Consumer Room Air Cleaners and Equivalent Air Changes per Hour

January 2026

AHAM
ASSOCIATION OF HOME APPLIANCE MANUFACTURERS

LEADERSHIP. ADVOCACY. A FORUM FOR ACTION.

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ABOUT THE ASSOCIATION OF HOME APPLIANCE MANUFACTURERS (AHAM)

AHAM represents manufacturers of home appliances as well as suppliers to the industry. AHAM's membership includes over 150 companies throughout the world. members employ tens of thousands of people and produce greater than 90% of the household appliances for sale within the United States. The factory shipment value of these products is more than $50 billion annually.

AHAM is also a standards development organization, accredited by the American National Standards Institute (ANSI). The Association authors numerous appliance test standards used by manufacturers, consumer organizations, and governmental bodies to rate and compare appliance performance. AHAM's consumer safety education program provides current educational resources to millions of consumers on ways to safely use appliances such as portable heaters, clothes dryers, and cooking products. The AHAM Verifide® program provides independent testing to verify a product's energy, performance, and efficiency, allowing it to bear the AHAM Verifide® Mark, allowing consumers to trust in the manufacturers stated claims.

The home appliance industry, through its products and innovation, is essential to consumer lifestyle, health, safety, and convenience. Through its technology, employees, and productivity, the industry contributes significantly to the US job market and the nation's economic security. Home appliances are also a success story in terms of energy efficiency and environmental protection. The purchase of new appliances often represents the most effective choice a consumer can make to reduce home energy use and costs.

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Introduction

Millions of people around the world rely on portable room air cleaners (air cleaners) to improve the air quality in their homes, offices, schools, and public spaces. Air cleaners are increasingly touted by experts as part of a plan to reduce the transmission of airborne illnesses. Physicians often recommend air cleaners to help allergy sufferers reduce symptoms. In areas affected by wildfire smoke, room air cleaners are important appliances to improve indoor air quality. The COVID-19 pandemic triggered a surge of interest in indoor air quality and the importance for empowering consumers to verify a manufacturer's performance claims and compare models best suited for their needs. Those empowering measurement values are the Clean Air Delivery Rate (CADR), Air Changes per Hour (ACH), and equivalent Air Changes per Hour (eACH). CADR, ACH, and eACH are established through rigorous, science-based testing and are widely accepted metrics for demonstrating how an air cleaner will perform in a given room size. Knowledge of these performance values will help consumers determine a model best suited for their situation. This paper focuses on the implication of equivalent Air Changes per Hour, which relates to how long it takes for an air cleaner to fully circulate the air in a given room. This 2025 version is an update to AHAM's white paper titled, "Portable Air Cleaners and Air Changes per Hour," published in October 2021.

Air Changes per Hour and Air Cleaners

Air Changes per Hour

Air Changes per Hour (ACH) is a term used to describe the rate at which outdoor air flows into buildings. ACH and air exchange rate are generally interchangeable terms, measuring how often a room's entire air volume is replaced or filtered hourly. ASHRAE 62.2, Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings, defines ACH as airflow in volume units per hour divided by the volume of the space on which the air change rate is based in identical units. It defines infiltration as the uncontrolled inward leakage of air through the dwelling-unit boundary. This term refers to airflows specifically NOT due to mechanical systems. For consumers, ACH is a way to tell how often the air in their room is circulated by the HVAC system and infiltration. In the home, a higher number of air changes in the room presents more opportunities for pollutants to be removed. In contrast, a higher number of infiltrations in homes — such as during a wildfire — can be the source of increased intrusion of outdoor pollutants. Thus, this white paper will refer to "equivalent air changes per hour" as the air changes within the room and the "infiltration rate" as the number of air exchanges between the house and the exterior.

People spend up to 90% of their time indoors. This means 9 out of 10 breaths are taken indoors, and having clean indoor air to breathe is essential. Modern homes are built to minimize energy losses and maximize energy efficiency. ASHRAE 62.2 recommends that the outdoor air should replace the indoor air in a residential building at least 0.35 times per hour. While this low air change rate may be beneficial for electricity costs, it also can reduce the rate at which allergens and pollutants are removed from the home even though it is preventing some intrusion of these pollutants into the home. It should be noted that most homes do not meet these ASHRAE 62.2 tightness levels. This means most homes are often getting more outdoor pollutants brought in and highlights that the lack of internal ventilation is not allowing dilution of the indoor air pollutants. This is why ASHRAE 62.2 additionally requires ventilation that provides 7.5 CFM per person per area and requires a minimum MERV 11 filter. The U.S. Environmental Protection Agency (EPA) estimates that indoor air pollutant levels are two to five times higher than outdoor pollutant levels. High levels of pollutants and allergens can trigger more asthmatic and allergic reactions. Moreover, in response to public health concerns, the U.S. Centers for Disease Control and Prevention (CDC) now recommends achieving at least 5 total ACH in occupied spaces to reduce airborne pathogens, which the EPA supports as part of its updated ventilation and filtration guidelines.

