Series Overview

SERIES:
School Indoor Air Quality Fact Sheets

This overview introduces the series and provides important background information.

School Indoor Air Quality Basics

In recent years, the COVID-19 pandemic and increased wildfire smoke events have heightened awareness around the critical need to improve indoor air quality (IAQ) in schools. Children are particularly vulnerable to poor IAQ due to their developing respiratory systems, higher respiratory rates relative to their body weight, and less efficient nasal filtering for larger particles during exercise.

Despite challenges such as limited funding, high occupant densities, aging infrastructure, and staffing shortages, schools can implement a range of practical and scalable IAQ improvement strategies.

Indoor Air Quality Standards and Targets

While there is no nationally adopted IAQ performance standard, trusted organizations such as the CDC, the EPA, and ASHRAE issue guidance that addresses IAQ. The CDC recommends aiming for at least 5 equivalent air changes per hour (eACH) to reduce airborne viral particles. ASHRAE is a globally recognized organization known for establishing standards for building design and operation. The three ASHRAE documents most relevant to school IAQ are Standard 62.1, Standard 241, and Guideline 44.

ASHRAE Standard 62.1 Ventilation and Acceptable Indoor Air Quality

ASHRAE Standard 62.1 establishes minimum targets for outdoor air and filtered/clean airflow in schools, for the purpose of achieving acceptable IAQ. These ventilation targets serve as a foundation that schools should aim to meet or exceed.

The minimum outdoor ventilation rate for classrooms is ~15 cfm/person. Requirements for offices (~17 cfm/person), cafeterias (~9 cfm/person), and gyms (~46 cfm/person) vary based on occupancy and activity levels.

ASHRAE Standard 241 Control of Infectious Aerosols

ASHRAE Standard 241 introduces an Infection Risk Management Mode (IRMM) designed for schools to implement during periods of elevated infection risk, such as pandemics (e.g., COVID-19) or seasonal endemics like influenza. New, occupancy-based clean airflow targets for the control of infectious aerosols are established.

For infection risk management, the minimum clean airflow rate for a classroom is 40 cfm/person. In offices (30 cfm/person), cafeterias (60 cfm/person), and gyms (80 cfm/person), target clean airflow rates depend on occupancy and activity.

ASHRAE Guideline 44 Protecting Building Occupants From Smoke During Wildfire and Prescribed Burn Events

Guideline 44 recommends measures to minimize the impact of outdoor smoke on IAQ. It provides procedures for schools to follow during wildfire or prescribed burn smoke events, including recommendations for the building envelope, ventilation, and air cleaning systems. See the **Indoor Air Quality During Wildfires Fact Sheet** for more information on Guideline 44.

Center for Green Schools at the U.S. Green Building Council

ASHRAE

Benefits of improving indoor air quality in schools include:

1. Reduced incidence of respiratory illnesses (including asthma and influenza) and associated absenteeism.
2. Reduced stale air and odors, as well as prevention of headaches and drowsiness.
3. Improved cognitive function and better learning outcomes.

Indoor Air Quality Best Practices

ASHRAE, the CDC, and the EPA recommend the following strategies for improving IAQ in schools:

- Ventilate spaces per minimum standards (ASHRAE Standard 62.1)
- Clean recirculated air using in-duct, high-efficiency filters
- Use air cleaners (HEPA or germicidal ultraviolet (GUV)) where needed to further minimize exposure while considering energy impacts
- Use only air cleaners for which evidence of safety is clear

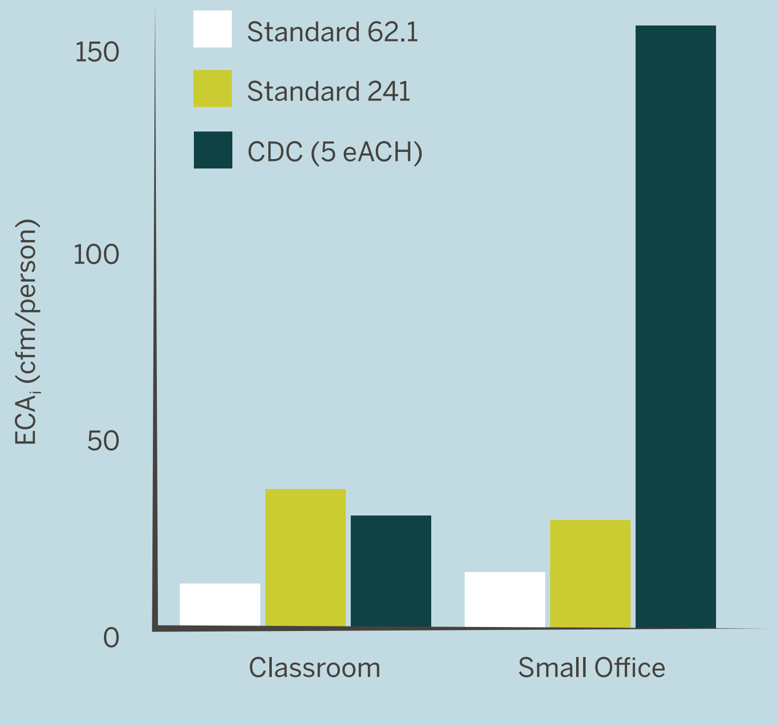
Learn more about implementing best practices for ventilation, HVAC filtration, air cleaners, and IAQ monitoring throughout this series.

Strategies proven to be safe include "subtractive" technologies, such as filters and sorbent media.

Strategies that may inadvertently result in harmful chemical exposures include "additive" technologies, such as some electronic air cleaners and fumigation, that add substances to the air to remove particles, inactivate microorganisms, or react with chemical contaminants.

Indoor Air Quality and Energy Use

While equivalent clean airflow (ECA_i) and equivalent air changes per hour (eACH) targets are similar when considering classrooms in IRMM, for other spaces in a school, goals vary considerably. Setting ventilation rate targets based on occupancy (per ASHRAE) vs. room volume (per the CDC) can result in substantial energy savings in particularly small and large school spaces (e.g., small school offices, gyms, and cafeterias). For example, the 5 eACH recommended by the CDC in a small school office equates to around 150 cfm/person,* which is much greater than the recommended 30 cfm/person established by Standard 241 to control for airborne illnesses.



*eACH has been converted to units of cfm/person assuming typical classroom (9,000 ft.[3]) and small school office (900 ft.[3]) dimensions and default occupant densities from ASHRAE Standard 62.1 (25 people per 1000 ft.[2] and 5 people per 1000 ft.[2], respectively).

Reaching Your Clean Airflow Goal

Compliance with IAQ standards is determined by combining the contributions of all ventilation and air cleaning strategies implemented and comparing the total to established targets.

Equivalent Clean Airflow (ECA_i)

ECA_i targets are based on airflow rates from all mitigation strategies and the **number of occupants in a space, regardless of room size.** ECA_i is a metric specific to ASHRAE Standard 241.

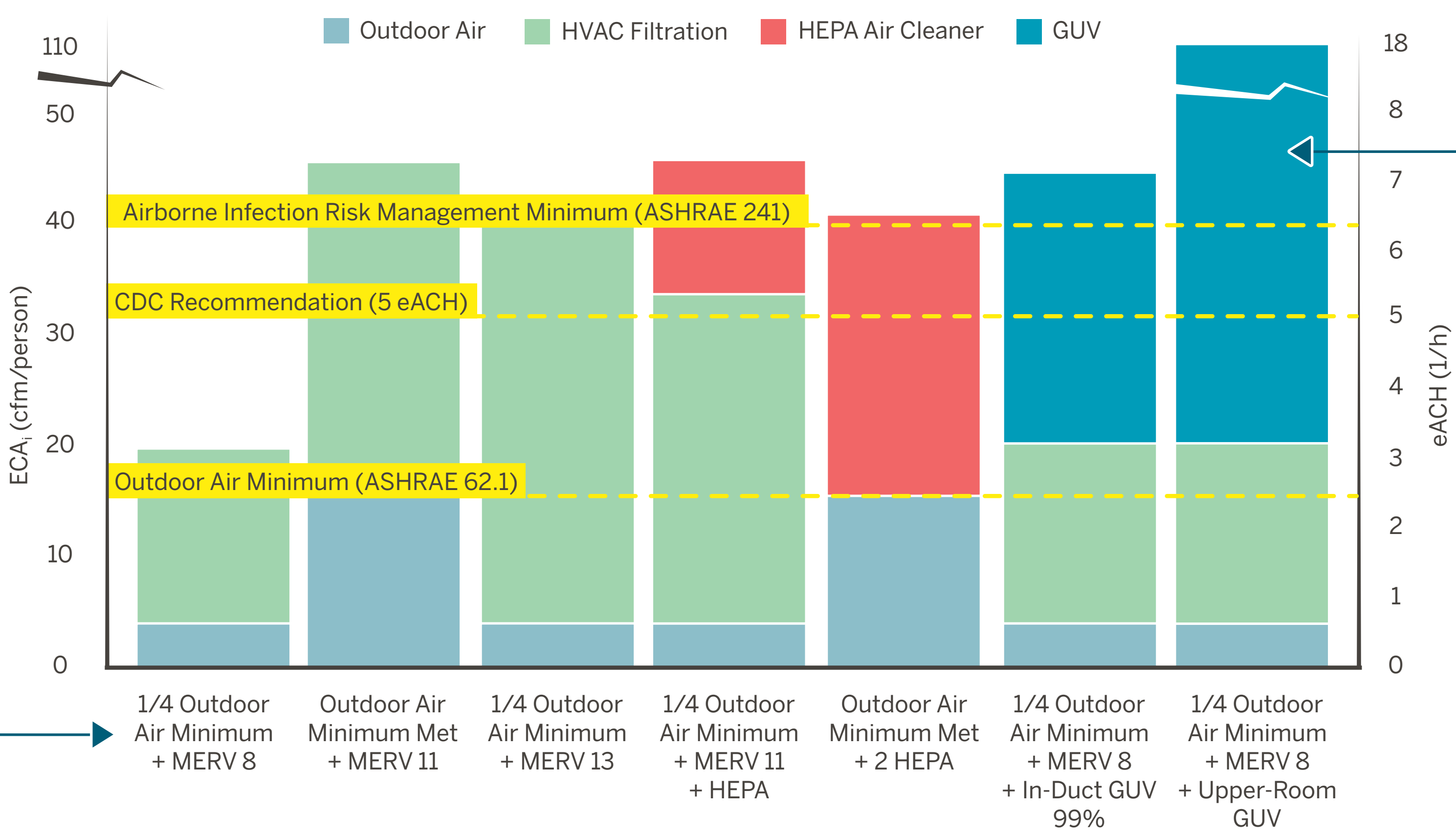
Equivalent Air Changes per Hour (eACH)

eACH represents the number of times the air in a space is replaced with clean air in one hour. It is based on airflow rates from all implemented strategies and **room size, without considering occupant density**. eACH is a metric that was widely used during the COVID-19 pandemic.

Outdoor ventilation goals are governed by ASHRAE Standard 62.1. However, older buildings may not meet this standard, and even newer buildings may not work as intended.

Outdoor ventilation and HVAC filtration are established strategies that work to reduce the risk of viral transmission. Where they're not available, air cleaners with HEPA filtration or GUV are good additional strategies.

Example assuming a typical 1,000 ft.^{2} classroom with a 9 ft. ceiling and 25 occupants:



This ECA_i calculation may vary based on factors such as the amount of air supplied from an HVAC system, the clean air delivery rate (CADR) of the HEPA air cleaner (assumed to be 325 cfm), and the CADR of the upper-room GUV unit (assumed to be 2,250 cfm). The graph is provided as an example of how strategies can be combined to meet clean airflow goals. Even without additional mitigation strategies, clean airflow goals for reducing infection risk can be met by reducing occupancy.

This fact sheet includes references to eACH and CDC guidance for contextual understanding only. ASHRAE does not recommend the use of eACH as a substitute for ECA_i or as a basis for ventilation system design, and does not endorse the use of 5 ACH as a performance target. ASHRAE Standard 241 defines ECA_i as the appropriate metric and recommends targets based on building and space type.

Ventilation

SERIES:
School Indoor Air Quality Fact Sheets

This fact sheet is one in a series. See Series Overview for background information.

