Series Overview

SERIES:
Indoor Air Quality Fact Sheets

This overview introduces the series and provides important background information.

What is airborne transmission?

Strong evidence tells us that the dominant way that diseases like COVID-19 spread is through droplets and respiratory aerosols, which can float and travel, infecting people who inhale them at short and long distances from the infected person.

Indoor air quality and COVID-19:

To protect against COVID-19, schools have implemented many measures recommended by public health professionals: distancing, cohorts, masking, hand-washing, and vaccination. These are effective actions to reduce the spread of the virus, but they rely on human behavior and choice.

After studying viral transmission pathways, scientists are confident that people are less likely to get sick from COVID-19 and other respiratory pathogens when the air around them is refreshed continuously with clean air that is free from the virus. Investing in indoor air quality (IAQ) is a straightforward and non-controversial way to stop the spread of COVID-19.

Know your buildings: What systems do you have?

- **Window unit, radiator, or no space conditioning:** If a mechanical system is present, it is for temperature only and not ventilation (window unit or radiator). Where no mechanical system is present, windows and/or fans may be in use.
- **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.
- **Decentralized heating/cooling systems:** Heats or cools recirculated air and, in some but not all systems, outdoor air. Typically, it has a 1" filter rack. Includes heat pumps and fan coil units.
- **Central system (100% recirculation):** Serves multiple rooms and heats and cools recirculated air. Typically has a filter. Examples: AHU and RTU units.
- **Central system (recirculation + ventilation):** Serves multiple rooms and mixes outside air with recirculated air while heating and cooling. Typically has a filter. Examples: AHU and RTU units.

The right strategy for your classrooms?

Mechanical systems can include heating, ventilation, and/or air-conditioning, but they do not always provide all three. Strategies that can be considered will depend on the capabilities of your system.

	Building System Type				
Fact Sheet Topic	Window unit, radiator, or no space conditioning	Unit ventilator or univent	Decentralized heating/cooling systems	Central System serving one or multiple rooms/zones	
				100% recirculation	Recirculation + ventilation
Ventilation: Mechanical		✓	Depending on system		✓
Ventilation: Natural (operable windows)	✓		✓	✓	
HVAC Filtration		Depending on pressure drop might need to increase filter rack from 1" to 2"	Depending on pressure drop might need to increase filter rack from 1" to 2"	Depending on pressure drop	Depending on pressure drop
In-Room HEPA Air Cleaners	✓	✓	✓	✓	✓
Upper-room Germicidal UV	✓	✓	✓	✓	✓
In-duct Germicidal UV				✓	✓

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The IAQ Fact Sheet Series was authored in collaboration with Marwa Zaatari, with technical assistance from Sarah Gudeman.

Recommendations for schools from ASHRAE's COVID Epidemic Task Force

ASHRAE is an organization known for establishing standards for building design, including strategies that impact air quality.

- Ventilate spaces per minimum standards (ASHRAE 62.1)
- Clean recirculated air using MERV 13 filtration or equivalent
- Use only air cleaners for which evidence of safety is clear
- Use air cleaners (HEPA, UVGI) where needed to minimize exposure while considering energy impacts

Proven strategies include "subtractive" technologies like filters, sorbent media, and UVGI, which remove targeted contaminants from the air.

Unproven strategies include "additive" technologies like electronic air cleaners, ionizers, and fumigation that add things to the air to remove particles, inactivate microorganisms, or react with chemical contaminants.

Reaching your air change rate goal:

eACH is equivalent air change rate. It is calculated by adding all ventilation and air cleaning strategies. A reasonable target for air change rate in a classroom is at least 6 eACH.

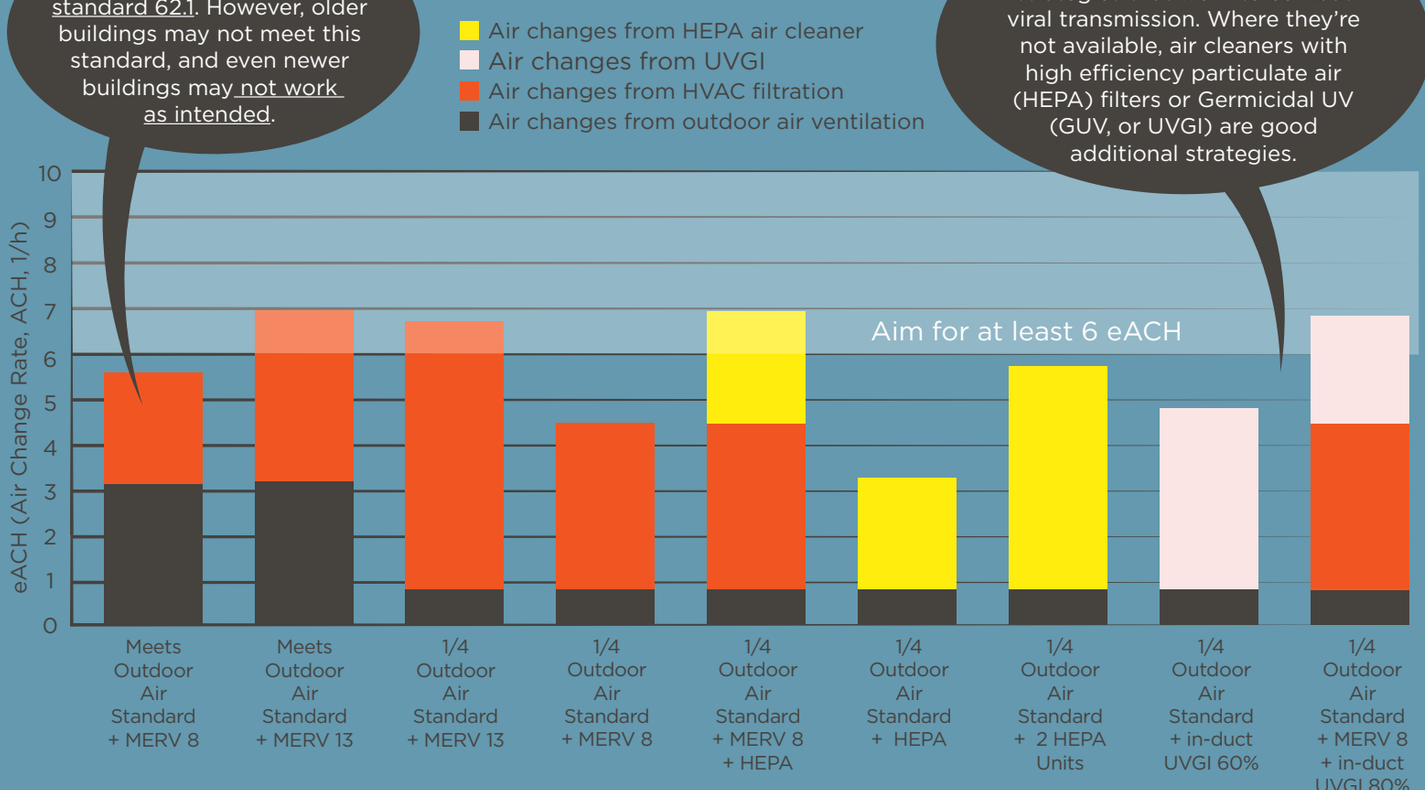
Example eACH for a typical 1,000 ft² classroom