Clean Air Delivery Rate (CADR)

While this paper focuses on Air Changes per Hour, CADR is the most important metric for measuring air cleaner performance. As the EPA states, CADR is a product of the fractional removal efficiency for a particular pollutant and the airflow rate through the air cleaner.[1] CADR is the volume of clean air provided by an air cleaner every minute. It is a measurement proven through rigorous testing of an air cleaner's ability to remove pollutants.[2] In general, an air cleaner with a higher CADR will be able to remove pollutants from the air at a higher rate than an air cleaner with a lower CADR.

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[1] https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality

[2] CADR is a measure of the reduction rate (cleaning speed) of specific particulates by an air purifier or other filtration system in a controlled environment. CADR is measured in cubic feet per minute or in cubic meters per hour. Three particles (engineering tobacco smoke, fine dust and paper mulberry pollen), representing fine, medium and large particles respectively, are cited in AC-1 and used for CADR testing of air cleaners. The higher the CADR numbers, the better the overall ability of the unit to clean your indoor air and the faster the air in the room will be cleaned. https://ahamverifide.org/wp-content/uploads/2020/06/Air-Cleaner-Performance-FAQs.pdf

To help consumers choose an air cleaner suitable for their needs and the room where the air cleaner will be used, ANSI/AHAM AC-1 defines how CADR can be converted into a Suggested Room Size.[3] A higher CADR translates to a larger Suggested Room Size. Certified Clean Air Delivery Rates are stated only by air cleaners that bear the AHAM Seal.

A product with the AHAM Seal allows consumers to be confident that the products have undergone the AHAM Verifide® testing process, which verifies that manufacturers' claims about the air cleaner's capabilities are legitimate and validates performance annually.

Equivalent Air Changes per Hour and The Relationship Between ACH and CADR

Filtered air can be considered in terms of Equivalent Air Changes per Hour (eACH) and added to the ACH from the HVAC system.[4,5] Hence, the focus of this paper is not on ACH in general or even total ACH, but on eACH, which is derived from the CADR.

Air cleaners are getting increased attention from experts in the indoor air quality (IAQ) community as a way to improve ACH in buildings and rooms. The air cleaner's CADR, and its accompanying Suggested Room Size are two of the factors used to determine the air cleaner's Air Changes per Hour. Air cleaners that carry the AHAM Verifide® Seal have a Suggested Room Size based on 4.8 Air Changes per Hour, which is to say **an AHAM Verifide® air cleaner can deliver cleaned air 4.8 times per hour to the suggested size of a room to maintain the level of cleanliness to the room**.

The "4.8 ACH" on the AHAM Verifide® Seal informs consumers of the Air Changes per Hour solely by an air cleaner. References state that filtered air can be considered eACH and added to the ACH from the HVAC system.

[3] The maximum Suggested Room Size of an air cleaner can be calculated by knowing the CADR from the smallest particle or smoke test. The Room Size is determined by mathematically modeling the steady-state (continuous) and is based on the CADR baseline requirement to remove 80% of cigarette smoke particles between 0.1 and 1.0 micrometer on a steady-state basis. This gives the consumer a way to relate CADR to the square feet or square meters of a room. Room Size (ft2) = CADR (Smoke) x 1.55; Room Size (m2) = CADR (Smoke) x 1.55 x 0.093. https://ahamverifide.org/wp-content/uploads/2020/06/Air-Cleaner-Performance-FAQs.pdf

[4] Filtered air can therefore be considered in terms of equivalent Air Changes per Hour (ACHe). Increasing Air Changes per Hour and air filtration is a simplified but important concept that could be deployed to help reduce risk from within-room, far-field airborne transmission of SARS-CoV-2 and other respiratory infectious diseases. Healthy building controls like higher ventilation and enhanced filtration are a fundamental, but often overlooked, part of risk reduction strategies that could have benefit beyond the current pandemic.

[5] As it is more general, AHAM uses the term eACH for equivalent Air Changes per Hour rather than "ACHe".

Suggested Room Size

Suggested Room Size

The Suggested Room Size for an air cleaner is based on the CADR obtained for reducing engineered cigarette smoke concentrations. This relationship and how CADR is used to calculate Suggested Room Size are captured in AHAM AC-1 Annex E, which is normative.[6] The room size is suggested based upon the ability of the air cleaner to reduce the concentration of smoke particles by 80% in a room to a new steady state when the air cleaner is operating. This includes contributions from room sources and infiltration of air from the outside as well as from other rooms connected to the one where the air cleaner is in use.

The 80% value, the modeling in Annex E, and the relationship between cleaning rate in CADR and Suggested Room Size have been verified by scientists at the National Institute of Standards and Technology (NIST) and recognized as reasonable by the U.S. Federal Trade Commission.[7] Due to the entrance of many new manufacturers to the marketplace and lack of awareness of this endorsed method, other ACH values have been used to claim the Suggested Room Size. These new Suggested Room Size methodologies are not aligned with the target pollutant removal levels defined in Annex E. As derived in Annex E, the following chart in Figure 1 demonstrates that the effectiveness of an air cleaner could vary 45% to 89% of the particles removed depending on if 1 eACH or 10 eACH is used.