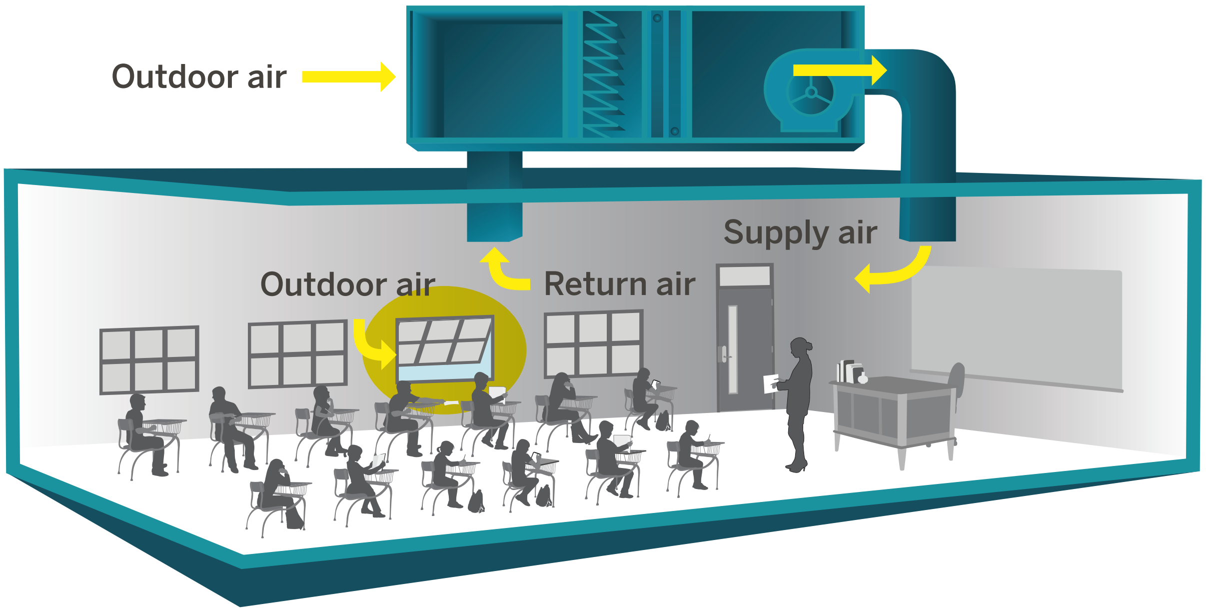
Ventilation Basics

Ventilation is the process of supplying outdoor air and treated recirculated air to a space to control air contaminant levels, temperature, and/or humidity.

There are two types of ventilation:

Natural ventilation allows outdoor air in via open windows and/or doors that are designed to serve the space's ventilation needs. It is most effective on windy days or when there is a large difference between indoor and outdoor temperatures, but its effectiveness can vary based on many factors.

Mechanical ventilation brings in outdoor air via a forced-air delivery system, such as an HVAC system.



Know Your Building: What Systems Do You Have?

- **No space conditioning:** Where no mechanical system is present, windows and/or fans may be in use.
- **Window unit or radiator:** Mechanical system is for temperature only, not ventilation.
- **Unit ventilator or univent:** Located on an outside wall with a filter, fan, and coil capable of mixing outdoor air with recirculated air. Air is heated/cooled as it passes the coil.
- **Central system (recirculation + outdoor ventilation):** Serves multiple rooms and mixes outdoor air with recirculated air while heating and cooling. Typically has a filter. Examples include: Air Handling Units (AHUs) and Rooftop Units (RTUs).
- **Central system (100% recirculation):** Serves multiple rooms and heats and cools recirculated air. Typically has a filter. Examples include: AHUs and RTUs.
- **DOAS (Dedicated Outdoor Air System) + decentralized heating/cooling systems:** A 100% outdoor air unit supplies air to decentralized systems, which condition recirculated air and mix it with outdoor air. In some cases, they also provide limited conditioning to the outdoor air. Decentralized systems typically include a 1" filter rack and can be configured as DOAS + heat pumps or DOAS + fan coil units.

Center for Green Schools at the U.S. Green Building Council

ASHRAE

System type informs the ventilation and air cleaning strategies that should be considered

	Building System Type					
				Central System Serving One or Multiple Rooms/Zones		
Ventilation or Air Cleaning Strategy	No Space Conditioning	Window Unit or Radiator	Unit Ventilator or Univent	Recirculation + Outdoor Ventilation	100% Recirculation	DOAS + Decentralized Heating/Cooling Systems
Ventilation: Natural (Operable Windows)	✓	✓			✓	✓
Ventilation: Mechanical			✓	✓		Depending on system
HVAC Filtration			Depending on pressure drop, may need to increase filter rack from 1” to 2”	Depending on pressure drop	Depending on pressure drop	Depending on pressure drop, may need to increase filter rack from 1” to 2”
In-Room Air Cleaners	✓	✓	✓	✓	✓	✓
Upper-Room Germicidal UV	✓	✓	✓	✓	✓	✓
HVAC/In-Duct Germicidal UV				✓	✓	

Ventilation Assessment

Research has demonstrated that classroom under-ventilation in the U.S. is far too common. Lack of verification at time of installation, deferred maintenance, and/or attempts to save energy may contribute to this issue. Once you’ve identified which systems you have, ventilation can be assessed using a variety of methods:

Airflow Measurement

For unit ventilators and central systems (the most common systems found in classrooms), airflow can be directly measured using relatively affordable devices like airflow hoods.

CO_2 Analysis

For any system, CO_2 concentrations can be continuously measured and compared to expected steady-state concentrations to determine if a space is adequately ventilated. For more information on CO_2 monitoring and data interpretation, see the Indoor Air Quality Monitoring Fact Sheet.

Tips for Selecting a TAB Provider

While procedures for assessing ventilation are well-documented, they require time and equipment that many schools do not have. Districts will often hire a testing, adjusting, and balancing (TAB) provider to assess the condition of HVAC equipment.

- Look for providers certified by reputable organizations such as NEBB (National Environmental Balancing Bureau), TABB (Testing, Adjusting, and Balancing Bureau), or AABC (Associated Air Balance Council).
- Ensure the provider follows industry standards, such as ASHRAE 111 or equivalent guidelines.
- Verify that the provider uses up-to-date, calibrated equipment for airflow measurements, pressure testing, and system diagnostics.
- The final report should include detailed findings, recommendations, and verification of system performance.

Costs and Benefits of Outdoor Air

Outdoor air, particularly humid or polluted air, needs to be treated before it can be introduced inside, which takes energy. The annual cost of supplying outdoor air ranges from a few dollars to a maximum of $10 per person per year. The benefits of increased ventilation include:

1. Reduced incidence of respiratory illnesses, including asthma and influenza.
2. Reduced stale air and odors, as well as prevention of headaches and drowsiness.
3. Better air quality, which is linked to improved cognitive function and higher academic achievement.

Using Ventilation to Reach Your Clean Airflow Goal

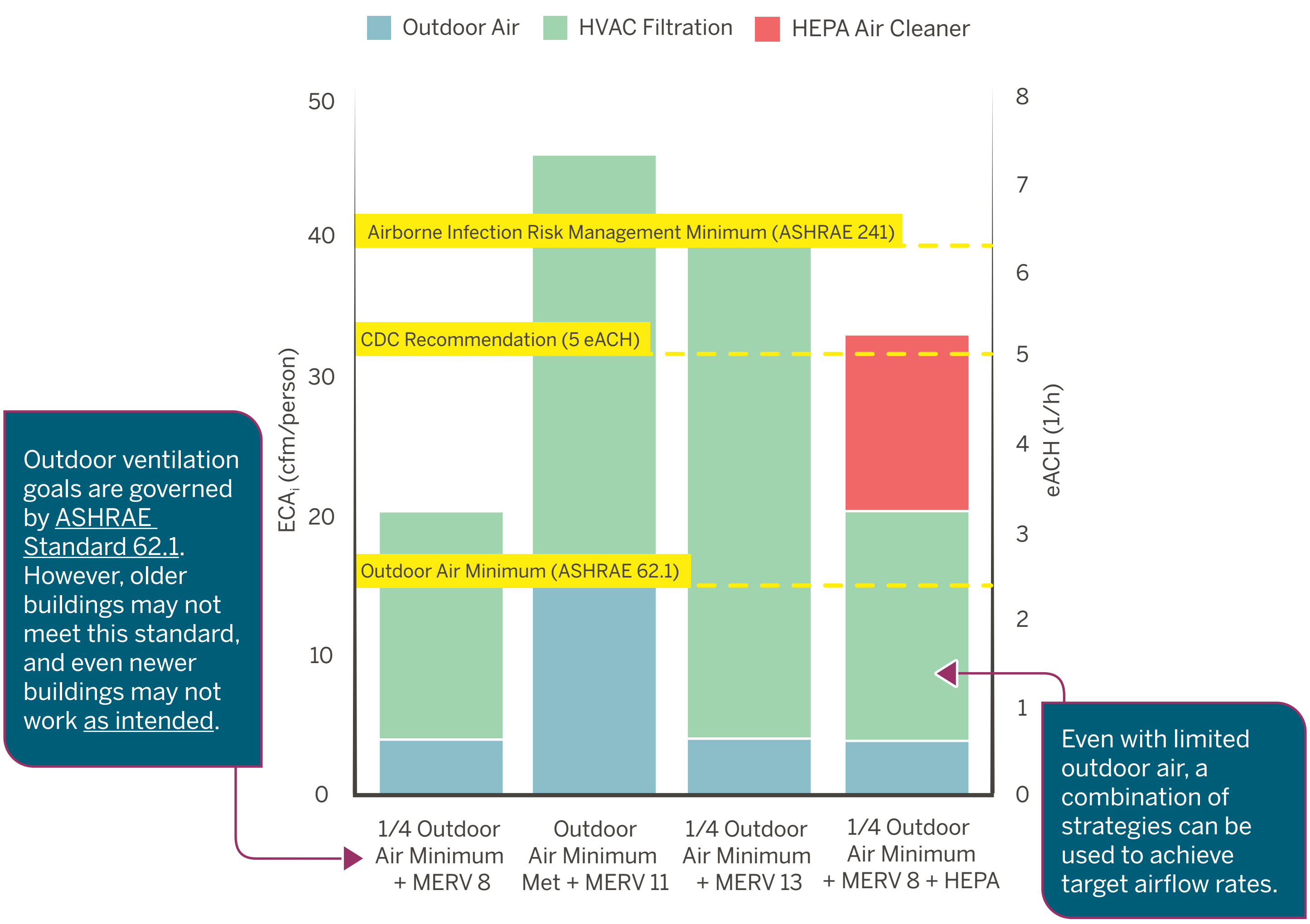
Equivalent Clean Airflow (ECA_i)

ECA_i targets are based on airflow rates from all mitigation strategies and the **number of occupants in a space, regardless of room size**. ECA_i is a metric specific to ASHRAE Standard 241. For more information on ASHRAE standards, see the Series Overview Fact Sheet.

Equivalent Air Changes per Hour (eACH)

eACH represents the number of times the air in a space is replaced with clean air in one hour. It is based on airflow rates from all implemented strategies and **room size, without considering occupant density**. eACH is a metric that was widely used during the COVID-19 pandemic.

Example assuming a typical 1,000 ft.² classroom with a 9 ft. ceiling and 25 occupants:



This ECA_i calculation may vary based on factors such as the amount of air supplied from an HVAC system and the clean air delivery rate of the HEPA air cleaner (assumed to be 350 cfm). The graph is provided as an example of how strategies can be combined to meet clean airflow goals. Even without additional mitigation strategies, clean airflow goals for reducing infection risk can be met by reducing occupancy.

This fact sheet includes references to eACH and CDC guidance for contextual understanding only. ASHRAE does not recommend the use of eACH as a substitute for ECA_i or as a basis for ventilation system design, and does not endorse the use of 5 ACH as a performance target. ASHRAE Standard 241 defines ECA_i as the appropriate metric and recommends targets based on building and space type.

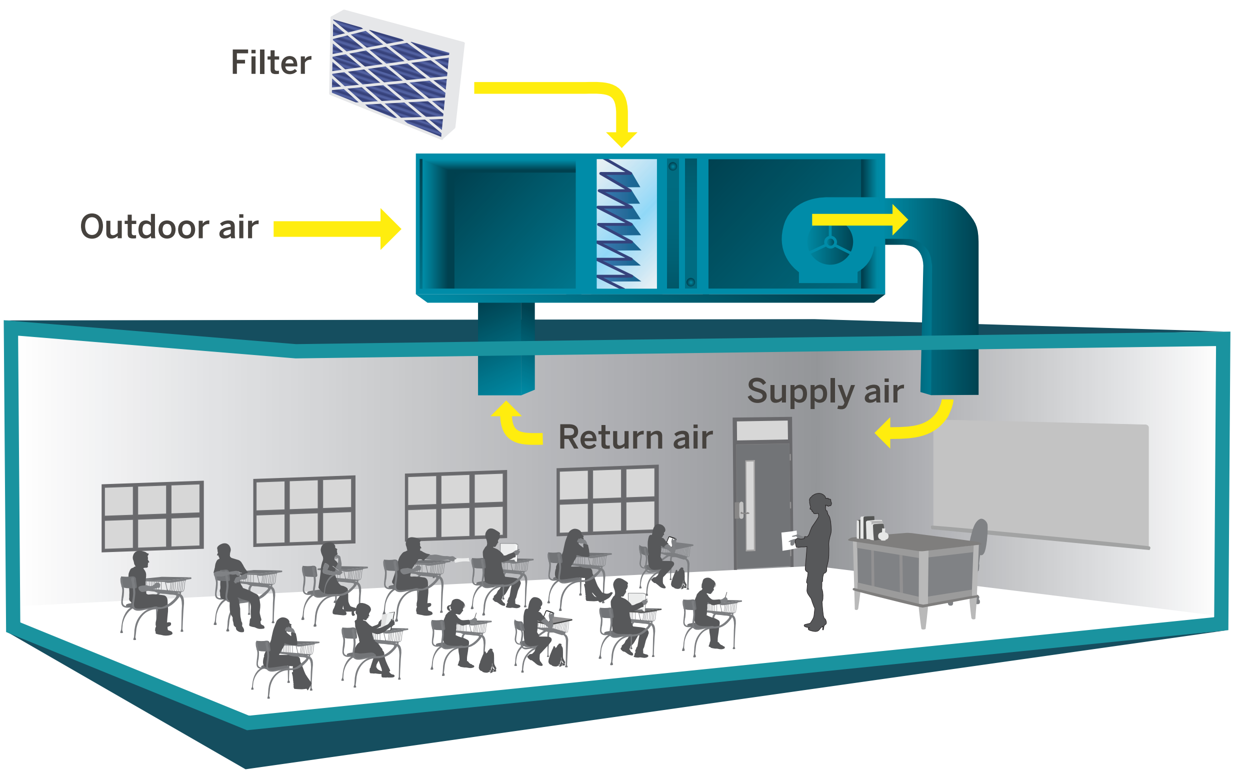
HVAC Filtration

SERIES:
School Indoor Air Quality Fact Sheets

This fact sheet is one in a series. See Series Overview for background information.