This eACH calculation may vary based on factors such as the amount of air supplied from an HVAC system. The graph is provided as a general comparison between strategies and as an example of how strategies can be combined for infection control.

Imagine measuring contaminants in a space and then starting a stopwatch. At 6 eACH, at the end of 30 minutes, 95% of the original contaminants would have been removed. At a lower eACH, it would take longer to get the same result. At a higher eACH, it would take less time.

Minimum outdoor air is governed by ASHRAE standard 62.1. However, older buildings may not meet this standard, and even newer buildings may not work as intended.

Ventilation and filtration are long-lasting strategies that work to combat viral transmission. Where they're not available, air cleaners with high efficiency particulate air (HEPA) filters or Germicidal UV (GUV, or UVGI) are good additional strategies.



Acronyms used in the fact sheet series

CADR: clean air delivery rate
eACH: equivalent air change per hour
HEPA: high efficiency particulate air (i.e., HEPA filters, HEPA air cleaner)
HVAC: heating, ventilation, and air conditioning
MERV: minimum efficiency reporting value
OA: outdoor air
PPE: personal protective equipment
PPM: parts per million
UVGI: ultraviolet germicidal irradiation, also know as germicidal UV (GUV)

Ventilation

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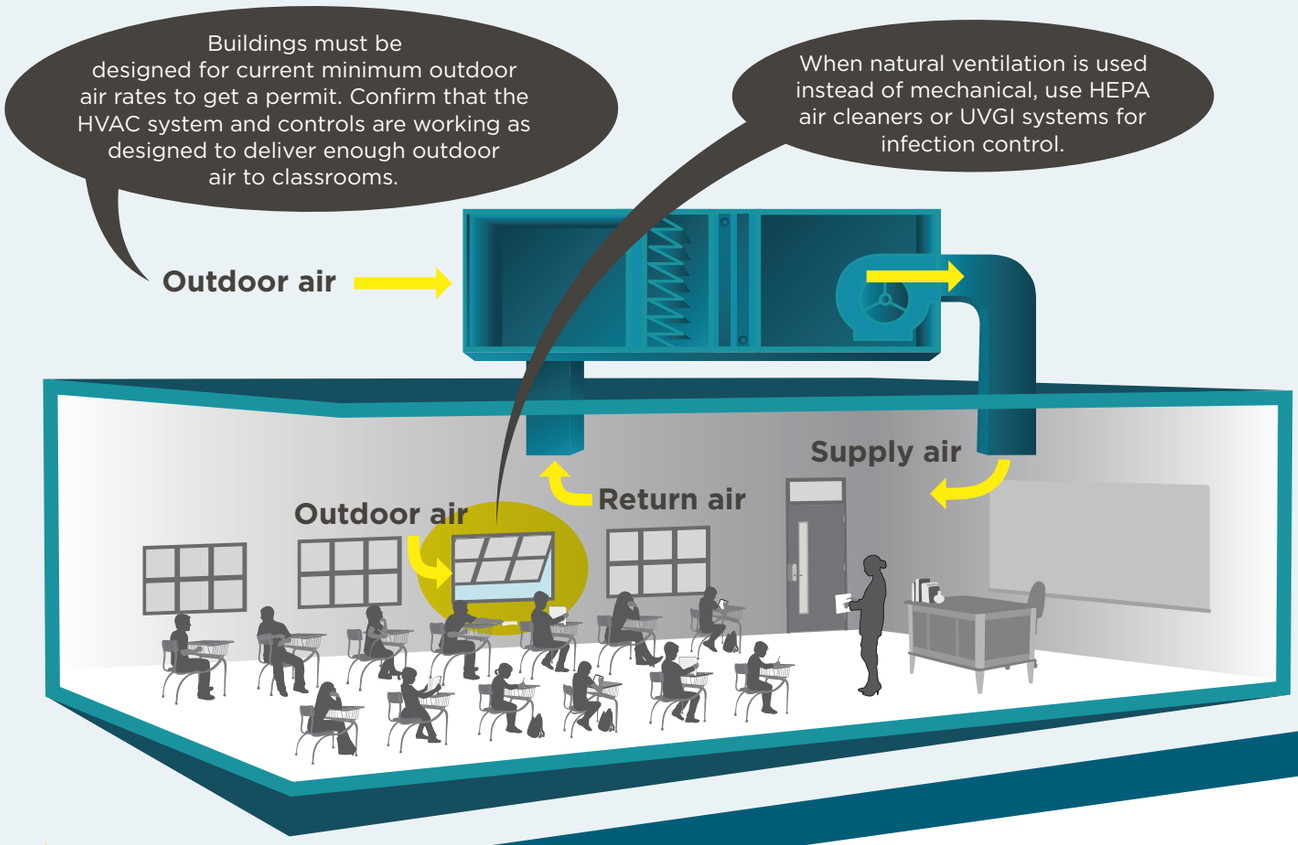
Ventilation basics:

Ventilation is outdoor air brought into a building intentionally, to control air contaminants. The required rate of outdoor air is based on occupancy and floor area. Since 1990, the minimum rate for typical classrooms has been approximately 15 cubic feet per minute (CFM) per person, set by ASHRAE Standard 62.1. There are two forms of ventilation: mechanical and natural.

Mechanical ventilation brings in outdoor air via a forced air delivery system, such as a heating, ventilation, and air conditioning (HVAC) system.

Natural ventilation allows in outdoor air via open windows and/or doors that are designed to serve the space's ventilation needs. Natural ventilation is most effective on windy days or when there is strong temperature difference between indoors and outdoors, but its effectiveness can vary based on many factors. For infection control, use High Efficiency Particulate Air (HEPA) cleaners or Germicide Ultraviolet Air Disinfection (GUV, also known as UVGI) systems during periods of low natural ventilation.



Costs and benefits of outdoor air

Outdoor air, particularly humid air, needs to be treated before it can be introduced inside, which takes energy. The annual cost of outdoor air ranges from a few dollars to a max of $10 per person per year. The benefits are enormous; studies show that under-ventilated schools are associated with increased transmission of infection, asthma exacerbation, and other cognitive and health impacts.

School ventilation in the U.S.:

Research has demonstrated that classroom under-ventilation in the U.S. is far too common.

Researchers hypothesize several reasons for low ventilation rates, including lack of verification when systems were installed, deferred maintenance, or attempts to save energy.

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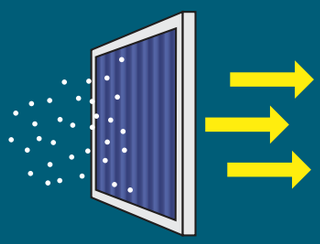
Carbon dioxide:

CO_2 concentration can be an indicator of ventilation effectiveness. Lower rates mean that exhaled air is being appropriately diluted.



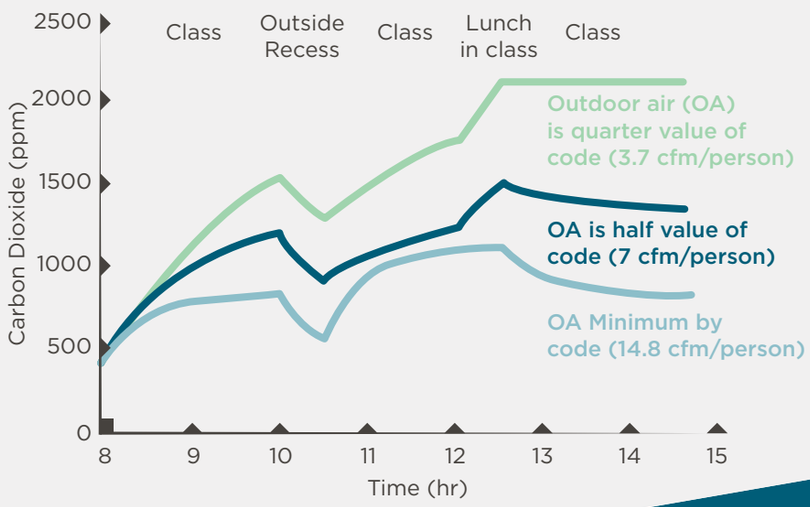
CO_2 does not directly indicate risk of exposure to COVID-19 because it cannot capture the impact of filtration strategies.

Monitoring CO_2:

The best use of carbon dioxide monitors in classrooms is to identify issues with the HVAC system or to indicate insufficient ventilation.

To interpret the data correctly, CO_2 levels must be logged throughout the school day in a typically occupied classroom. CO_2 spot checks will not give you the maximum CO_2 or the general trend of the values. For example, at typical occupancy and outdoor air that is below code, a reading could be 800 ppm at 8:30am or 2,200 ppm at midday.

Example classroom with 21 students (ages 5-9) and 2 adults



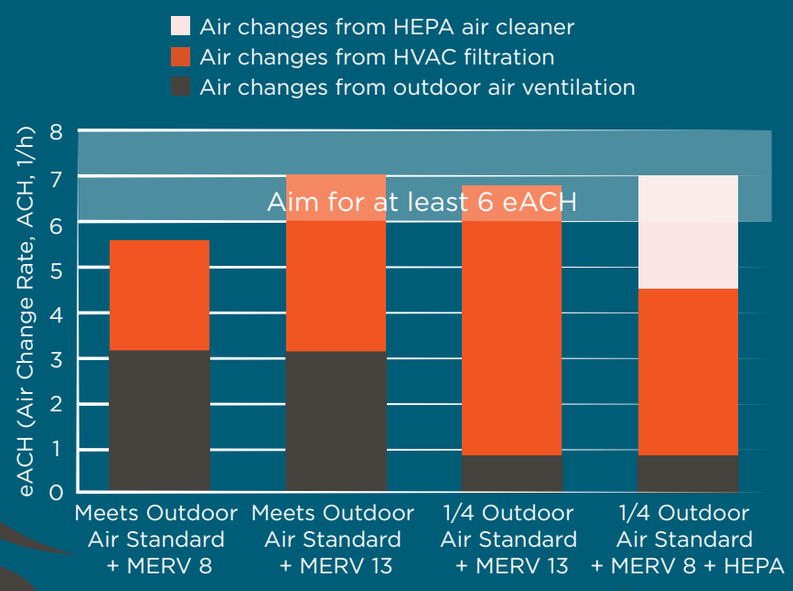
Using ventilation to reach your air change rate goal:

eACH is equivalent air change rate. It is calculated by adding all ventilation and air cleaning strategies. A reasonable target for air change rate in a classroom is at least 6 eACH.