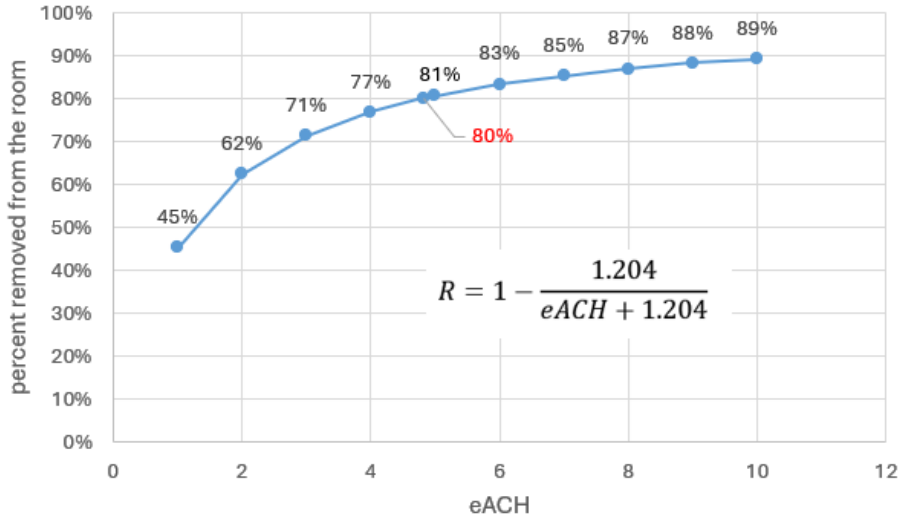

Figure 1. Effectiveness of eACH[8]

As most homes do not meet these ASHRAE 62.2 tightness levels of 0.35 ACH and the CDC recommends achieving at least 5 total ACH**,** when comparing air cleaners, a consumer must consider the air cleaner eACH for the room that the air cleaner is placed in and the percentage of the pollutant that is removed under these conditions.

[6] Mandatory and prescriptive
[7] FTC letter to AHAM (dated May 21, 1993, on file with AHAM).
[8] The relationship between R and eACH is derived from Equation (2) considering a standard construction value of ACH = 1, and the findings in (6) and (7).

Effectiveness of eACH

As highlighted in Table 1 below, an eACH of at least 4.8 for the room size where the air cleaner is to be placed is recommended because it delivers the 80% pollutant removal that has been defined as the acceptance criteria. Depending on the eACH that an air cleaner can deliver, the cleanliness of a room, $1 - R$ (%), varies as shown in Table 1.

Table 1. Effectiveness of eACH[9]

eACH	1	2	3	4	4.8	5	6	7	8	9	10
R	45%	62%	71%	77%	80%	81%	83%	85%	87%	88%	89%

If the air cleaner is used in a room larger than the Suggested Room Size, the number of Air Changes per Hour will be less than 4.8 and the pollutant concentration in the indoor air will be higher. The opposite applies if an air cleaner is used in a room smaller than the Suggested Room Size where the air cleaning and circulation per hour will be greater than 4.8. An air cleaner with a higher CADR will be able to remove pollutants from the air at a higher rate than an air cleaner with a lower CADR.

How eACH is Calculated

The steady state for cleaning has been defined by AHAM's Air Cleaner Council since the early 1990s as 20% or less of the initial particle load in a room, or in other words, a continuous removal of at least 80% of smoke particles. The eACH calculation is based on an air cleaner's ability to reduce the concentration of pollutants by 80% in a room appropriately sized for the device. The calculation assumes one outside ACH of infiltration with a recirculation fan providing complete mixing of air in the room.[10] More importantly, the air cleaner continues to maintain the pollutant concentration at this level even with an influx of polluted air from ventilation, household activities, infiltration, etc.[11]

Concentration of indoor particles is dynamic and results from the competition between various sources and removal processes. Steady state is a situation where neither the sources nor the removal processes are rapidly changing, and thus the indoor concentration is relatively constant. Concentration at steady state in a room is expressed as:

$$C_{ss} = \frac{\text{Source Terms}}{\text{Removal Terms}} = \frac{C_{out} \times ACH}{eACH + ND + ACH} \quad (1)$$

[9] The relationship between R and eACH is derived from Equation (2) considering a standard construction value of ACH = 1, and the findings in Equations (6) and (7).