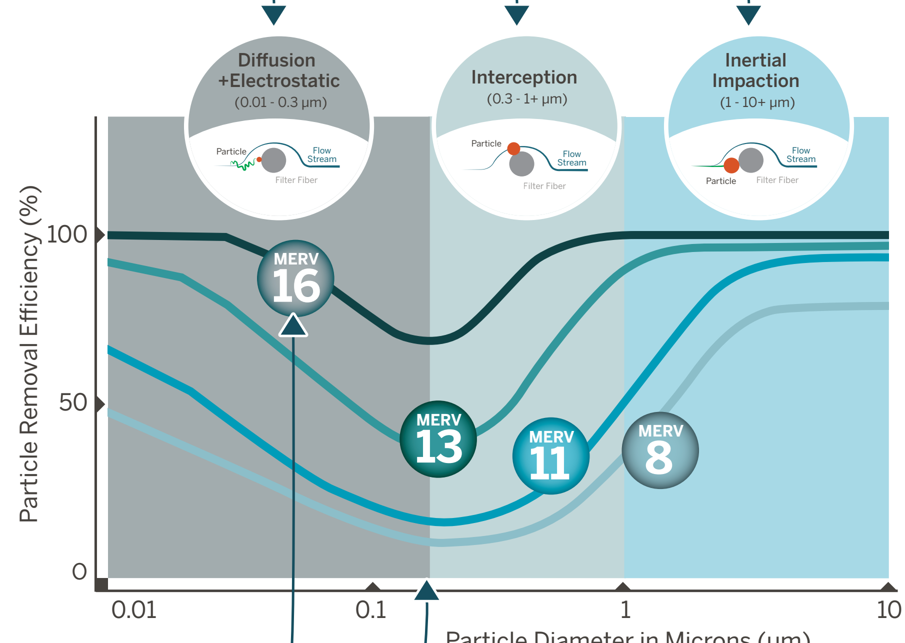
Filter Basics

Mechanical filters in HVAC systems use porous media, such as networks of fibers or fibrous fabrics, to remove particles from the air. The fraction of particles removed from air in a single pass through a filter is referred to as its particle removal efficiency.



Minimum efficiency reporting value (MERV) ratings express a filter's ability to capture particles of various sizes. Filters used in HVAC systems typically range from MERV 1 (lowest particle removal efficiency) to MERV 16 (highest particle removal efficiency). Some filters have charged media to enhance particle removal while maintaining a lower pressure drop. Since the efficiency of these filters often decreases after initial use, a MERV-A rating, if available, will reflect the actual minimum efficiency better than a standard MERV. High Efficiency Particulate Air (HEPA) filters are more efficient than MERV 16, but since HVAC systems in schools are not typically designed to handle HEPA filters, they are usually not a feasible in-duct upgrade.

Filters work to capture particles through a variety of mechanisms. The efficiency of HVAC filters, as well as the mechanism by which particles are removed, vary as a function of particle diameter.



MERV 16 filters are efficient at removing very small and very large particles.

Filters are least effective at removing particles around 0.3 microns.

Center for Green Schools at the U.S. Green Building Council

ASHRAE

HVAC Filtration for Viruses vs. Wildfires

A common misconception is that HVAC filters are unable to remove small, virus-containing aerosols. In reality, airborne particles that carry infectious viruses, including SARS-CoV-2, influenza, and RSV, are typically 0.5–10 microns and are captured efficiently by high-efficiency MERV filters. In contrast, wildfire smoke particles are more difficult to remove from air due to their size range (0.05–0.4 microns), and wildfires also produce gas-phase pollutants that even HEPA filters cannot capture. If your school is located in a region frequently affected by wildfire smoke (or near a high-traffic area), a combination of high-efficiency MERV filters and sorbent filters is recommended to address both particle- and gas-phase contaminants.

	Particle Removal Efficiency	
MERV	Infectious Aerosols (Standard 241)	Wildfires (Guideline 44)
8*	0%	27.1%
11	60%	48.9%
13	77%	68.9%
16	95%	96.3%

*While ASHRAE Standard 241 states a particle removal efficiency of 0% for MERVs <11, data from the filter's manufacturer can be used to estimate their performance.

Myth

High-rated MERV filters are going to choke my school's HVAC system.

Because filters are placed in the airstream of an HVAC system, they cause a pressure drop (resistance) when air flows through them. However, pressure drop does not always correlate directly with the MERV of the filter (higher MERV does not always mean higher pressure drop), which means higher MERV filters will not necessarily use more energy. There is a wide range of pressure drops for a given MERV depending on how filters are constructed (for example, a deeper or electrostatically charged filter may have a lower pressure drop).

MERV 13 can have similar pressure drop to a MERV 8 filter.

Ask your filter provider for manufacturer data to compare the pressure drop of the existing filter to a more efficient one. If it will be higher, an engineer will need to determine if the additional pressure drop is within the capability of the HVAC fan.

HVAC Filtration Assessment

To ensure optimal operation, inspect the filters in your school's HVAC system quarterly or during filter changes, whichever is more frequent. At the district level, tracking the following filter information is essential for proper maintenance and resolving indoor air quality concerns:

- Location and quantity of filters in the system (air path), including prefilters
- Size of existing filter rack
- MERV rating of existing filters
- Evaluation of filter installation quality, including use of spacers or tape and the presence of air gaps
- Each fan's design allowable pressure drop for both clean and dirty filters

Benefits of improved HVAC filtration in schools include:

1. Reduced incidence of respiratory illnesses, including asthma and influenza.
2. Increased ability to operate when outdoor particulate matter levels are high, such as during a wildfire smoke event.
3. Better air quality, which is linked to improved cognitive function and higher academic achievement.

Using HVAC Filtration to Reach Your Clean Airflow Goal

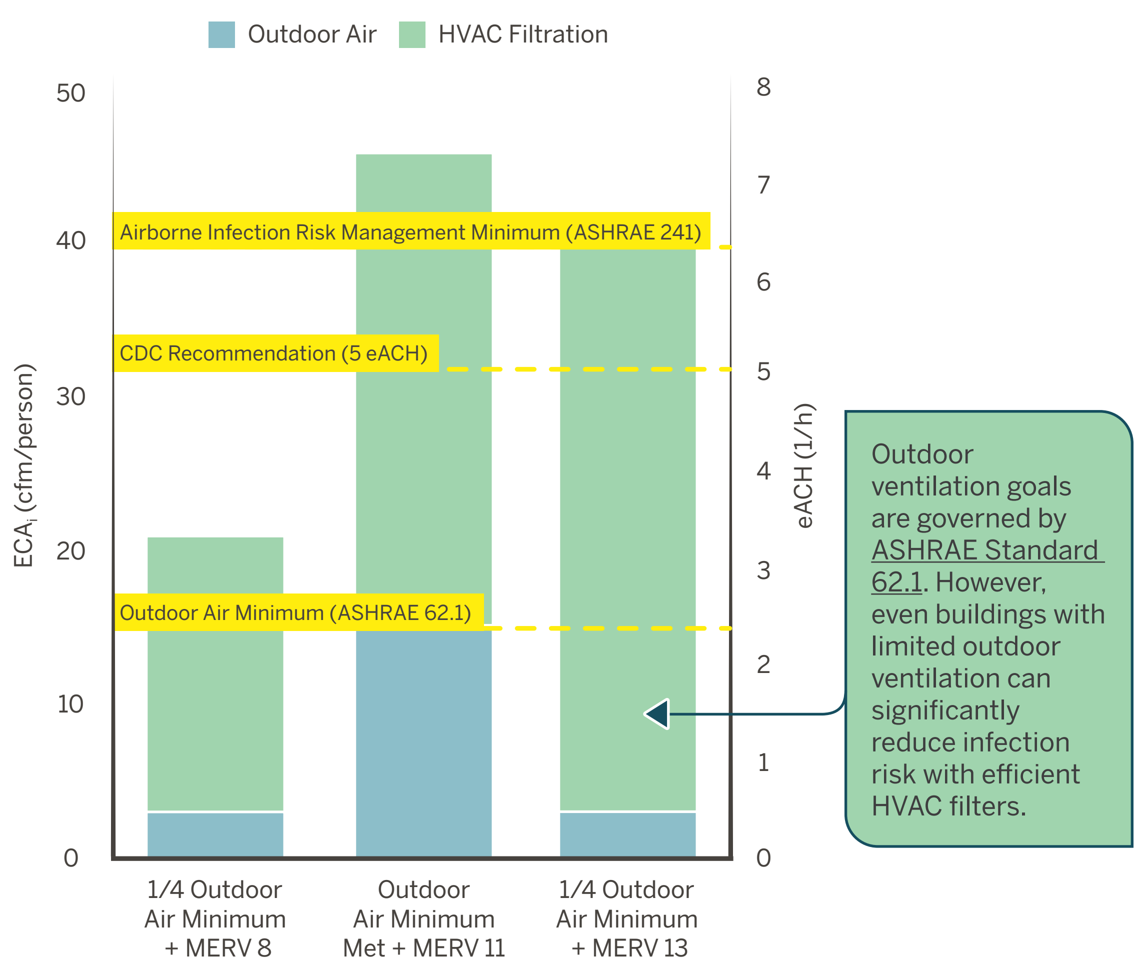
Equivalent Clean Airflow (ECA_i)

ECA_i targets are based on airflow rates from all mitigation strategies and the **number of occupants in a space, regardless of room size**. ECA_i is a metric specific to ASHRAE Standard 241. For more information on ASHRAE standards, see the Series Overview Fact Sheet.

Equivalent Air Changes per Hour (eACH)

eACH represents the number of times the air in a space is replaced with clean air in one hour. It is based on airflow rates from all implemented strategies and **room size, without considering occupant density**. eACH is a metric that was widely used during the COVID-19 pandemic.

Example assuming a typical 1,000 ft.^{2} classroom with a 9 ft. ceiling and 25 occupants:



This ECA_i calculation may vary based on factors such as the amount of air supplied from an HVAC system. The graph is provided as an example of how strategies can be combined to meet clean airflow goals. Even without additional mitigation strategies, clean airflow goals for reducing infection risk can be met by reducing occupancy.

This fact sheet includes references to eACH and CDC guidance for contextual understanding only. ASHRAE does not recommend the use of eACH as a substitute for ECA_i or as a basis for ventilation system design, and does not endorse the use of 5 ACH as a performance target. ASHRAE Standard 241 defines ECA_i as the appropriate metric and recommends targets based on building and space type.

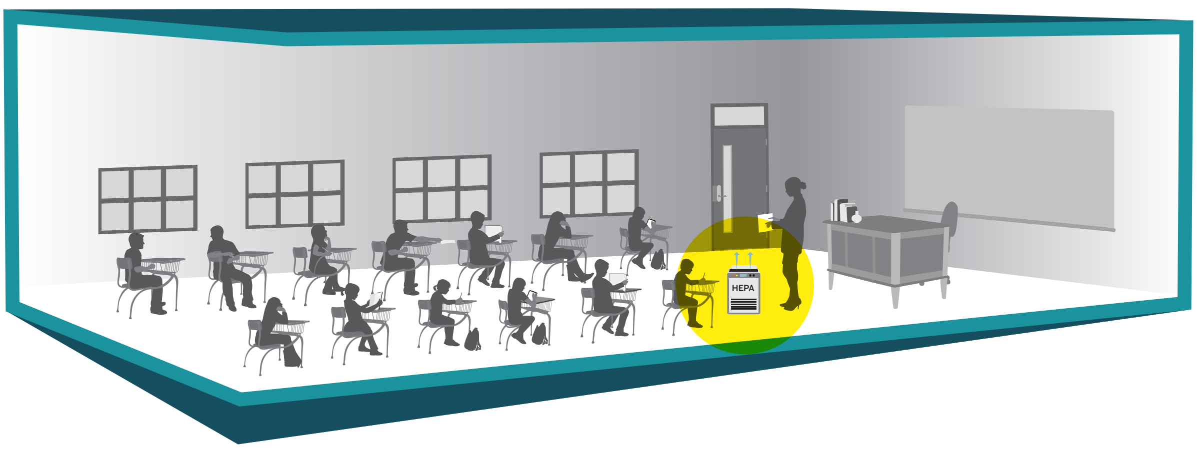
In-Room Air Cleaners

SERIES: School Indoor Air Quality Fact Sheets

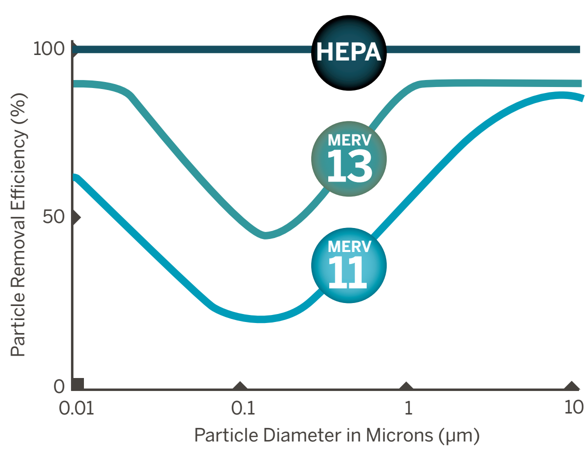
This fact sheet is one in a series. See Series Overview for background information.