Imagine measuring contaminants in a space and then starting a stopwatch. At 6 eACH, at the end of 30 minutes, 95% of the original contaminants would have been removed. At a lower eACH, it would take longer to get the same result. At a higher eACH, it would take less time.

Example eACH for a typical 1,000 ft² classroom

This eACH calculation may vary based on factors such as the amount of air supplied from an HVAC system. The graph is provided as a general comparison between strategies and as an example of how strategies can be combined for infection control.



Minimum outdoor air is governed by ASHRAE standard 62.1. However, older buildings may not meet this standard, and even newer buildings may not work as intended.

Even with limited outdoor air, a combination of strategies can achieve 6 eACH or higher.

Benefits of ventilation beyond COVID

1. Reduced incidence of respiratory illness, including asthma, common cold, and influenza.
2. Reduced stale air and odors and prevention of headaches and drowsiness.
3. Contributes to better air quality, which is linked to improved cognitive function and higher academic achievement.

HVAC Filtration

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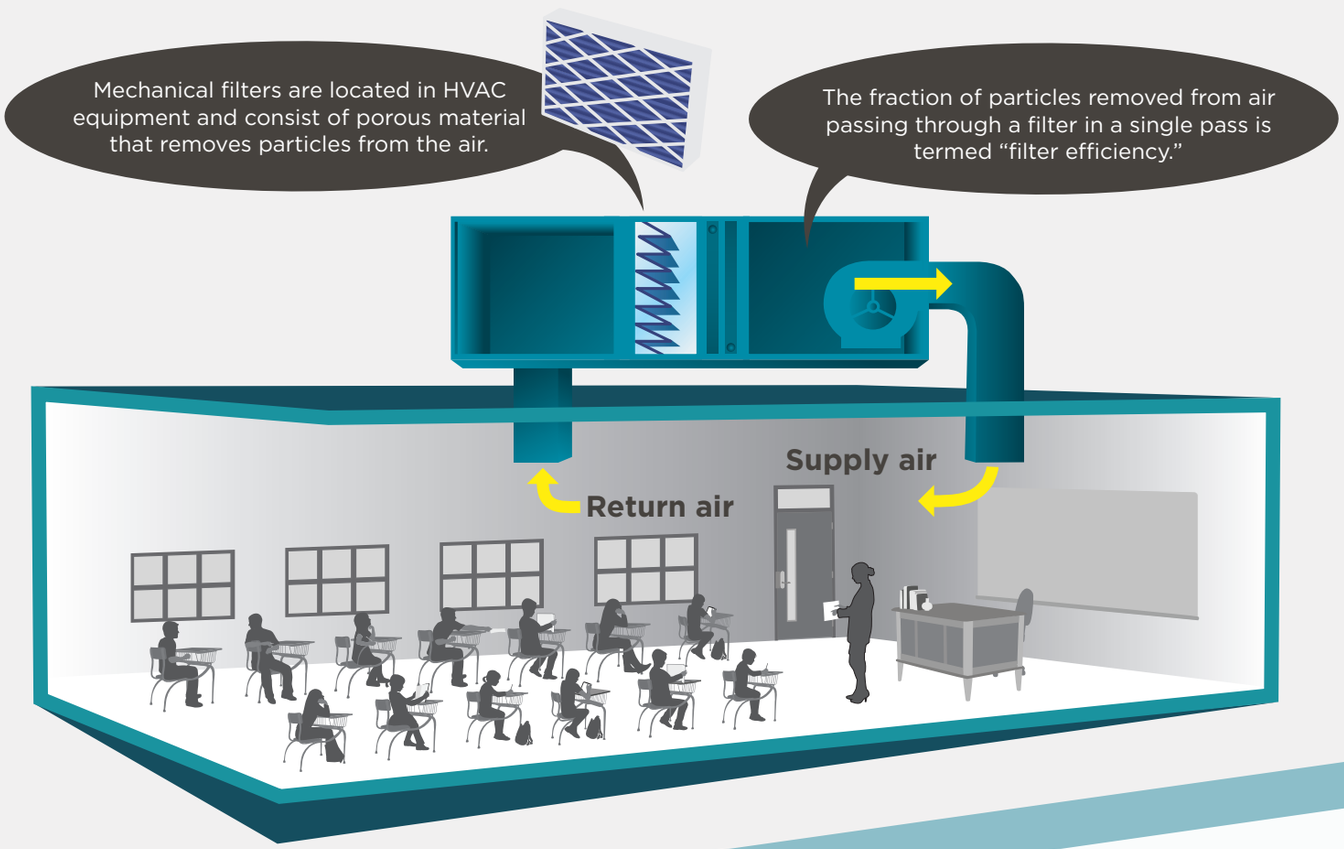
This fact sheet is one in a series. See series overview for background information.

Filter basics:

The Minimum Efficiency Reporting Value (MERV) expresses a filter's ability to capture particles of various sizes. Filters used in heating, ventilation, and air conditioning (HVAC) systems typically range from MERV 1 (least efficient) to 16 (most efficient). 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 not a feasible upgrade. To get the best performance, it is critical to change the filter on the schedule recommended by the manufacturer and ensure a proper fit so that air cannot pass next to the filter.