[10] For AC-1, test chambers use a ceiling fan mounted in the center of the ceiling to stir or mix the pollutants before testing. In the AC-1 test, this fan is shut off during the test. A continuously operating recirculation fan assures uniform mixing of the contaminants during the entire set of tests. The recirculation fan is mounted out of the air stream against a wall to reduce the chance of contaminants gathering in a corner. The recirculation fan runs for all tests whether the air cleaner is operating or not. This recirculation fan does not contribute to the measured performance of the air cleaner but creates a fair and comparable environment for small, medium and large air cleaners so that consumers can equally compare the results of all air cleaners. https://ahamverifide.org/wp-content/uploads/2020/06/Air-Cleaner-Performance-FAQs.pdf

[11] The Suggested Room Size for an air cleaner is based upon the CADR obtained for reducing engineered cigarette smoke concentrations (See Annex E of AC-1). The Room Size is based upon the ability of the air cleaner in smoke CADR to reduce the concentration of particles by 80 % in a room at steady-state to a new steady-state when the air cleaner is operating. This includes contributions from room sources and infiltration of air from outside as well as other rooms connected to the one where the air cleaner is in use. https://ahamverifide.org/wp-content/uploads/2020/06/Air-Cleaner-Performance-FAQs.pdf

Where,

C_{ss}	Concentration in a room at steady state
C_{out}	Concentration of outdoor air that flows into a room
ACH	Outdoor air which flows into a room [hour-1]
$eACH$[12]	Filtered air from an air cleaner in a room; air cleaner delivered ACH [hour-1]
ND	Natural decay in a room [minute-1]

Based on the field measurement data,[13] it is known that the deposition rates of smoke particles are close to 0.0034 minute^{-1}, which is natural decay rate:

$$C_{ss} = \frac{C_{out} \times ACH}{eACH + (0.0034 \times 60) + ACH} = \frac{C_{out} \times ACH}{eACH + 0.204 + ACH} \quad (2)$$

At the initial state of the room where the Air Changes per Hour of the room is a standard construction value of $ACH = 1$, and there is no air cleaner in the room:

$$eACH = 0 \quad (3)$$

$$ACH = 1 \quad (4)$$

Substitute (3) and (4) into Equation (2):

$$C_{ss} = C_{in} = \frac{C_{out} \times 1}{0 + 0.204 + 1} \quad (5)$$

$$C_{out} = 1.204\, C_{in} \quad (6)$$

Where,

C_{in}	Concentration of indoor particles to be reduced by an air cleaner excluding natural decay

As mentioned above, steady state for cleaning is defined as at least 80% continuous removal of smoke particles. Hence, $C_{in} = 1$, at initial state.

$$R = 0.8$$

$$C_{ss} = 1 - R = 0.2 \quad (7)$$

Where,

R	Continuous % reduction in decimals $(= 1 - C_{ss})$

When there *is* an air cleaner in the room of the Suggested Room Size ($eACH \neq 0$), Equation (2) can be solved for $eACH$ knowing (6) and (7) at initial state:

[12] Another understanding of the CADR is how many times an air cleaner can process the entire room's air volume to maintain the indoor particle concentration to 20% of its initial level.

[13] Derived from over 35 years of the AHAM Air Cleaner Certification Program annual verification testing.

$$0.2 = \frac{(1.204 \times 1) \times 1}{eACH + 0.204 + 1}$$

$$0.2 = \frac{1.204}{eACH + 1.204}$$

$$eACH = 4.816 \quad (8)$$

AHAM rounds the 4.816 eACH down to 4.8 eACH. The Suggested Room Size of an air cleaner stated on the AHAM Verifide® Seal is always based on the air cleaner's ability to clean and circulate the air in the room 4.8 times per hour. For the air cleaner to be able to keep up with unfiltered infiltration air entering a room with the Suggested Room Size, the air cleaner must deliver a sufficient amount of clean air to the whole room 4.8 times per hour.

The result in (8) is aligned with what was previously explained and what is derived in Annex E, which is to say, when the volume of a room is V ft^3, an AHAM Verified air cleaner is able to provide clean air of V ft^3 to the room 4.816 times per hour to maintain the 80% steady-state cleanliness defined above.

How AHAM Suggested Room Size is Calculated

For an accurate calculation based on eACH, 4.816 eACH is used in place of the rounded 4.8 eACH. Translating 4.816 eACH to the air cleaner's smoke CADR in cubic feet per minute (CFM) that is required to meet the 20% concentration level in an 8-foot ceiling room with the square footage of A (ft^2):

$$\text{smoke CADR } [\text{ ft}^3/\text{min }] = 4.816\, V \ [\text{ ft}^3/\text{hour }]^{14}$$

$$\text{smoke CADR } [\text{ft}^3/\text{min}] = \frac{4.816}{60\ [\text{min}]} \times (8\ [\text{ft}] \times\ A\ [\text{ft}^2]) \quad (9)$$

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[14] While this revision of the paper provides further clarity in deriving the 1.55 multiplier to calculate room sizes, this footnote is to supplement the gaps for those who are familiar with the formulars in the previous version of this paper.