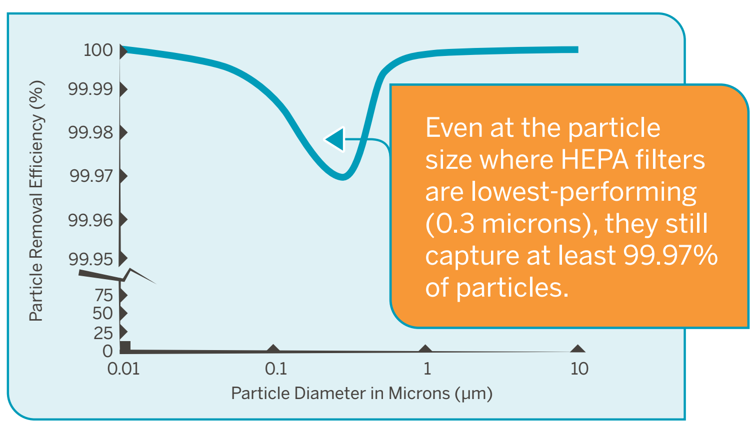
In-Room Air Cleaner Basics

In-room air cleaners work by pulling in air and filtering it before sending it back into an occupied space. They are independent from an HVAC system and come in several types and sizes, including miniature desktop units, portable units operated on the floor or tabletop, and larger fixed units that can be installed on ceilings, walls, or floors.



In-room air cleaners typically contain High Efficiency Particulate Air (HEPA) filters, which are certified to meet their stated efficiency. HEPA filters can trap at least 99.97% of virus-containing and wildfire smoke particles.

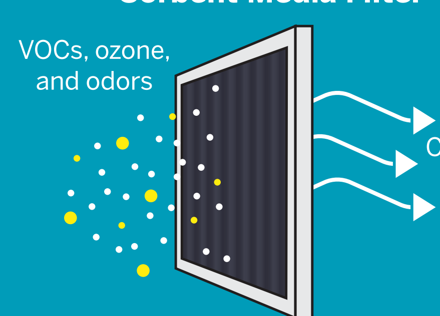




Gas-Phase Pollutants

While HEPA and MERV-rated filters are effective at removing particulate matter, they do not remove gas-phase pollutants. Sorbent materials are often used alongside HEPA filters in air cleaners to capture certain gaseous pollutants, including volatile organic compounds (VOCs) and inorganic gases like ozone. In schools, harmful (and sometimes unpleasant-smelling) VOCs and ozone can originate from both indoor and outdoor sources, including cleaning, cooking, personal care products, wildfires, and idling school buses.

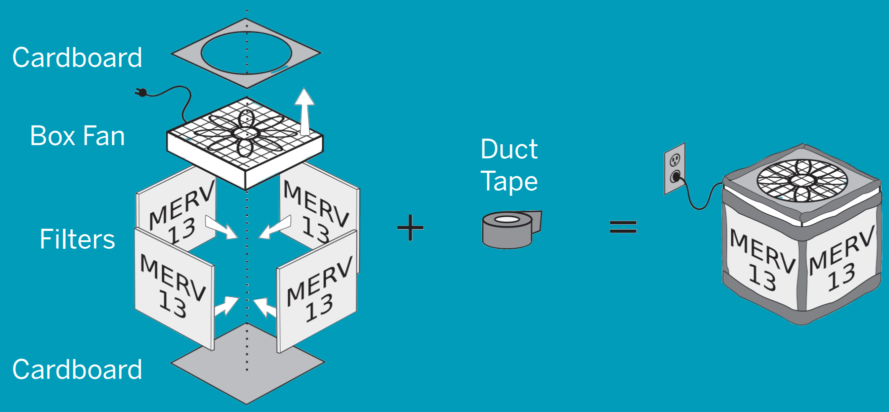
Sorbent Media Filter



For more information on VOCs, see the Indoor Air Quality Monitoring Fact Sheet.

DIY Air Cleaners

A variety of affordable, do-it-yourself (DIY) air cleaner designs have gained popularity in recent years. One option, the original Corsi-Rosenthal Box (which is comprised of four MERV 13 filters, a cardboard base, and a shroud, all affixed to a box fan with duct tape), delivers more clean air per dollar than many commercial devices, but may be noisier or bulkier. Newer Corsi-Rosenthal Box designs vary in fan type, filter type, and number of filters, and are often much quieter and smaller.



In-Room Air Cleaner Assessment

An in-room air cleaner should be chosen so that its clean air delivery rate (CADR)—the airflow rate of clean air delivered by the device—meets the needs of the room. CADRs (in units of cfm) can be directly added to other ASHRAE Standard 241 equivalent clean airflow contributors, such as ventilation and HVAC filtration. CADR is usually given for the highest fan speed, so if the unit runs at lower speeds, the CADR will be lower.

Tips for Selecting, Using, and Maintaining In-Room Air Cleaners

- **IDENTIFYING HEPA FILTERS:** Filters that are HEPA-certified will have their factory test reports easily accessible, either on the filter packaging or by request. HEPA filters will not be called "better than HEPA," "HEPA-type," or "HEPA-like." These terms are misleading.

- **COMPONENTS:** Check for add-ons you do not want or need. High-efficiency filters are the most effective method for removing particles, and additional technologies are often more problematic than helpful.

- **NOISE:** Check manufacturer's data for noise levels and choose an air cleaner that meets the recommended 35–45 dBA for classrooms. If a unit is too noisy at its highest fan speed, consider running two units at a lower speed.

- **TESTING:** Ask manufacturers to provide third-party lab reports in compliance with ASHRAE Standard 241 safety and effectiveness testing requirements.

- **COST:** Look for the price, availability, and expected lifetime of replacement filters. Include this cost in your planning.

- **PLACEMENT:** Place the air cleaner 3 ft. away from walls or open windows and doors. Do not block the unit's air inlet or outlet. Place it as close as possible to anyone speaking in the space (in classrooms, typically the teacher).

- MAINTENANCE: Clean prefilters and replace filters as recommended by the manufacturer.

Benefits of In-Room Air Cleaners in Schools

1. Air cleaners can be used for supplemental filtration when outdoor air quality is poor, such as during a wildfire event.
2. HEPA filtration is an effective method for reducing airborne allergen concentrations and asthma symptoms.
3. Continuous use of air cleaners is associated with respiratory and cardiovascular benefits for both healthy and at-risk populations.

Using In-Room Air Cleaners to Reach Your Clean Airflow Goal

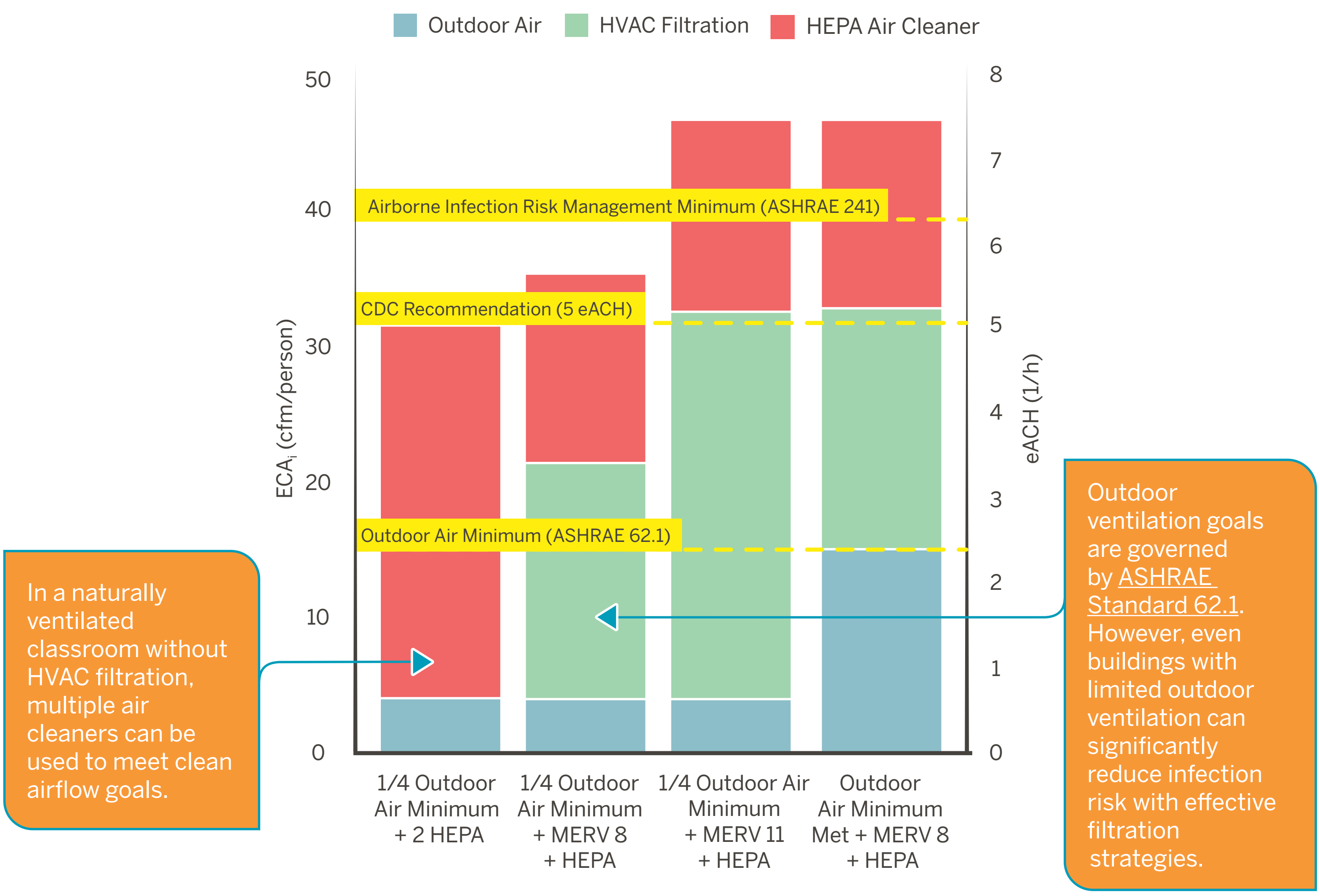
Equivalent Clean Airflow (ECA_i)

ECA_i targets are based on airflow rates from all mitigation strategies and the **number of occupants in a space, regardless of room size**. ECA_i is a metric specific to ASHRAE Standard 241. For more information on ASHRAE standards, see the Series Overview Fact Sheet.

Equivalent Air Changes per Hour (eACH)

eACH represents the number of times the air in a space is replaced with clean air in one hour. It is based on airflow rates from all implemented strategies and **room size, without considering occupant density**. eACH is a metric that was widely used during the COVID-19 pandemic.

Example assuming a typical 1,000 ft.^{2} classroom with a 9 ft. ceiling and 25 occupants:



This ECA_i calculation may vary based on factors such as the amount of air supplied from an HVAC system and the CADR of the HEPA air cleaner (assumed to be 325 cfm). The graph is provided as an example of how strategies can be combined to meet clean airflow goals. Even without additional mitigation strategies, clean airflow goals for reducing infection risk can be met by reducing occupancy.

This fact sheet includes references to eACH and CDC guidance for contextual understanding only. ASHRAE does not recommend the use of eACH as a substitute for ECA_i or as a basis for ventilation system design, and does not endorse the use of 5 ACH as a performance target. ASHRAE Standard 241 defines ECA_i as the appropriate metric and recommends targets based on building and space type.