MYTH 1

MERV 13 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, the pressure drop does not always correlate directly with the MERV for the filter (higher MERV does not always mean higher pressure drop). There is a wide range of pressure drop for a given MERV depending on how filters are constructed (for example, a deeper 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 versus a more efficient filter. If the pressure drop will be higher, an engineer will need to determine if the additional pressure drop is within the capability of the HVAC fan.

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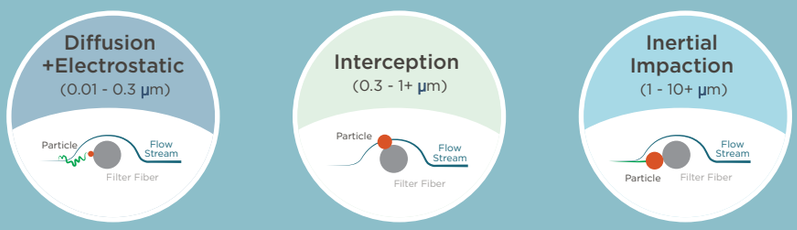
Mechanism:

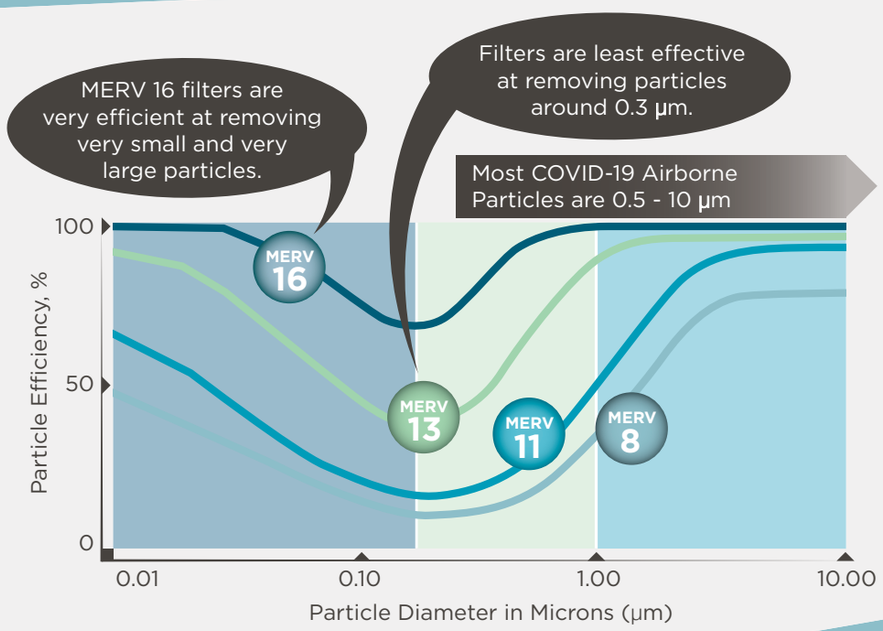
Filtration captures particles through multiple mechanisms.



MYTH 2

HVAC filters are not able to capture the kind of small particles that contain a virus.

This is a misconception. Filters work to capture particles in many ways; they are not sieves, where only particles bigger than the openings will be trapped. High efficiency filters are effective at capturing particles that carry viruses.



Using filtration to reach your air change rate goal:

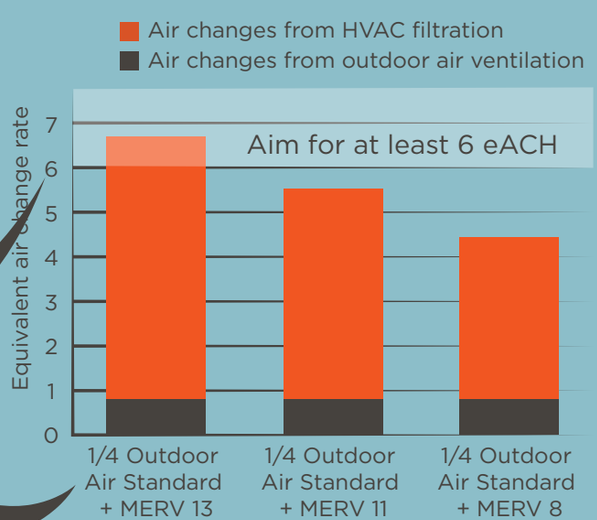
eACH is equivalent air change rate. It is calculated by adding all ventilation and air cleaning strategies. A reasonable target for air change rate in a classroom is at least 6 eACH.

Example eACH for a typical 1,000 ft² classroom

This eACH calculation may vary based on factors such as the amount of air supplied from an HVAC system. The graph is provided as a general comparison between strategies and as an example of how strategies can be combined for infection control.

Imagine measuring contaminants in a space and then starting a stopwatch. At 6 eACH, at the end of 30 minutes, 95% of the original contaminants would have been removed. At a lower eACH, it would take longer to get the same result. At a higher eACH, it would take less time.

Even with limited outdoor air, 6 eACH can be achieved with high efficiency filters.



Minimum outdoor air is governed by ASHRAE standard 62.1. However, older buildings may not meet this standard, and even newer buildings may not work as intended.

Benefits of improved filtration beyond COVID

1. Reduced incidence of respiratory illness, including asthma, common cold, and influenza.
2. Increased ability to operate when outdoor air is too hot or cold or when particulate levels are high, such as due to wildfire smoke.
3. Contributes to better air quality, which is linked to improved cognitive function and higher academic achievement.