The general form of this formula by leaving eACH as a variable is,

$$\text{smoke CADR } [\text{ ft}^3/\text{min }] = eACH \times V\ [\text{ ft}^3/\text{hour }]$$

$$\text{smoke CADR} = \frac{eACH}{60} \times V\ [\text{ ft}^3/\text{min }]$$

$$eACH = \frac{\text{smoke CADR} \times 60}{V}$$

$$eACH = \frac{\text{smoke CADR} \times 60}{8 \times A} \quad (15.1)$$

Solving (15.1) for Room Size, *A*:

$$A\ (\text{Room Size}) = \frac{\text{smoke CADR} \times 60}{eACH \times 8} \quad (15.2)$$

Target eACH is 4.816 :

$$A = \frac{\text{smoke CADR} \times 60}{4.816 \times 8} \quad (15.3)$$

(15.3) turns out to be identical to in (10).

Solving (9) for room size (A):

$$A\,[\mathrm{ft}^2] = \frac{60}{8 \times 4.816} \times \text{smoke CADR} = 1.557 \times \text{smoke CADR} \qquad (10)^{17}$$

Rounding down 1.557 to two decimal points for simplicity, Equation (10) becomes:

$$\textbf{Suggested Room Size } [\mathbf{ft}^2] = \mathbf{1.55} \times \textbf{smoke CADR} \qquad (11)$$

It should be noted that the multiplier 1.55 in Equation (11) is the same derivation of room size starting with removal rate calculation in Annex E.

By knowing the relationship in Equation (11), an air cleaner with a smoke CADR rating of 100 CFM can be suggested for use to clean a 155 ft^2 room, as shown in Figure 2. If an air cleaner with a smoke CADR rating of 100 CFM when measured in the AC-1 test chamber is used in a room with an AC-1 Suggested Room Size, it is calculated to be able to provide clean air to the whole room 4.8 times per hour. This results in a continuous 80% reduction of pollutants from the room. It should be noted that the room is assumed to have a continuous pollutant infiltration or intrusion rate of 1 ACH.

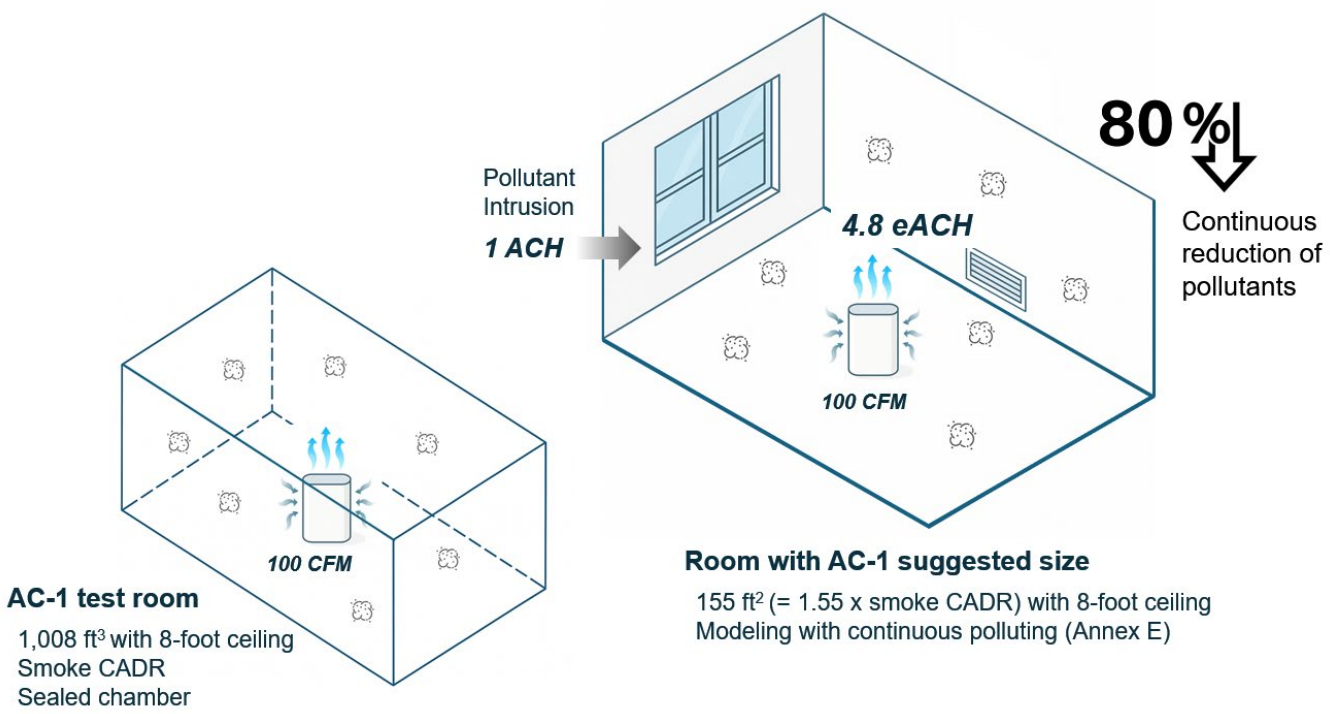

Figure 2. Performance of an air cleaner in AC-1 Suggested Room Size

Comparatively, for a room size of 100 ft^2, an air cleaner with a smoke CADR rating of at least 65 CFM can be suggested for use. This can be calculated solving Equation (11):