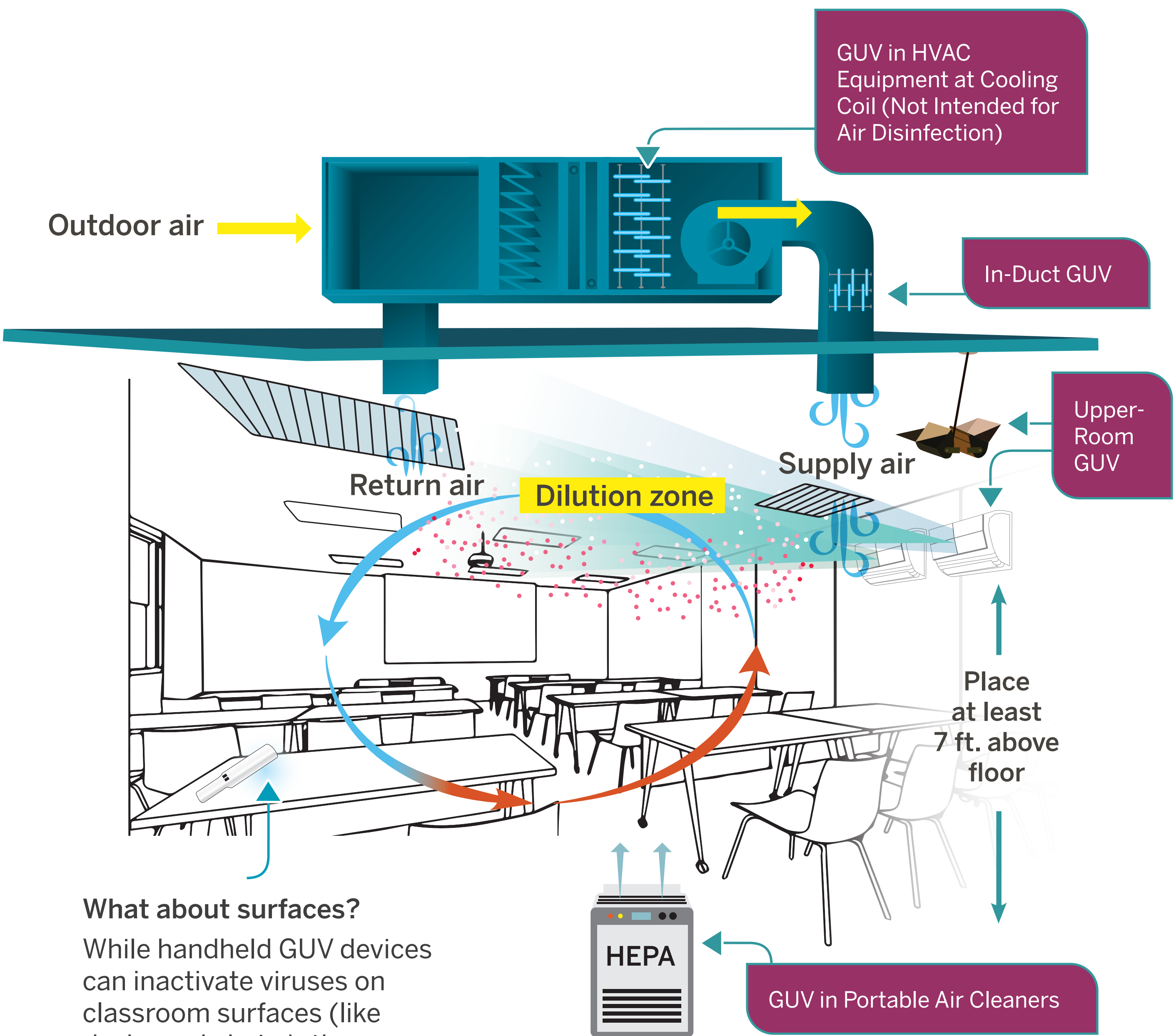
Germicidal Ultraviolet

SERIES:
School Indoor Air Quality Fact Sheets
This fact sheet is one in a series.
See Series Overview for background information.

Germicidal Ultraviolet Basics

Germicidal ultraviolet (GUV) is an established technology that inactivates viruses, bacteria, and fungi. The most effective germicidal wavelengths lie within the UV-C spectrum, with most commercially available GUV systems operating at a wavelength of 254 nm. This wavelength is favored because it is cost-effective, does not produce ozone, and damages the DNA and RNA of microorganisms. Far-UVC technologies have recently emerged, using a 222 nm wavelength that is potentially safer. This document does not cover 222 nm devices, as further research is needed to better understand their effectiveness and safe use.

Appropriate applications of GUV in schools include situations where a large equivalent clean airflow rate is needed, contaminants need to be removed near a source, and/or mitigation is needed in higher-risk locations, such as nurse's suites or high-occupancy areas.



What about surfaces?
While handheld GUV devices can inactivate viruses on classroom surfaces (like desks and chairs), they are not effective against viruses that are primarily transmitted through the air and should not be used in an occupied space.

Center for Green Schools at the U.S. Green Building Council
ASHRAE

Upper-room, HVAC/in-duct, and portable GUV systems are among the most common found in schools.

Upper-Room

Upper-room GUV systems, installed on walls or ceilings, create a disinfection zone using UV-C light to inactivate airborne pathogens. Adequate air mixing, either through an HVAC system or with additional fans, significantly improves the effectiveness of upper-room GUV systems. To ensure safety, systems should be installed a minimum of 7 ft. from the floor and should comply with safety standards such as UL 1598.

HVAC/In-Duct

In-duct GUV systems, installed within a building's HVAC system downstream of high-efficiency filters, use UV-C light to inactivate airborne pathogens. They can be installed near coils and other HVAC components to prevent microbial growth and improve system efficiency by reducing biofilm buildup. These systems operate safely out of sight and away from occupants.

Portable

Portable GUV systems can be used to disinfect air or surfaces. The effectiveness of GUV in air cleaners is limited by the airflow through the device, generally resulting in reduced performance compared to other GUV systems. Handheld GUV devices target high-touch surfaces and should be used with PPE, motion sensors, and/or timers to prevent direct UV-C exposure.

Germicidal Ultraviolet Assessment

The amount of UV-C light (dose) determines how effectively it can kill or inactivate microorganisms; a higher dose results in better disinfection. The dose is calculated by multiplying the strength of the UV-C light (called irradiance, measured in watts per square meter) by how long viruses, bacteria, or fungi are exposed to it. The strength of the light and duration of exposure are both critical for successful disinfection.

- **SAFETY:** UV-C energy can cause skin and eye irritation. Get assistance from a qualified professional to install. Ensure that lamps are off and use PPE when cleaning and servicing the unit and anything in the disinfection zone. GUV systems should be installed with on/off switches and interlocks to limit access only to trained personnel and staff.

- **INSTALLATION:** For systems installed in HVAC equipment and/or ducts, UV-C energy can degrade filter material, insulation, and electrical wiring, so an assessment is required before installation. For upper-room systems that are non-shielded, UV-C energy can fade wood and wallpaper and degrade plastics and wire coatings. Place away from ornate elements and plants.

- **VERIFICATION:** After installation, obtain on-site performance testing. For the safe use of upper-room systems, UV-C levels should not exceed 0.4 $\mu W/cm^2$ anywhere in the room when measured with a sensitive UV-C meter, and units should be installed no less than 7 ft. above the floor. Portable and handheld devices should be regularly tested with a UV-C meter to ensure appropriate intensities.

- **MAINTENANCE:** The effective dose of UV-C lamps can degrade over time. Maintain the system by replacing lamps per manufacturer recommendations (usually once per year).

Benefits of Germicidal Ultraviolet in Schools

1. GUV inactivates airborne pathogens that cause respiratory illnesses, including SARS-CoV-2 and influenza.
2. GUV reduces biofilm buildup on HVAC coil surfaces, which can help maintain system performance and energy efficiency.
3. GUV provides chemical-free disinfection, reducing reliance on harsh cleaning agents.

Using Germicidal Ultraviolet to Reach Your Clean Airflow Goal

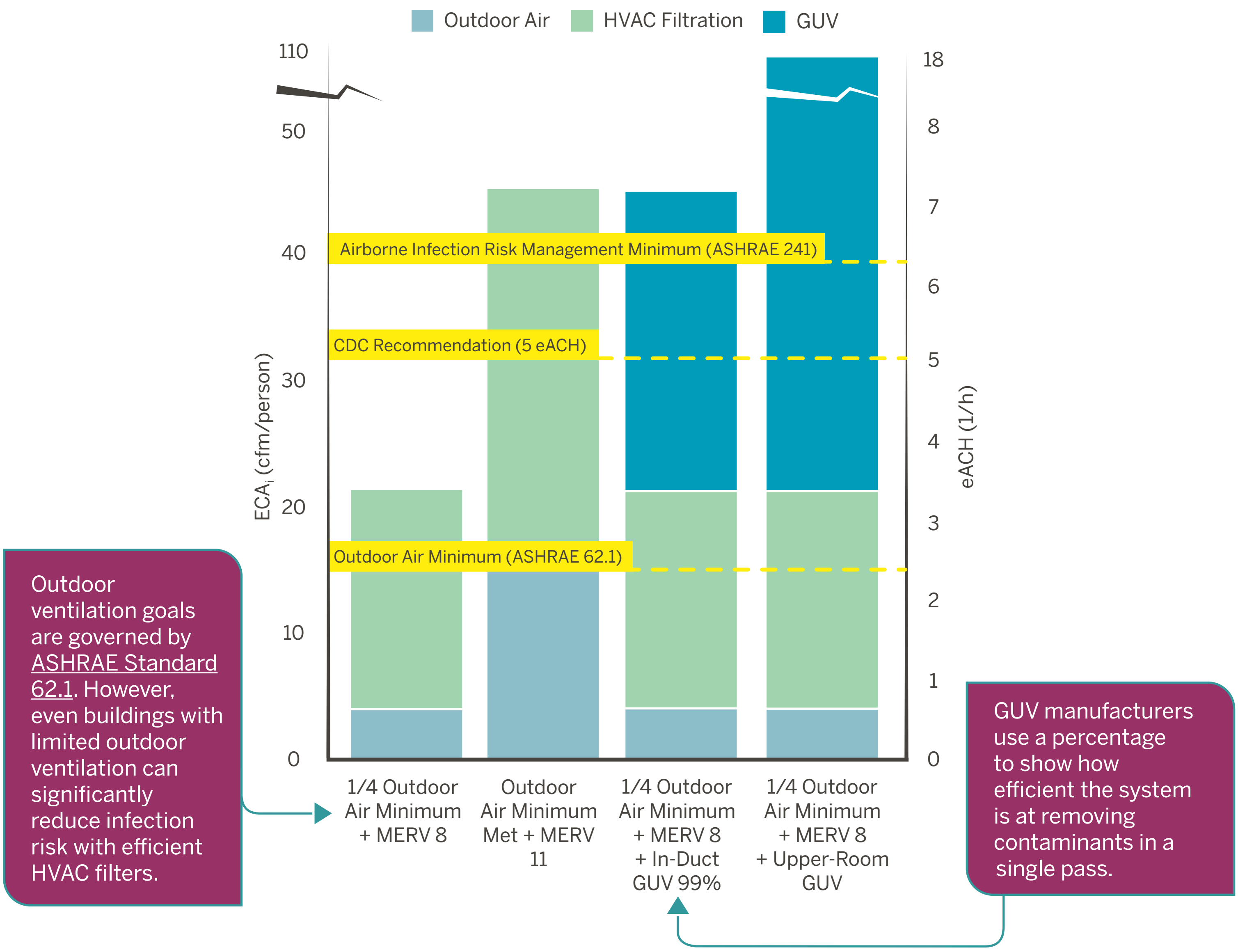
Equivalent Clean Airflow (ECA_i)

ECA_i targets are based on airflow rates from all mitigation strategies and the **number of occupants in a space, regardless of room size**. ECA_i is a metric specific to ASHRAE Standard 241. For more information on ASHRAE standards, see the **Series Overview Fact Sheet**.

Equivalent Air Changes per Hour (eACH)

eACH represents the number of times the air in a space is replaced with clean air in one hour. It is based on airflow rates from all implemented strategies and **room size, without considering occupant density**. eACH is a metric that was widely used during the COVID-19 pandemic.

Example assuming a typical 1,000 ft.^{2} classroom with a 9 ft. ceiling and 25 occupants:



This ECA_i calculation may vary based on factors such as the amount of air supplied from an HVAC system and the clean air delivery rate (CADR) of the upper-room GUV unit (assumed to be 2,250 cfm). The graph is provided as an example of how strategies can be combined to meet clean airflow goals. Even without additional mitigation strategies, clean airflow goals for reducing infection risk can be met by reducing occupancy.

This fact sheet includes references to eACH and CDC guidance for contextual understanding only. ASHRAE does not recommend the use of eACH as a substitute for ECA_i or as a basis for ventilation system design, and does not endorse the use of 5 ACH as a performance target. ASHRAE Standard 241 defines ECA_i as the appropriate metric and recommends targets based on building and space type.

Electronic Air Cleaners

SERIES: School Indoor Air Quality Fact Sheets

This fact sheet is one in a series. See Series Overview for background information.

Air Cleaning Technology Basics

Based on how they are designed to work, air cleaning technologies are often categorized as "subtractive" or "additive."