In-Room Air Cleaners

SERIES:
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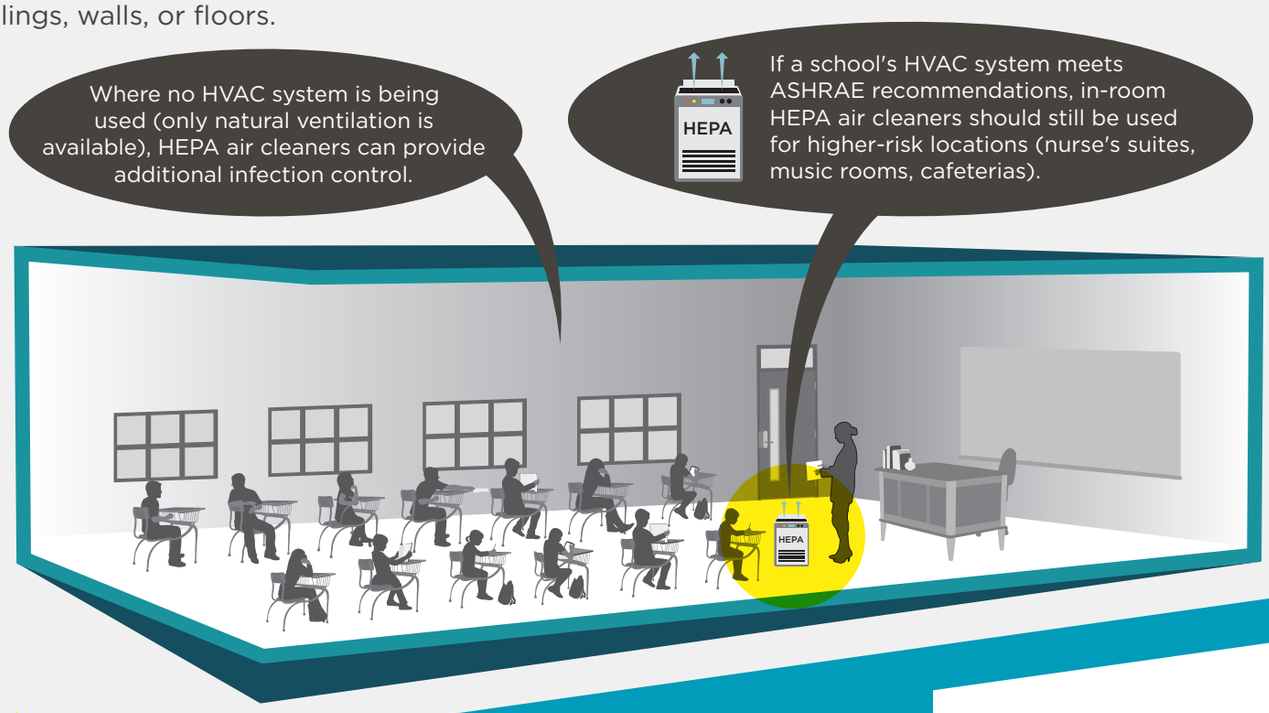
This fact sheet is one in a series. See series overview for background information.

Air cleaner basics:

In-room air cleaners are installed within an occupied space and work by pulling in air and filtering it before sending it back out into the space. They are independent from a heating, ventilation, and air conditioning (HVAC) system. In-room HEPA air cleaners contain high efficiency particulate air (HEPA) filters, which are certified to meet their stated efficiency.

In-room air cleaners 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 or above ceilings, walls, or floors.



Tips for selecting air cleaners:

- **IDENTIFYING HEPA FILTERS:** Filters that are HEPA 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.
- **PLACEMENT:** Place 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 the teacher and between the teacher and the students.
- **NOISE:** Check manufacturer's data for noise levels, and choose one that meets the recommended 35-50 dBA for classrooms. If a unit is too noisy at its highest fan speed, consider running two units at a lower speed to keep noise down.
- **COST:** Look for the price, availability, and expected lifetime of replacement filters. Include this cost in your planning.
- **COMPONENTS:** Check for add-ons you do not want or need. HEPA filters are the most effective method for removing particles that may contain the virus, and additional technologies are often more problematic than helpful.
- **MAINTENANCE:** Clean prefilters and replace filters as recommended by the manufacturer.

What is CADR?

An in-room air cleaner should be chosen so that its clean air delivery rate (CADR) meets the needs of the room. The CADR is usually given for the highest fan speed, so if the unit runs at lower speeds, the CADR will be lower. Look for a unit with a CADR at least 2/3 your room's area. For example, a 20′ x 30′ room (600 ft^2) would require CADR of at least 400. Multiple air cleaners can be added to get the total required CADR (e.g., two units with 200 CADR would meet the 400 CADR requirement).

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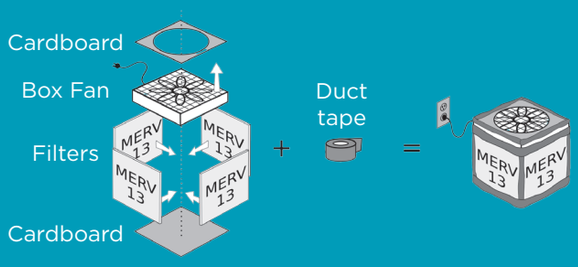
DIY in-room air cleaner:

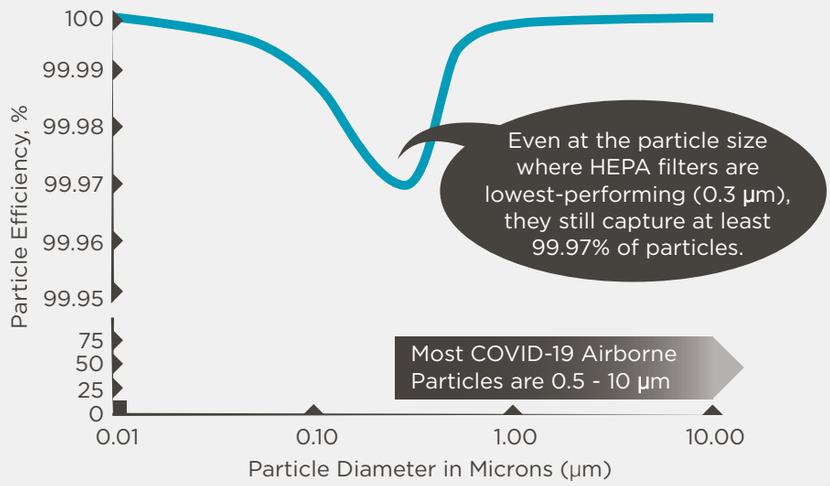
A cheaper alternative to purchasing an in-room air cleaner is the DIY Corsi-Rosenthal filter box, made with a box fan, MERV 13 or MERV 11 filters, cardboard, and duct tape.