$$\text{smoke CADR} = \frac{100}{1.55} = 65\ [\,\mathrm{ft}^3/\mathrm{min}\,]$$

Additionally, if a consumer uses an air cleaner with a smoke CADR rating of 100 CFM in a 750 ft^2 room, the

unit will only deliver eACH of 1. This leads to a 45% continuous reduction (see Table 1). The unit is used in a room much larger than the Suggested Room Size of 155 ft^2 and therefore, the 80% reduction is not achieved (Figure 2). This larger room situation is illustrated in Figure 3, and the eACH calculation is shown below:

$$A\,[\mathrm{ft}^2] = \frac{60}{8 \times eACH} \times \text{smoke CADR} \tag{12}$$

$$eACH = \frac{60}{8 \times A\,[\mathrm{ft}^2]} \times \text{smoke CADR} = \frac{60}{8 \times 750} \times 100 = 1$$

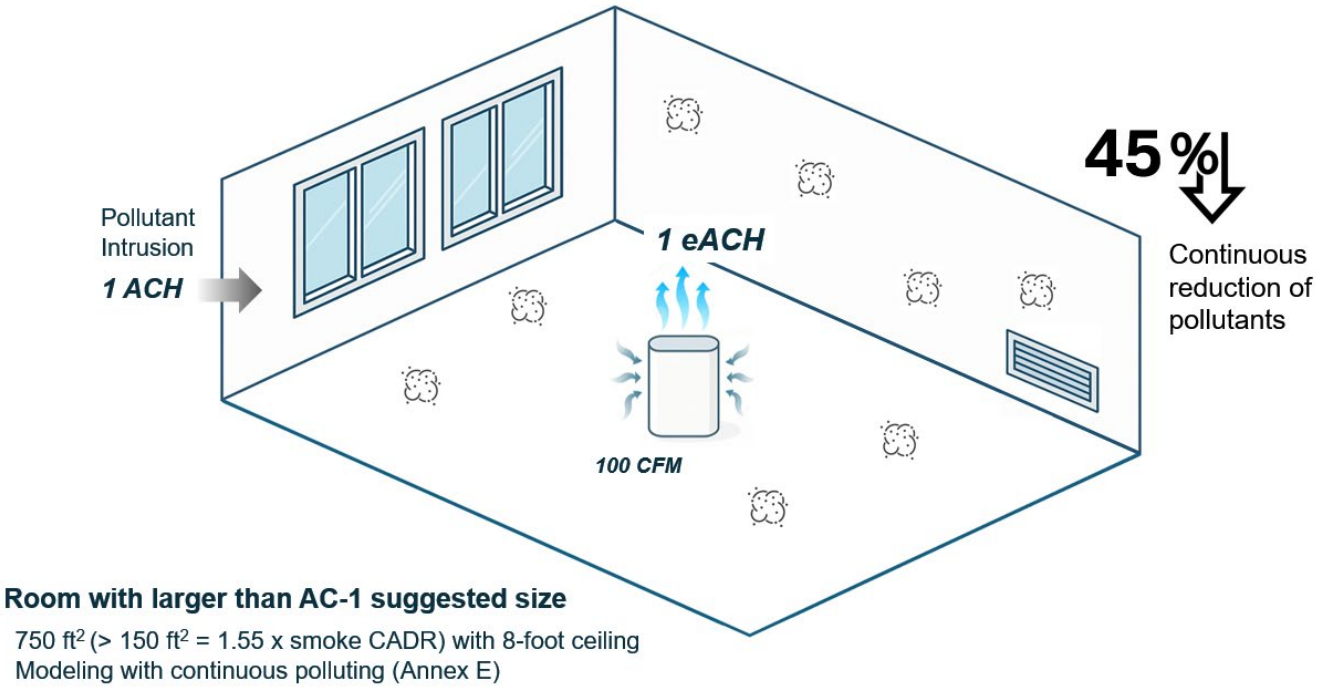

Figure 3. Performance of an air cleaner in a room *larger than* AC-1 Suggested Room Size

Conditions Requiring Additional Calculation Considerations

Wildfire Smoke

Due to the higher concentration of pollutants that can be found in wildfire smoke, above the normal polluted outdoor environmental air, AHAM has added the recommendation for room size for use in the situation of a wildfire event:

$$\text{Suggested Room Size } [\text{ft}^2] \;=\; \text{smoke CADR , under a wildfire circumstance} \tag{13}$$

This means:

1. The load seen by the air cleaner is reduced by $35\% = 1 - 1/1.55$ (ft^3/min). This will provide additional life on the filter, which is critical during wildfire smoke events.
2. Due to the higher concentration of the particles in the air, the reduction is greater than the standard 80% reduction. This revision raises the percentage (%) removal from 80% to 86% in the room size. This is a 6% increase in removal, but more importantly, it moves the air cleaner air exchange rate from 4.8 eACH to 7.5 eACH. This is just over a 50% increase in the equivalent air change rate. This can be calculated from Equation (12), as follows:

$$\text{A } [\text{ft}^2] = \frac{60}{8 \times \text{eACH}} \times \text{smoke CADR} \tag{14}$$

Substituting the relationship in (13) into (14) yields: $\text{smoke CADR} = \frac{60}{8 \times eACH} \times \text{smoke CADR} eACH = \frac{60}{8} = 7.5$

ASHRAE 62.2 Compliant Homes

As noted previously, ASHRAE 62.2-2016 (or later) recommends a minimum tightness of 0.35 outdoor Air Changes per Hour for residential buildings to ensure acceptable indoor air quality from a tight boundary and requires 7.5 CFM per person per area for proper in-home ventilation. The purpose of these recommendations is to improve indoor air quality, minimize adverse health effects, and maintain acceptable levels of pollutants, odors, temperature and humidity. Tighter homes have less intrusion, and their indoor air quality considers total occupant loading as well if homes are equipped with better than MERV 13 filters and are continuously moving air through indoor HVAC ventilation. Dwellings meeting these requirements would reduce the loading of the air cleaner and could impact the size of the air cleaner that consumers need. However, consumers would still want to be confident that they are dealing with other sources of pollutants to get good results, and the previous definition of clean (80% reduction of pollutants) is still valid. The eACH to deliver the 80% reduction with an ASHRAE 62.2 defined tighter home is 2.216. This eACH calculation based on Equation (2) is as follows:

At the initial state of the room where there is no air cleaner in the room and the Air Changes per Hour of the room is 0.35,

$$eACH = 0 \tag{15}$$

$$ACH = 0.35 \tag{16}$$

Substituting (15) and (16) into Equation (2):

$$C_{ss} = C_{in} = \frac{C_{out} \times 0.35}{0 + 0.204 + 0.35} = 0.631\ C_{out}$$

$$C_{out} = 1.583\ C_{in} \tag{17}$$

As it is assumed that $C_{in} = 1$ at initial state and $C_{ss} = 0.2$ to deliver the 80% reduction as well as from the relationship in (17), Equation (2) becomes:

$$0.2 = \frac{1.583 \times 0.35}{eACH + 0.204 + 0.35} \tag{18}$$

Solving Equation (18) about eACH:

$$0.2(eACH + 0.554) = 0.554$$

$$eACH = 2.77 - 0.554 = 2.216$$

ASHRAE 241 (Control of Infectious Aerosols) New Ventilation Levels and Total ACH

During the COVID-19 pandemic, researchers at Harvard University and The University of Colorado-Boulder developed a, *"Portable Air Cleaner Calculator for Schools v1,"* spreadsheet[15] to help with the analysis of total ACH including an air cleaner and achieving the ideal ACH for classrooms. Total air changes[16] include the ACH provided by the HVAC system in addition to the eACH from the air cleaner. The spreadsheet asks users to enter room size and HVAC ventilation levels then estimates how large of a room the selected air cleaner will work in effectively. This tool provides a system to evaluate whether a space would meet the target total ACHs (actual HVAC ventilation together with the CADR from the air cleaner).

TARGET IS AT LEAST 5 TOTAL AIR CHANGES PER HOUR	
	Ideal (6 ACH)
	Excellent (5-6 ACH)
	Good (4-5 ACH)
	Bare minimum (3-4 ACH)
	Low (<3 ACH)

Figure 4. Indoor air quality rating by total ACH

ASHRAE 241 is a standard that provides guidance for controlling infectious aerosols like flu or COVID in a building environment. It introduced the concept of using CFM per person per space. This is a total airflow CFM recommendation (both cleaned air and new air). ASHRAE 241 recommends between 30 and 50 total CFM per person for residential spaces per Table 1 in that document. For example, if two people occupy a 1,000 cubic foot room, they would need a total of 60 to 100 total CFM of clean air, which is equivalent to 3.6 to 6.0 eACH, respectively, if the air cleaner is the only source to clean all of the indoor air. The

[15] Harvard-CU Boulder Portable Air Cleaner Calculator for Schools.v1.3 - Google Sheets

[16] An ACH rating of 6 is ideal for ventilation as identified in a 5-Step Guide to Checking Ventilation Rates in Classrooms, Harvard T.H. Chan School of Public Health. Guide to measuring ventilation rates in schools.

recommendation of 6.0 eACH per ASHRAE 241 is for a situation where the building is operating in the standard's Infection Risk Management Mode and may or may not have an ASHRAE 62.1[17] compliant HVAC system. This total eACH level is higher than what AHAM Verifide recommends for the room size, and the ASHRAE 241 V_{ACS} calculation takes precedence over AHAM's recommendation when the building is in the Infection Risk Management Mode.