Subtractive Air Cleaners

Subtractive air cleaners remove targeted contaminants from indoor air upon contact with engineered materials. Examples include fibrous filters (e.g., MERV and HEPA filtration) and sorbent media (e.g., activated carbon filters). Standards and guidelines for the proper design, maintenance, and testing of subtractive air cleaners are well-established.

Additive Air Cleaners

Electronic Air Cleaners: devices that remove or inactivate target pollutants by producing reactive compounds or via direct energy application. With the exception of electrostatic precipitators (ESPs), comprehensive standards do not currently exist for electronic air cleaners.

Germicidal Ultraviolet (GUV): an additive technology that does not remove particles, but at certain wavelengths, can inactivate pathogens. For more information on this technology, see the **Germicidal Ultraviolet Fact Sheet**.

Understanding Electronic Air Cleaner Technologies

Ion generators, ESPs, and photocatalytic oxidation devices are among the most common electronic air cleaners.

Ion Generators

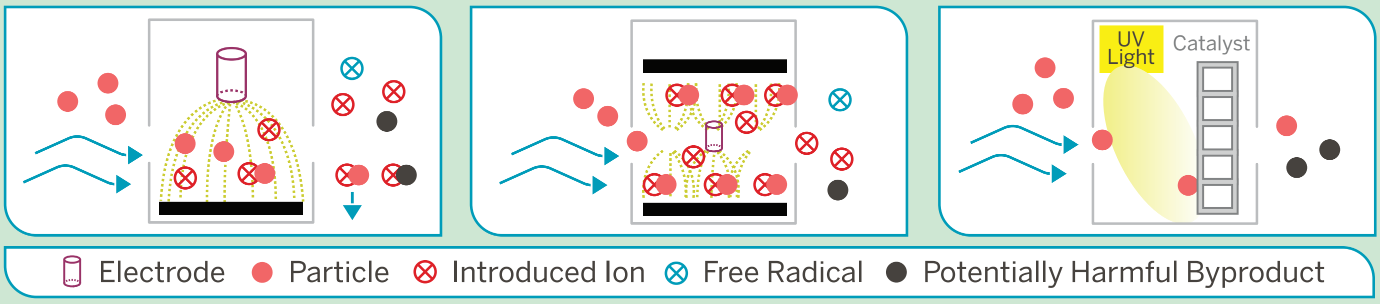
Electricity is used to create charged molecules, called ions, as air passes by the air cleaner. These ions attach to airborne particles, making them clump together and either settle on surfaces or become trapped in filters.

Electrostatic Precipitators

An electric field charges airborne particles as they pass through the device. The charged particles are drawn toward oppositely charged plates inside, where they can accumulate, reducing their presence in the air.

Photocatalytic Oxidation

Ultraviolet light activates a metal catalyst, which then reacts with airborne pollutants like viruses and chemicals, altering or breaking down these substances inside of the device.



Research has shown that electronic air cleaners can alter indoor air chemistry in unintended ways.

Contaminants that are meant to be targeted by electronic air cleaners may be transformed into other potentially harmful byproducts. Ozone and other reactive oxygen species, ultrafine particles (UFPs), and/or volatile organic compounds (including aldehydes, such as formaldehyde) can be produced unintentionally by electronic air cleaners.

Statements From a Few Trusted Organizations About the Use of Electronic Air Cleaners

- ASHRAE
- U.S. Centers for Disease Control
- California Air Resources Board
- Allergy and Asthma Foundation
- U.S. Environmental Protection Agency
- The Lancet COVID-19 Commission
- John Hopkins University, School of Public Health
- The U.K.'s Scientific Advisory Group for Emergencies
- Children's Environmental Health Network
- New York Department of Health

Electronic Air Cleaner Assessment

Before purchasing an air cleaner, schools should request certified third-party testing reports that demonstrate compliance with ASHRAE Standard 241 or industry standards specific to each technology, such as those created by ASHRAE, UL, AHAM, and ASTM.

Safety

- **OZONE:** Air cleaners can be tested for ozone emissions using standards UL 867 and UL 2998. UL 867 allows up to 50 ppb and is the only air cleaner testing method currently cited by a regulatory body in the U.S. UL 2998 is stricter, limiting emissions to 5 ppb, and has been included in ASHRAE Standards 62.1 and 241. Products meeting UL 2998 earn a "zero ozone" certification, though some ozone production is permissible.

- **CHEMICALS:** ASHRAE Standard 241 sets a maximum limit for formaldehyde emissions from air cleaners at 50 micrograms per hour.

- **PARTICULATE MATTER:** ASHRAE Standard 241 specifies that if an air cleaner emits particles larger than 0.3 microns, it must not degrade air quality by more than one ISO class (relative to the empty test chamber or duct), as described in ISO 14644-14.

Effectiveness

- **PARTICULATE MATTER:** Standards like ANSI/ASHRAE Standard 52.2 and ANSI/AHAM AC-1 measure how well filters and air cleaners remove particulate matter from the air. Clean air delivery rates are determined for smoke-, dust-, and pollen-sized particles, and a weighted average can be used to comply with ASHRAE Standard 241.

- **INFECTIOUS AEROSOLS:** AHAM AC-5 and ANSI/ASHRAE Standard 185.3 test how effectively air cleaners reduce airborne microbes. AC-5 is for in-room devices, while Standard 185.3 covers both in-room and in-duct systems. ASHRAE 241 requires testing with a virus-like microorganism (bacteriophage MS2).

- **CHEMICALS:** AHAM AC-4 evaluates how well air cleaners remove common chemical gases in residential applications. The test uses a sealed chamber and introduces gases like ammonia and formaldehyde to measure a chemical clean air delivery rate.

A number of adverse health effects are associated with byproducts that can be produced by electronic air cleaners.

1. Direct exposure to ozone is associated with respiratory issues such as reduced lung function, asthma exacerbation, and emphysema, as well as increased risk of cardiovascular conditions.

2. UFPs can penetrate the lungs, enter the bloodstream, and diffuse into organ systems, causing lung inflammation, cardiovascular conditions, and neurodegenerative disease.

3. In addition to being carcinogenic to humans, formaldehyde exposure is linked to sensory irritation, respiratory inflammation, and cognitive impairment.

Myth

"Zero ozone" electronic air cleaners are proven to be safe for the lifetime of the equipment.

Even though some electronic air cleaners have UL 2998 certification for zero ozone production, independent investigations of ozone emissions as equipment ages have not been conducted.

Studies are needed to examine how equipment performs over time in various installations.

It is possible that ozone and other harmful byproducts could be generated as a result of equipment aging, incorrect usage or maintenance, and/or changing environmental chemistry conditions.

Established Alternatives to Electronic Air Cleaners

Strategies such as outdoor air ventilation, HVAC filtration, and in-room air cleaners are safe, effective alternatives to electronic air cleaners for reaching your clean airflow goals. More information about each strategy can be found in the linked School Indoor Air Quality Fact Sheets.

Outdoor Air Ventilation

The introduction of clean outdoor air into a building. Outdoor ventilation is achieved via natural (e.g., opening windows and doors) or mechanical (e.g., forcing outdoor air through HVAC units) systems.

HVAC Filtration

The use of fibrous, often electrostatically charged filters in a mechanical ventilation system to remove particles from both outdoor and recirculated air. HVAC filter performance depends on particle size, and efficiency is often rated using a minimum efficiency reporting value (MERV).

In-Room Air Cleaners

Standalone units, independent from HVAC systems, designed to pull in air, filter it through high-efficiency particulate air (HEPA) filters and/or sorbent media, and send it back into a space.

Disinfectants

SERIES:
School Indoor Air Quality Fact Sheets
This fact sheet is one in a series. See Series Overview for background information.

Disinfectant Basics

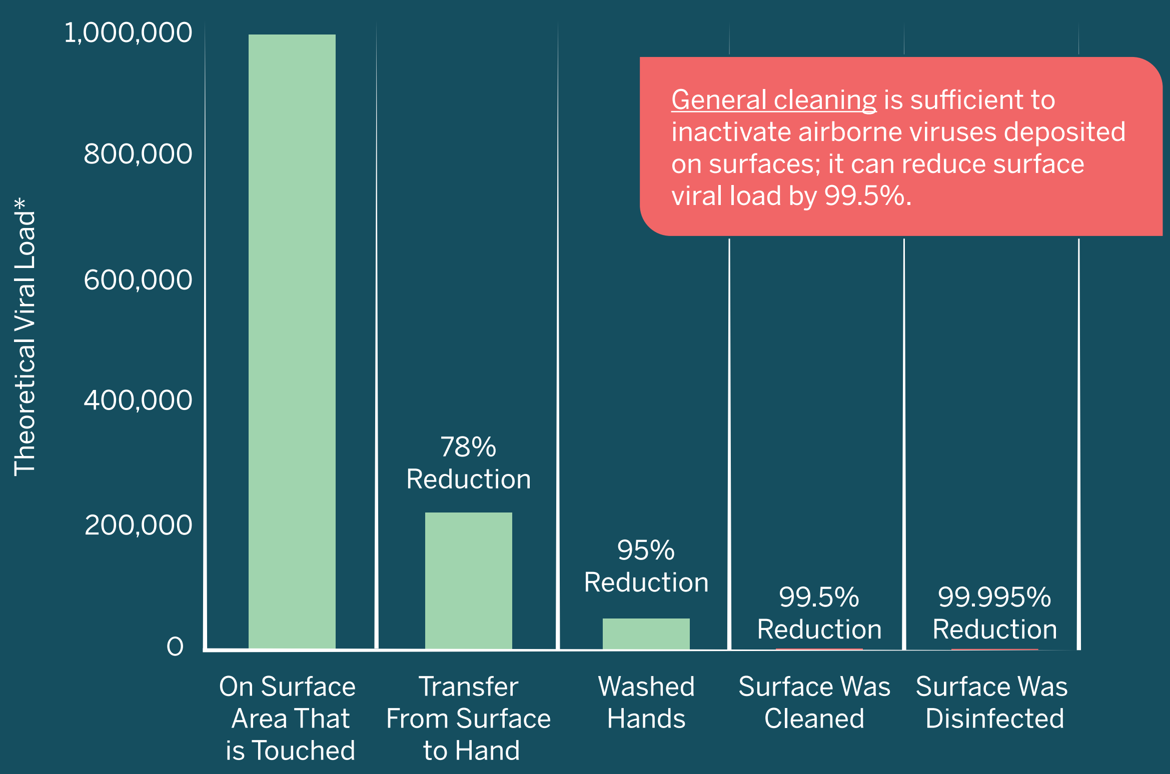
Disinfectants are chemical substances used to inactivate or reduce the concentration of bacteria, viruses, and fungi. While disinfectants can be effective against pathogens that accumulate on surfaces, they have little effect on airborne viruses. This fact sheet focuses on intersections between disinfectant use and indoor air quality (IAQ).

Myth

Disinfectants are necessary for stopping the spread of airborne viruses.

General surface cleaning is sufficient for preventing the spread of primarily airborne viruses, such as SARS-CoV-2, influenza, and RSV. Taking SARS-CoV-2 as an example, the risk of infection via surfaces is estimated to be only 1 in 10,000; the EPA and CDC emphasize that, unless otherwise mandated, increased disinfection is only needed when a COVID-19 case has been confirmed.

*See chart: Comparative Impact of Activities on Reducing Viral Load. Graph generated from an interpretation of quantitative microbial risk assessment research, found in The American Journal of Infection Control and Environmental Science & Technology Letters.



Center for Green Schools at the U.S. Green Building Council

ASHRAE

Potential Risks Associated With Disinfectant Use

Misuse or overuse of surface disinfectants can be harmful to humans and the environment. During the COVID-19 pandemic, misconceptions about SARS-CoV-2 transmission contributed to a surge in disinfectant use, resulting in increased exposure risks to the disinfectants themselves. In 2020, reports of disinfectant exposure to U.S. Poison Control Centers rose by 20% compared to the same period in 2019.

1. Alcohol-based disinfectants (e.g., hand sanitizer) may cause skin dryness, as well as throat, nose, and eye irritation.
2. The use of chlorine-based disinfectants (e.g., bleach) is associated with increased asthma rates and triggering asthma symptoms in children and adults.
3. Overuse of quaternary ammonium compound disinfectants can contribute to antimicrobial resistance.

Tips for Selecting and Applying Disinfectants

- **LOOK FOR THIRD-PARTY CERTIFICATION:** The EPA, Green Seal, and UL provide searchable databases of cleaning products that may offer safer and/or more environmentally friendly alternatives to commonly used options.

- **AVOID FUMIGATION AND ELECTROSTATIC SPRAYING:** The EPA generally does not recommend using airborne methods to apply disinfectants. Other air cleaning methods, such as in-room air cleaners and germicidal ultraviolet, provide more prolonged air disinfection.

  For more information about green cleaning, see the Healthy Green Purchasing for Asthma Prevention policy guidebook.

- **FOLLOW DIRECTIONS:** Use the product exactly as directed, wear the correct PPE, and allow for the required dwell time.

- **PRE-CLEAN:** Ensure you are maximizing disinfection by pre-cleaning with soap.