MYTH

Viruses are too small to be captured by filters.

HEPA filters are more than 99.97% efficient at capturing particles of all sizes, including those that carry the COVID-19 virus. Using HEPA in-room air cleaners correctly is the most effective way to increase clean air delivery in schools.



Using air cleaners to reach your air change rate goal:

eACH is equivalent air change rate. It is calculated by adding all ventilation and air cleaning strategies. A reasonable target for air change rate in a classroom is at least 6 eACH.

Example eACH for a typical 1,000 ft² classroom

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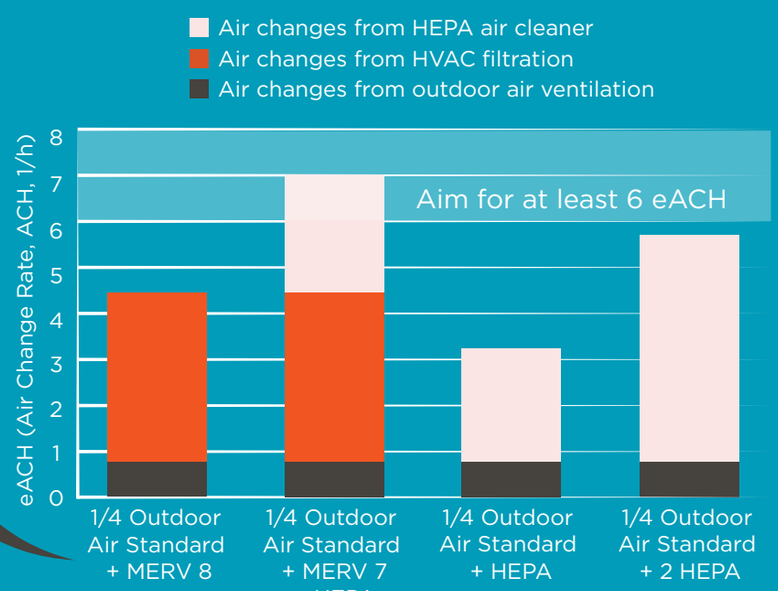
Imagine measuring contaminants in a space and then starting a stopwatch. At 6 eACH, at the end of 30 minutes, 95% of the original contaminants would have been removed. At a lower eACH, it would take longer to get the same result. At a higher eACH, it would take less time.



Even with limited outdoor air and MERV 8 filters, air cleaners can help reach 6 eACH.

The effectiveness of natural ventilation (usually through windows) can vary. Where windows are the only outdoor air available, air cleaners are an important strategy to remove contaminants.

Benefits of air cleaners beyond COVID

1. Air cleaners can be used as supplemental filtration when outdoor air quality is poor, such as during wildfires.
2. HEPA filtration is the most effective method at reducing particles like allergens in the air and can reduce respiratory symptoms like asthma.
3. Continuous use of air cleaners is associated with respiratory and heart health benefits for both healthy and at-risk populations.

Germicidal Ultraviolet

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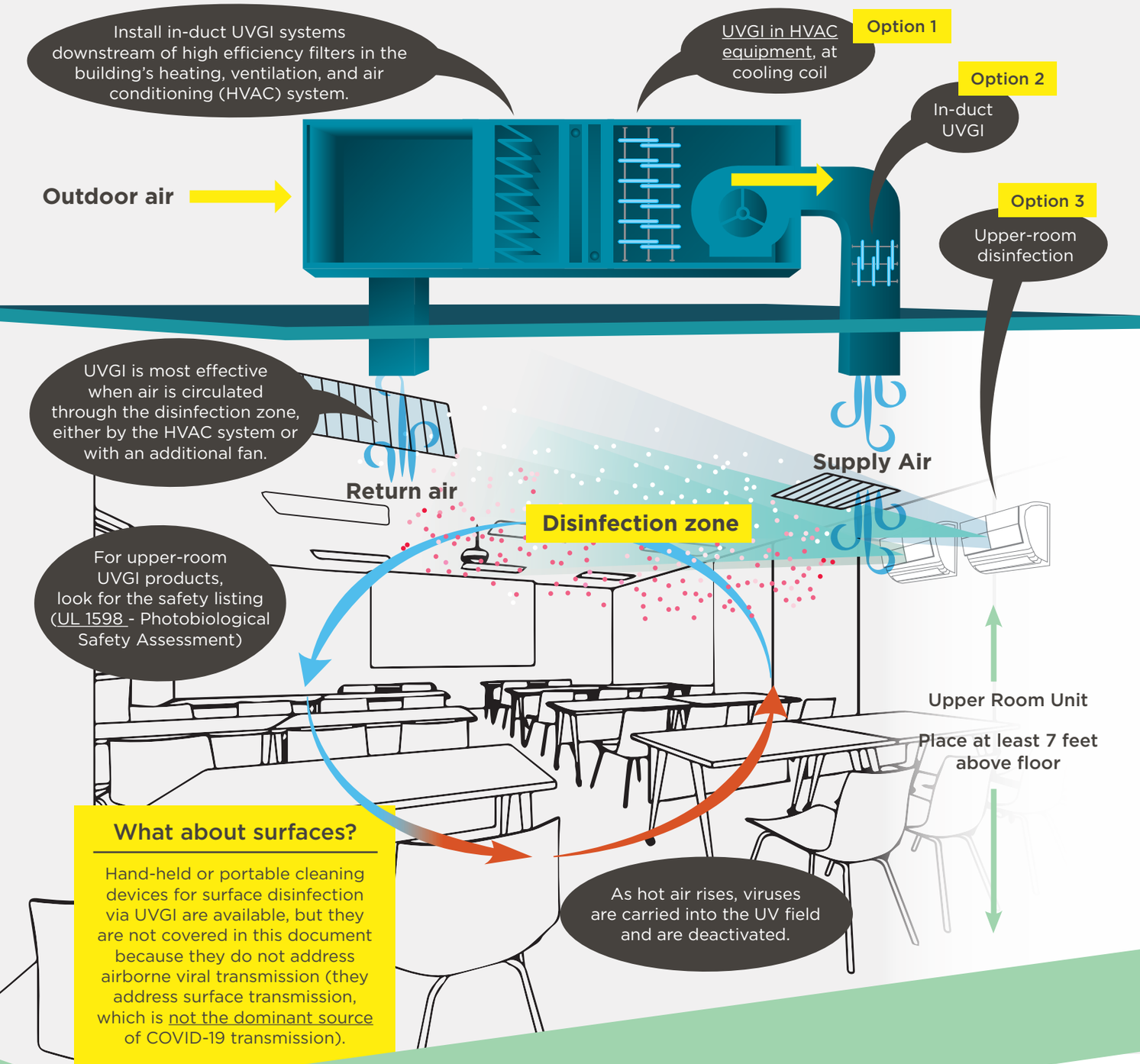
Germicidal ultraviolet basics:

Germicidal ultraviolet (GUV), sometimes referred to as ultraviolet germicidal irradiation (UVGI), inactivates viruses, bacteria, and fungi. It is a strategy that has been documented in research and real-world applications to reduce airborne viral transmission by 80% or more when properly applied. The wavelength of light with the most germicidal effect is in the UV-C spectrum. Current technology on the market uses the wavelength 254 nm because it is cost-effective, does not generate ozone, and damages the DNA and RNA of viruses, bacteria, and fungi.

UVGI should be considered when there is a need to provide a large equivalent air change rate, to remove contaminants near a source, and/or to mitigate higher-risk locations such as nurse's suites or places where people are gathering in high density. There are several types of UVGI systems used in locations like schools: in HVAC equipment in-duct, and upper room.



What about surfaces?

Hand-held or portable cleaning devices for surface disinfection via UVGI are available, but they are not covered in this document because they do not address airborne viral transmission (they address surface transmission, which is not the dominant source of COVID-19 transmission).

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Dose:

The dosage determines the ability of UV-C to inactivate microorganisms. The higher the dose, the higher the ability to disinfect. Dose is calculated by multiplying the germicidal radiation level (how powerful the UV-C energy is, in watts per square meter) by the amount of time a virus, bacteria, or fungi spends in the UV-C field.

Tips for using UVGI:

UVGI systems should be installed with on/off switches and interlocks to limit access only to trained personnel and staff.

- **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 protective PPE when cleaning and servicing the unit and anything in the disinfection zone.
- **INSTALLATION:** For systems in the 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 be no more than 0.4 $\mu W/cm^2$ at 6.5 ft above the floor anywhere in the room, measured with a sensitive UV-C meter.
- **MAINTENANCE:** The effective dose of UV-C lamps can degrade over time. Maintain the system by replacing lamps per manufacturer recommendation (usually once per year).

Using UVGI to reach your air change rate goal:

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Example eACH for a typical 1,000 ft^2 classroom

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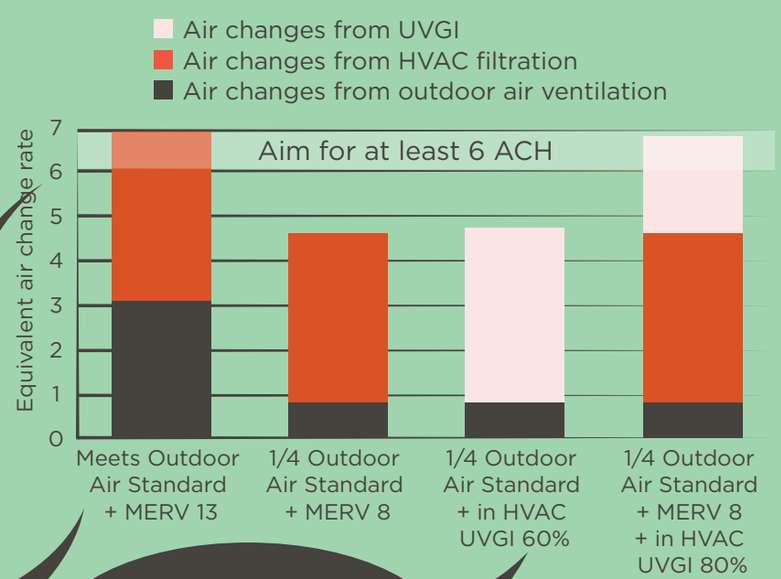

Even with limited outdoor air, a combination of strategies can achieve 6 eACH or higher.

Minimum outdoor air is governed by ASHRAE standard 62.1. However, older buildings may not meet this standard, and even newer buildings may not work as intended.

Manufacturers of UVGI use a percentage to show how efficient the system is in removing contaminants in a single pass.

Benefits of UVGI beyond COVID

1. Fights the cause of respiratory illness, including common cold, and influenza.
2. In HVAC (on coil surfaces): Reduced biofilm buildup on the HVAC coil, which can help maintain system performance.
3. Non-chemical approach to disinfection.