Using Equation (C-2) of ASHRAE 241:

$$eACH = \frac{60 \times V_{ACS}}{V} \quad \text{(C-2)}$$

If the size of a room is 1,000 cubic feet, as in the aforementioned example, the V_{ACS} is 100 CFM, which we can set equivalent to smoke CADR from a conservative standpoint:

$$eACH = \frac{60 \times 100}{1000} = 6.0$$

This means that cleaned air from filtration as well as ventilation should be 100 CFM to meet the 6.0 eACH requirement in the 1,000 cubic-foot space for two people.

To repeat for the lower airflow, if the size of a room is the same but V_{ACS} is 60 CFM, eACH can be calculated from Equation (C-2) as follows:

$$eACH = \frac{60 \times 60}{1000} = 3.6$$

Again, this means that to meet the 3.6 eACH requirement for two people in the 1,000 cubic foot space, 60 CFM of cleaned air from filtration, as well as ventilation, is needed.

To expand on the earlier paragraphs, we have provided the sizing chart in Table 2. It varies from 2.2 to 7.5 eACH and provides different pollutant removal with the lowest reduction being 75 % and the highest as 86 % with continuous pollutant infiltration/intrusion.

Table 2. Room size comparison

Condition	ASHRAE 62.2 Tighter home	ASHRAE 241, 30 CFM/person[a]	AC-1	ASHRAE 241, 50 CFM/person[a]	Higher pollutant intrusion (wildfire event)
Room size multiplier	3.4 × smoke CADR	2.08 × smoke CADR	1.55 × smoke CADR	1.25 × smoke CADR	1 × smoke CADR
Pollutant reduction	80%	75%	80%	83%	86%
ACH[b] by intrusion	0.35[c]	1	1	1	1
eACH by air cleaner	2.2	3.6	4.8	6.0	7.5

[a] 2 people per 1000 ft^3
[b] pollutant intrusion
[c] ASHRAE 62.2 level

[17] ASHRAE 62.1, Ventilation and Acceptable Indoor Air Quality applies to spaces intended for human occupancy within buildings except those within dwelling units in residential occupancies in which occupants are nontransient.

Conclusion

The current AHAM recommendation, based on Annex E in AHAM AC-1, still represents the nominal condition of all of these use cases and can be used for a fair estimation of the environments an air cleaner might be placed in and reasonable anticipated pollutant levels the air cleaner will be used to address.

It is noted in the marketplace that one eACH is often used by many air cleaner manufacturers. However, we have not found evidence that there are manufacturers stating that the 1 eACH room size reduces only 45% of the pollutants with a continuous intrusion rate of 1 ACH. The 45% reduction is not equivalent to the cleanliness level provided by the AHAM Verifide® Suggested Room Size, which aims for an 80% reduction, as specified in Annex E of AHAM AC-1. One eACH also does not deliver the level of cleanliness required by ASHRAE 241 or the level needed for a wildfire smoke event when comparing the values provided in Table 2. Lastly, even in an ASHRAE 62.2 compliant dwelling, the air cleaner based on the room size of 1 eACH would be undersized and not provide the target level of cleanliness.

The AHAM Suggested Room Size method has been endorsed by both NIST and the FTC. Consumers should look for the AHAM Verifide® Seal that lists the Suggested Room Size. That Suggested Room Size is based on the air cleaner's CADR and the chosen eACH. These claims, when applied together, provide the percentage of pollutant removal in the room. Currently, the pollutant removal percentage is not communicated to consumers by manufacturers.

- An AHAM Verifide® air cleaner, when used in a room of its Suggested Room Size, will deliver 4.8 eACH. This provides an 80% continuous reduction of the pollutants with a continuous pollutants intrusion rate of 1 ACH, as defined in Annex E in AHAM AC-1.
- Other eACH rates may provide acceptable performance in combination with the total ventilation, however, without communicating their impact on pollutant removal, they may imply that the level of cleanliness is the same as in AHAM's eACH of 4.8, which is not correct.

There are many factors impacting total ACH, including the HVAC system's design and operation and room geometry and its tightness in addition to the performance of air cleaners, although the precise relationships between these variables and their combined effect have not yet been vetted thoroughly. Total ACH is the sum of the HVAC ACH and the room air cleaner eACH.

For a consumer room air cleaner, higher CADR ratings mean more frequent equivalent air changes will occur in the room. As the number of eACH increases/becomes more frequent, more harmful particulates are removed from the room. AHAM does not recommend, based on Table 2, that the Suggested Room Size coverage be based on less than 2.2 eACH. The size based on the 2.2 eACH should only be considered acceptable for a dwelling built to the ASHRAE 62.2 tightness and building ventilation requirements as well as the absence of a potential contagious aerosol or a wildfire smoke event.

Finally, AHAM also recommends that manufacturers use ANSI/AHAM AC-1 Annex E to calculate suggested room size. If any derivations from the AHAM's approach are made, the resultant percent pollutant reduction should be clearly communicated for transparency to the consumer, especially if it is less than an 80% reduction.