- **VENTILATE BEFORE AND AFTER APPLICATION:** Most products instruct the user to apply in a "well-ventilated area," which is not well-defined. Use caution and, when possible, apply during unoccupied periods, keep ventilation systems running and/or the windows open, and leave the space for a few hours.

  If a disinfectant is needed, **DO NOT** ask children to apply it.

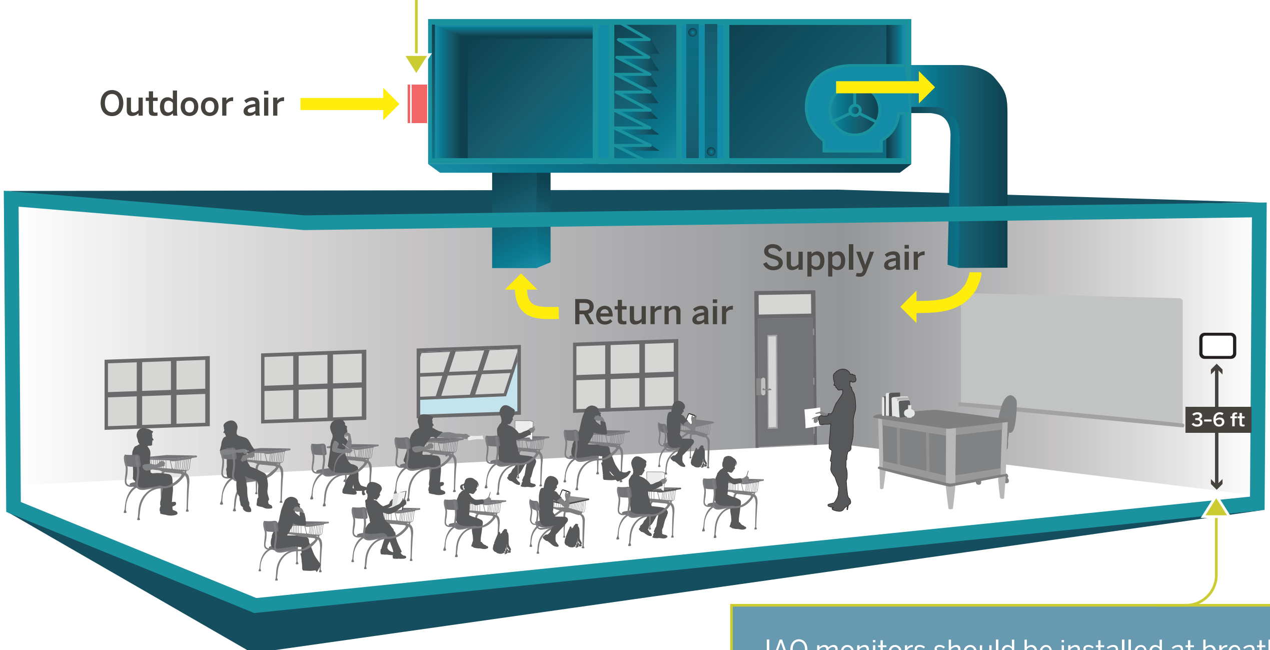
Indoor Air Quality Monitoring

SERIES:
School Indoor Air Quality Fact Sheets
This fact sheet is one in a series. See Series Overview for background information.

Monitoring Basics

An air quality monitor is a device that measures and reports pollutant levels and environmental conditions. Schools can utilize continuous indoor air quality (IAQ) monitoring networks, such as those in Boston Public Schools and Montgomery County Public Schools, to collect real-time data, assess ventilation performance, detect sudden changes in IAQ, and track long-term trends. Alternative IAQ monitoring options include handheld devices, which provide IAQ data only at a specific moment in time, and professional IAQ performance testing, which offers in-depth analysis when more advanced investigation is warranted.

Monitors can be installed outdoors to help understand how outdoor air pollutants contribute to IAQ. For schools with mechanical ventilation systems, outdoor air monitors should be placed near the outdoor air intake.



IAQ monitors should be installed at breathing zone height, 3–6 ft. above the floor, and away from vents, windows, and heat sources.

Benefits of Indoor Air Quality Monitoring in Schools

1. IAQ monitoring helps proactively identify issues before they escalate, protecting health, reducing complaints, and avoiding unnecessary repair or energy costs.
2. IAQ monitoring can be used to evaluate the efficacy of school improvements, such as upgraded HVAC systems and in-room HEPA air cleaner deployment.
3. Visible monitors can engage and empower teachers and students to identify and address IAQ issues in real time.

Center for Green Schools at the U.S. Green Building Council

ASHRAE

Choosing What to Monitor

Deciding which parameters to measure may vary between schools and school spaces, depending on district goals, regional climate, and existing HVAC and building systems. Organizations such as the EPA, ASHRAE, the World Health Organization (WHO), the California Air Resources Board (CARB), and the U.S. Green Building Council provide broadly applicable air quality guidelines that can be used to set IAQ goals.

Parameter	Reasons for Monitoring	Indoor Thresholds
Relative Humidity (RH)	High RH can contribute to indoor moisture sources, promoting the growth of mold, bacteria, and dust mites.	The EPA recommends that indoor RH be maintained below 60%, ideally between 30% and 50%.
Carbon Dioxide (CO_2)	Continuous monitoring can help identify insufficient ventilation (using CO_2 as an indicator of airflow) and/or detect excessively high CO_2 levels (where CO_2 functions as a pollutant).	**As a proxy for ventilation**: Recommended maximum CO_2 levels are 1,000 ppm (classrooms), 1,600 ppm (multi-use assembly spaces), and 2,500 ppm (music/theater spaces). **As a pollutant:** No established health standard, but recent data suggest levels <2,500 ppm.
Fine Particulate Matter ($PM_{2.5}$)	Sources include outdoor air, cooking, heating, and cleaning products. Exposure is associated with lung cancer, increased blood pressure, risk of dementia, respiratory infections, and decreased academic performance.	No U.S. indoor $PM_{2.5}$ standard exists, so outdoor guidelines are often used. The WHO recommends a 5 μg/m³ annual and 15 μg/m³ 24-hour limit, while the EPA sets 9 μg/m³ annual and 35 μg/m³ 24-hour thresholds. ASHRAE Standard 62.1 cites 12 μg/m³ as an indoor design limit.
Ozone (O_3)	Ozone in schools mainly comes from outdoor sources, but printers, copiers, and some electronic air cleaners may emit it, potentially leading to respiratory issues and the production of harmful byproducts.	ASHRAE Standard 62.1 sets an indoor ozone design limit of 70 ppb. CARB cites 1-hour and 8-hour average limits of 90 and 70 ppb, respectively.
Carbon Monoxide (CO)	CO can be emitted from gas cooking, boilers/furnaces, and science laboratory experiments. Short-term CO exposure is the leading cause of poisoning death in the U.S.	The WHO sets 15-minute and 1-hour indoor CO exposure limits at 25 and 8.75 ppm, respectively. ASHRAE Standard 62.1 sets a design limit of 9 ppm.
Total Volatile Organic Compounds (TVOCs)	Harmful VOCs can be released from building materials, cleaning products, and stored chemicals, and while TVOC levels alone may not indicate poor IAQ, continuous monitoring can help identify potential sources of concern.	ASHRAE Standard 62.1 sets limits for select harmful VOCs. The standard recommends not setting a target for TVOCs, arguing that “there is insufficient evidence that TVOC measurements can be used to predict health or comfort effects.”

Myth

All VOCs are equally harmful and monitoring TVOCs is a representative measure of IAQ.

Not all VOCs are dangerous, and low levels don’t always mean the air is safe. Tracking TVOCs over time can still be helpful. For example, a sudden spike may signal a new pollution source, while steady levels in an empty room could indicate ongoing emissions from appliances or outdoor air. Instead of treating TVOCs as a definitive measure of air quality, they should be used as a screening tool to identify potential concerns.

Tips for Selecting and Maintaining IAQ Monitors

- Choose continuous monitors that comply with ASHRAE Standard 62.1 minimum performance specifications.
- Prioritize NDIR sensors for CO_2 monitoring, as they provide direct measurements, while lower-cost e-sensors estimate CO_2 levels based on TVOC concentrations.
- Verify the frequency of data collection, how many data points the device can store, how the sensors store data, and how the data is reported.
- Consider connectivity options to the building automation system through API, Modbus, BACnet, or other protocols.
- Regularly calibrate monitors based on manufacturer recommendations and replace batteries as needed.
- For more information on sensor selection, performance, and best practices, visit the EPA's Air Sensor Toolbox and the South Coast Air Quality Management District's Air Quality Sensor Performance Evaluation Center.

ASHRAE Standard 62.1 Minimum Sensor Specifications

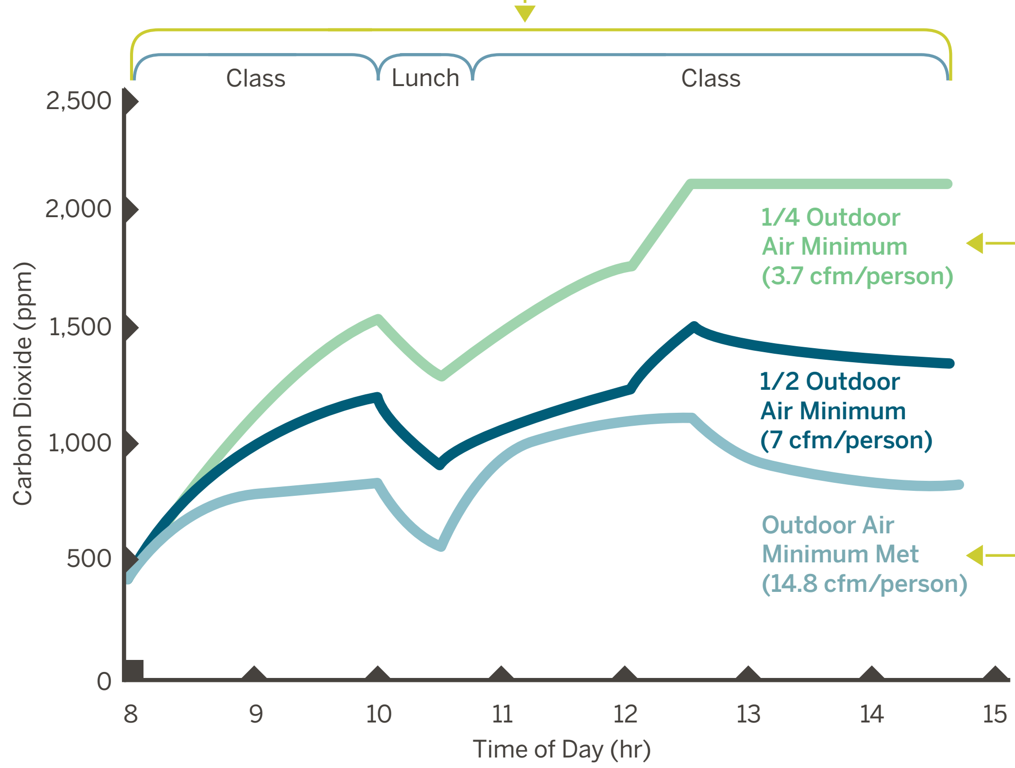
Parameter	Accuracy (±)	Resolution (±)
CO_2	75 ppm at concentrations of 600, 1,000, and 2,500 ppm	N/A
$PM_{2.5}$	Greater of 5 µg/m³ or 20% of reading	5 µg/m³
O_3	5 ppb	1 ppb
CO	Greater of 3 ppm or 20% of reading	1 ppm

Using Continuous CO_2 Monitoring to Assess Ventilation

CO_2 monitors in schools are best used to identify HVAC issues or insufficient ventilation, not to directly assess infection risk, as CO_2 levels cannot capture the impact of filtration or air cleaning strategies. Existing evidence linking indoor CO_2 concentrations to health, well-being, and learning outcomes is inconsistent. Minimum outdoor air targets are established by ASHRAE Standard 62.1. For more information on ASHRAE standards, see the **Series Overview Fact Sheet**.

Example assuming a 1,000 ft.^{2} classroom with 21 students (ages 5–9) and 2 adults:

To interpret CO_2 data correctly, levels must be logged throughout the school day in a typically occupied classroom. Spot checks will not provide maximum CO_2 concentrations or reveal general trends.



In a typical classroom with constant occupancy, it takes ~2 hours for occupant-generated CO_2 to reach equilibrium with the rate of CO_2 being removed, a level referred to as the steady-state concentration.

Lower steady-state CO_2 concentrations indicate adequate outdoor air ventilation.

CO_2 concentrations may vary based on factors such as room dimensions, occupancy, ventilation rate, and CO_2 generation rate. All calculations made with NIST's Quick Indoor CO_2 Tool.

