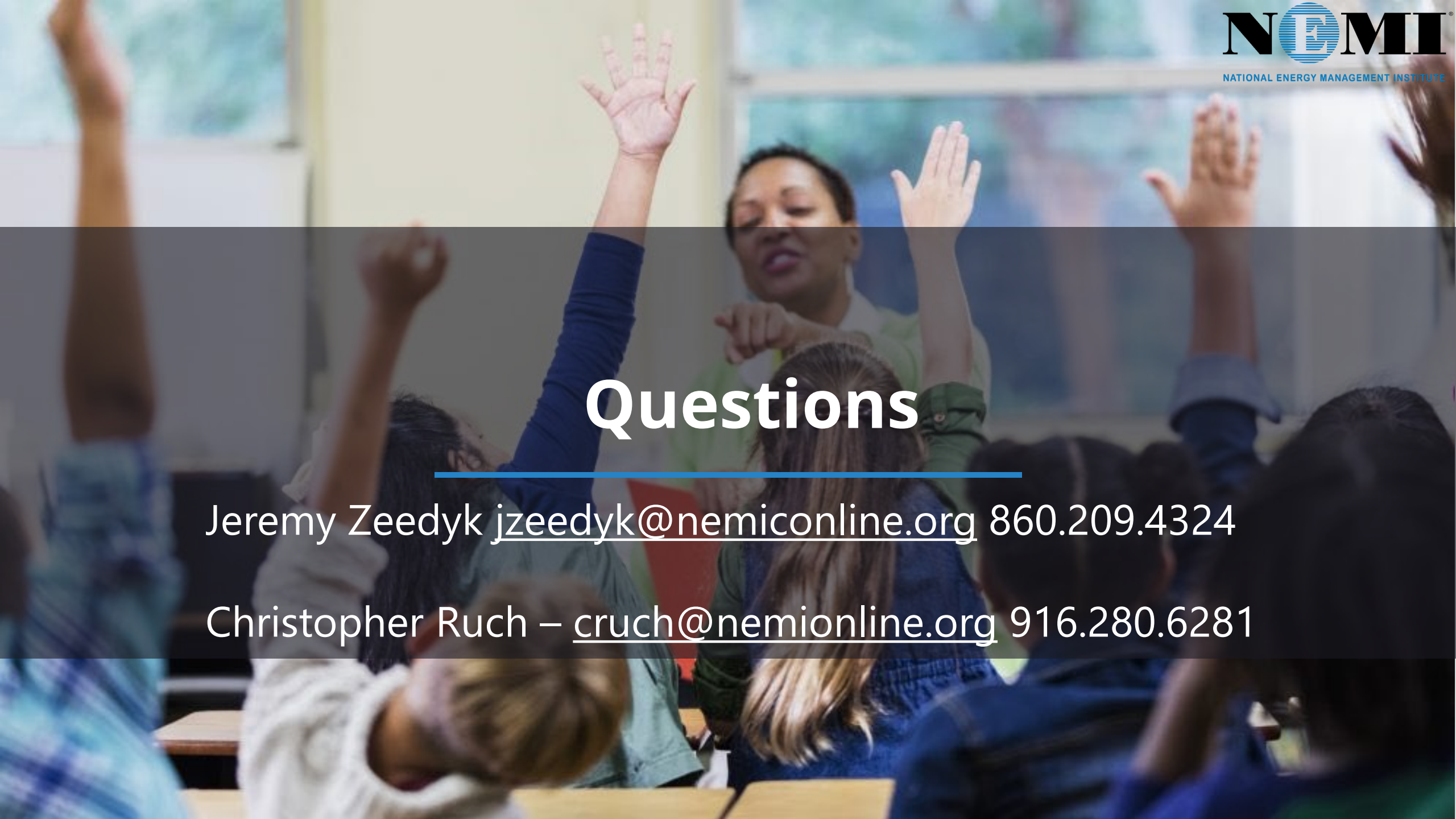
(1) Chan, et al, Ventilation rates in California classrooms: Why many recent HVAC retrofits are not delivering sufficient ventilation, Building and Environment Journal 167 (2020) (https://www.sciencedirect.com/science/article/pii/S0360132319306365).



Questions

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