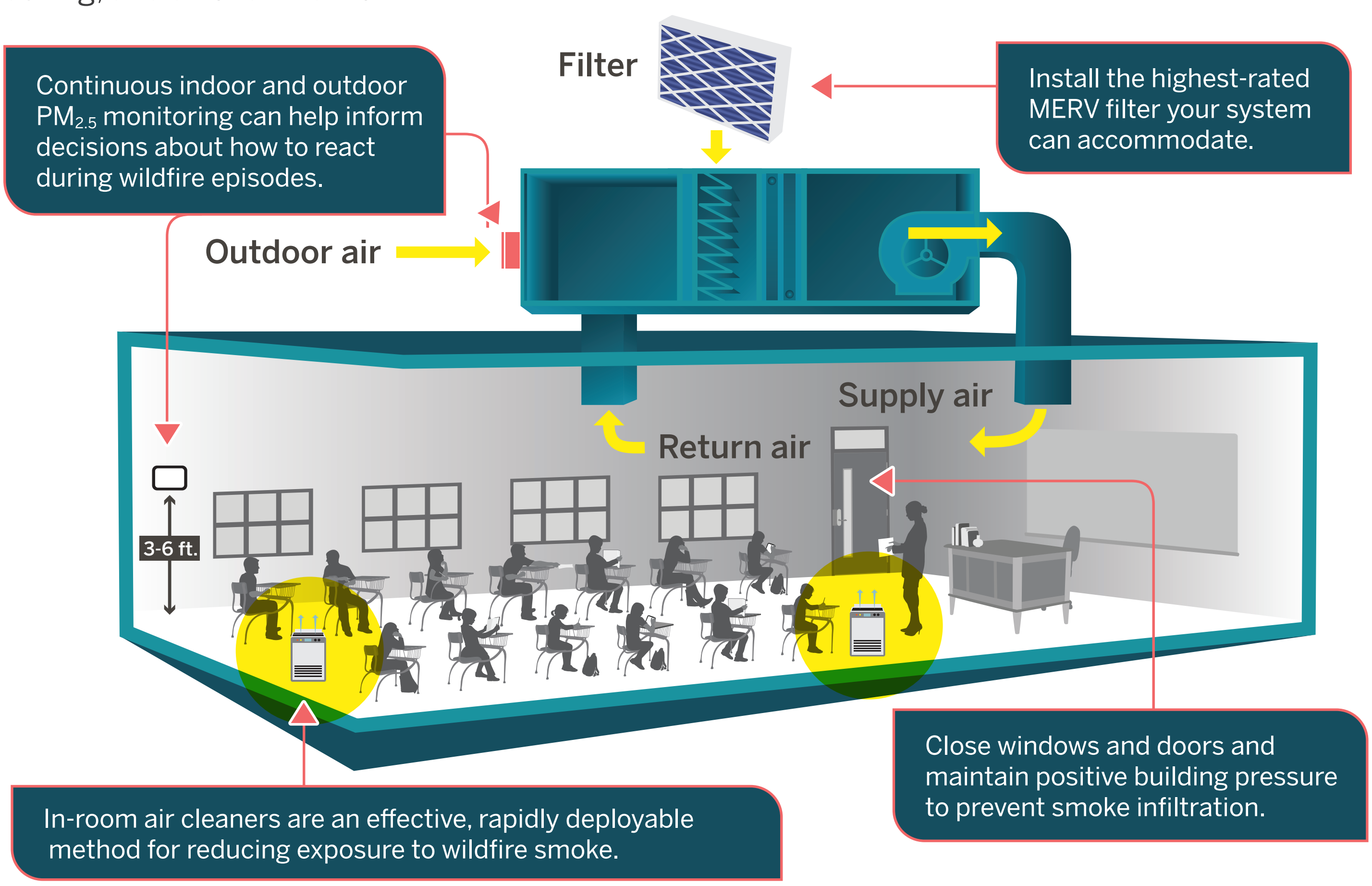
Indoor Air Quality During Wildfires

SERIES:
School Indoor Air Quality Fact Sheets
This fact sheet is one in a series. See Series Overview for background information.

Wildfire Basics

In recent years, the U.S. has experienced increasingly frequent and severe wildfire events, resulting in episodes of degraded air quality that can persist for days, weeks, or months. Wildfire smoke is a complex mixture of gases and particulate matter, with its composition depending on the materials being burned, their moisture content, fire temperature, and distance traveled. Fine particulate matter ($PM_{2.5}$) is commonly used as an indicator of smoke-related air quality because it poses significant respiratory and cardiovascular health risks, is a federally regulated pollutant that is routinely monitored, and consistently increases during wildfire events.

ASHRAE Guideline 44 recommends building measures to minimize occupant health impacts from wildfire events, including developing a Smoke Readiness Plan with protocols to follow before, during, and after a wildfire.



How do I know when to implement my Smoke Readiness Plan?

ASHRAE Guideline 44's **Smoke Readiness Plan Decision Matrix** is a tool that provides actionable guidance for responding to wildfire events based on both current smoke conditions and forecasted air quality.

Smoke Conditions	Action
No current smoke, and no smoke forecast	Carry on with normal operations. Have Smoke Readiness Plan prepared and ready.
Current smoke OR smoke forecast in coming days	Consider implementing Smoke Readiness Plan, for example, if at-risk populations are likely to be impacted.
Current smoke AND smoke forecast in coming days	Implement Smoke Readiness Plan.

Preparation

Outdoor Ventilation

Verify that dampers and building automation controls are functioning properly and can be used to limit outdoor air intake. Establish optimal airflow rates that balance pollutant removal, comfort, and building pressure.

HVAC Filtration

Ensure that HVAC systems can filter both outdoor and recirculated indoor air to remove $PM_{2.5}$. Depending on system compatibility, schools in wildfire-prone areas should consider upgrading to a minimum of MERV 13 or equivalent filters. Purchase back-up filters to have on hand.

In-Room Air Cleaners

If budget allows, purchase air cleaners with HEPA filters, which are >99.97% efficient at removing $PM_{2.5}$ and often include sorbent media that capture gases; DIY air cleaners constructed with MERV 13 filters (such as the Corsi-Rosenthal Box) deliver more clean air per dollar than many commercial devices, but may be noisier or bulkier. For use during wildfires, a rule of thumb is that an air cleaner's smoke clean air delivery rate (CADR) should be equal to the floor area of the room. Place devices away from walls and furniture and keep replacement filters on hand. Ensure that teachers and staff receive training on proper air cleaner operation.

Building Envelope

Aim to maintain positive building pressure and identify gaps in the building envelope via visual checks, thermal imaging, or a professional energy audit. Seal openings (such as windows, doors, skylights, and roof vents) using weatherstripping or caulking and replace broken windows and door closures.

$PM_{2.5}$ Monitoring

Consider installing continuous $PM_{2.5}$ monitors indoors and outdoors. Select $PM_{2.5}$ sensors with a recommended minimum accuracy of ±5 $\mu g/m^3$ or ±20% of the measured reading (whichever is greater), and a resolution of ±5 $\mu g/m^3$. Install indoor monitors in areas that reflect general building use, away from pollution sources like kitchens. Position outdoor monitors near the HVAC system's outdoor intakes.

Taking Action

Placing Buildings into Smoke-Ready Mode

- Adjust outdoor air dampers, disable or reduce relief fan airflow, adjust exhaust fans, and block exhaust grills.
- Install higher-rated MERV filters and temporary outdoor intake filters.
- Deploy in-room air cleaners.
- Implement identified HVAC operations for optimal airflow rates that balance pollutant removal and comfort.

Returning Buildings to Normal Operations

- Refer to documentation and photos of the original HVAC system settings and re-enable outdoor air dampers and exhaust fans.
- Inspect and change return air filters to the type used for normal operation. Remove temporary outdoor intake filters.
- Verify operation of system after returning to normal.
- Clean indoor surfaces and HVAC interior surfaces to remove ash deposited from the smoke as needed.

How do I know when indoor $PM_{2.5}$ concentrations are too high?

ASHRAE Guideline 44 emphasizes keeping indoor $PM_{2.5}$ as low as reasonably achievable during wildfire events, aiming to maintain indoor levels below 20% of outdoor levels. Even without a continuous monitoring network, low-cost handheld $PM_{2.5}$ monitors can quickly assess concentrations in and around your building.

Reliable platforms such as AirNow.gov and the Fire and Smoke Map provide real-time outdoor $PM_{2.5}$ data. The Air Quality Index (AQI) assesses outdoor air quality and health risks, with $PM_{2.5}$ concentrations aligned to AQI ranges, indicating wildfire severity. Refer to guidance from California and Washington state agencies for information about when to close school or cancel school activities.

AQI Category	AQI Range	Outdoor $PM_{2.5}$ Range (µg/m³)
Good/Moderate	0–100	0–35
Unhealthy for Sensitive Groups	100–150	34–55
Unhealthy	151–200	55–150
Very Unhealthy	201–300	150–250
Hazardous	301+	250–500

Meeting Your Indoor $PM_{2.5}$ Target During a Wildfire

A combination of mitigation strategies can be used to reduce indoor $PM_{2.5}$ during a wildfire. For more information on the strategies featured here, see the **HVAC Filtration** and **In-Room Air Cleaners** fact sheets.

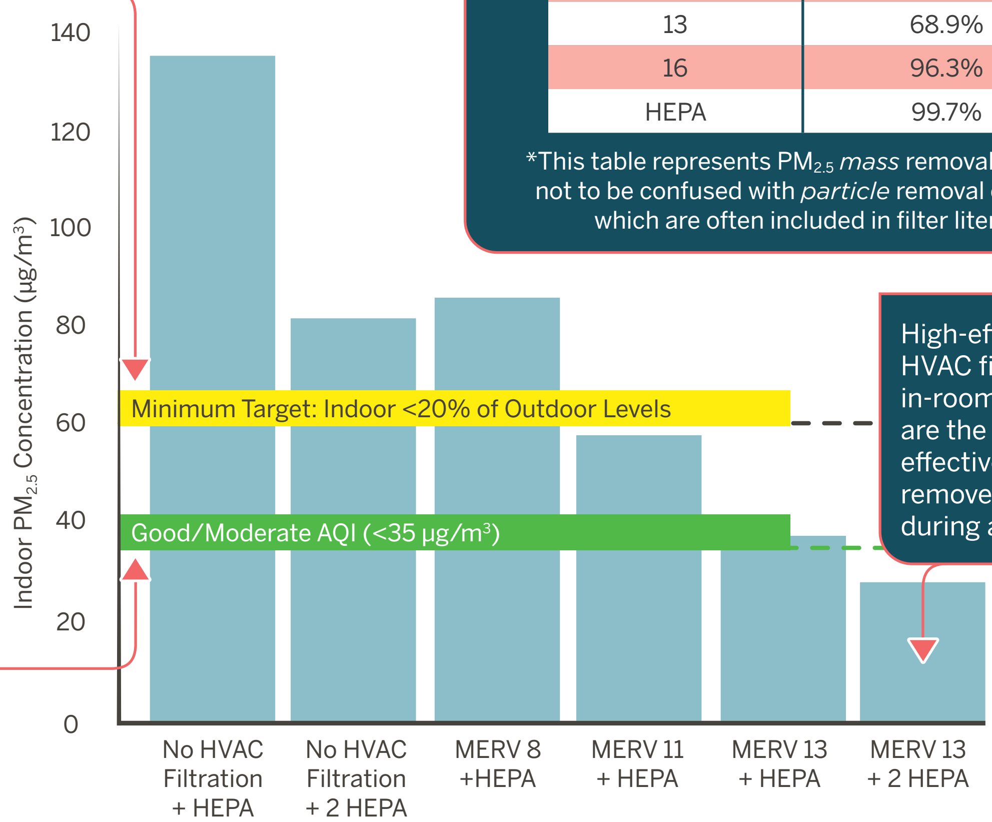
Example assuming a typical 1,000 ft.² classroom with a 9 ft. ceiling and 25 occupants, while the outdoor $PM_{2.5}$ concentration is 300 µg/m³:

Guideline 44 provides an equation for estimating target indoor $PM_{2.5}$ concentrations during a wildfire event. Alternatively, a rule of thumb is to keep indoor $PM_{2.5}$ at <20% of outdoor levels. This target will change based on outdoor $PM_{2.5}$ levels.

$PM_{2.5}$ removal efficiency varies by filter MERV rating.

Filter MERV rating	$PM_{2.5}$ Mass Removal Efficiency*
8	27.1%
11	48.9%
13	68.9%
16	96.3%
HEPA	99.7%

*This table represents $PM_{2.5}$ *mass* removal efficiencies, not to be confused with *particle* removal efficiencies, which are often included in filter literature.



During extreme wildfire events when the AQI reaches hazardous levels, even 20% of outdoor $PM_{2.5}$ concentrations can result in unhealthy indoor air. Aim to keep indoor $PM_{2.5}$ as low as reasonably achievable.

High-efficiency HVAC filters and in-room air cleaners are the most effective way to remove indoor $PM_{2.5}$ during a wildfire.

Example informed by section 5.4.1.1 of Guideline 44, with inputs adjusted to be representative of a classroom. Indoor $PM_{2.5}$ concentration may vary based on factors such as the amount of air supplied from an HVAC system (outdoor air assumed to be reduced to ~7.3 cfm/person), the airtightness of the building envelope (infiltration airflow rate assumed to be 45 cfm), and the CADR of the HEPA air cleaner (assumed to be 325 cfm).