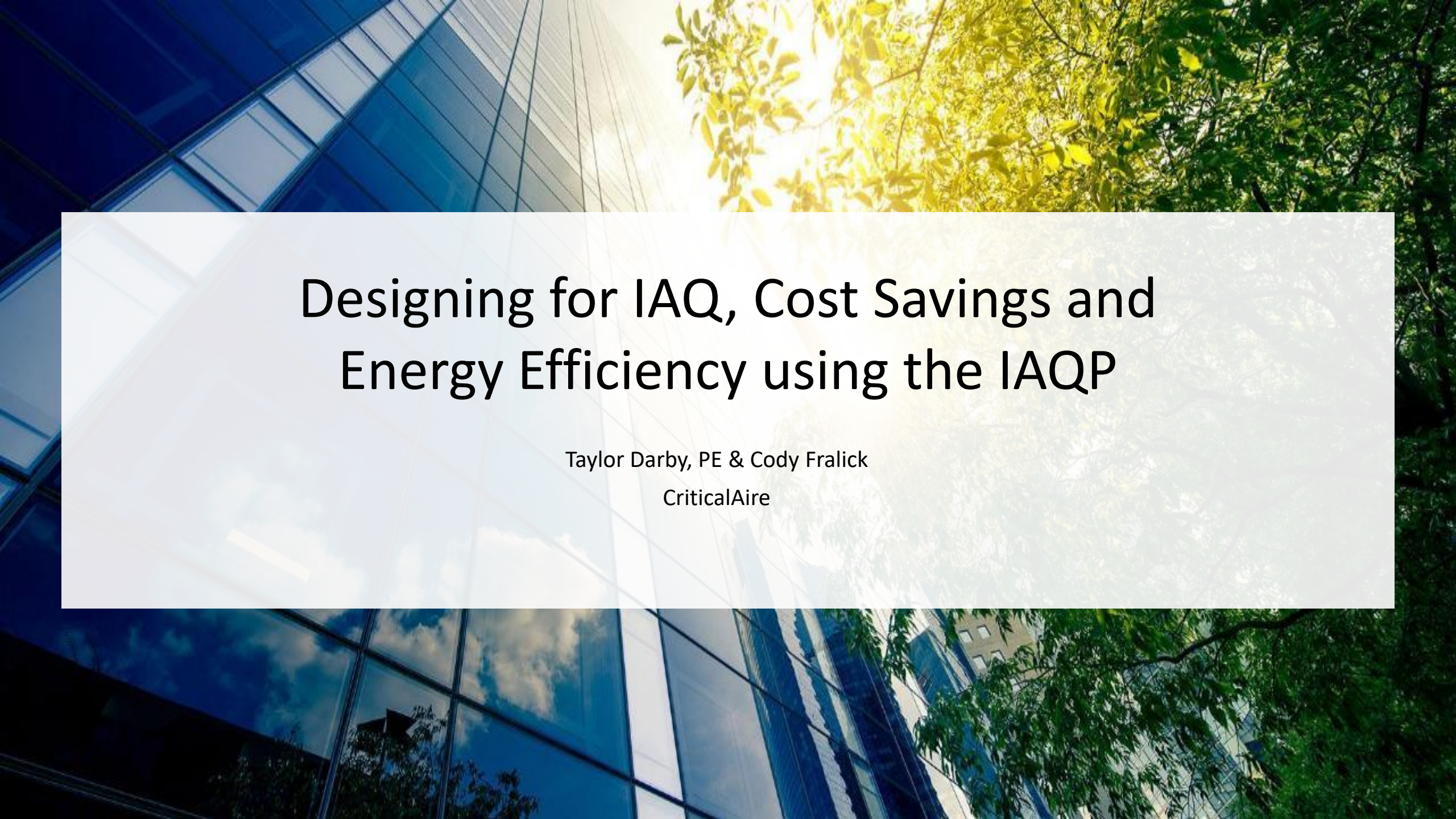


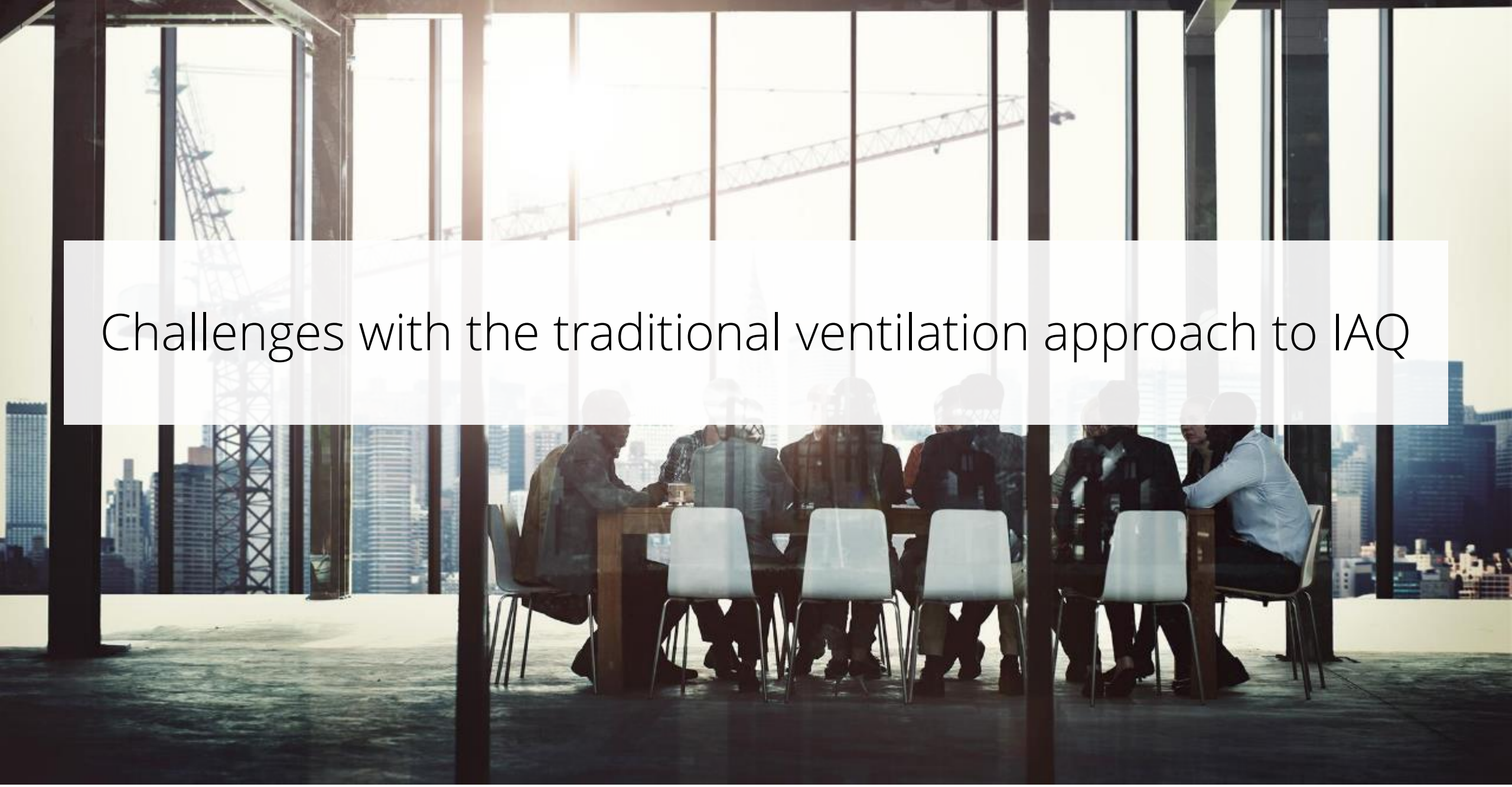
Designing for IAQ, Cost Savings and Energy Efficiency using the IAQP

Taylor Darby, PE & Cody Fralick

CriticalAire

Agenda

- Challenges to Ventilating Commercial Buildings
- Roles of Codes & Standards: ASHRAE 62.1 – Standard for Ventilation & IAQ
- Ventilation Rate Procedure (VRP) Overview
- Indoor Air Quality Procedure (IAQP) – Performance Based Method
- Air Cleaning Technologies
- Project Examples



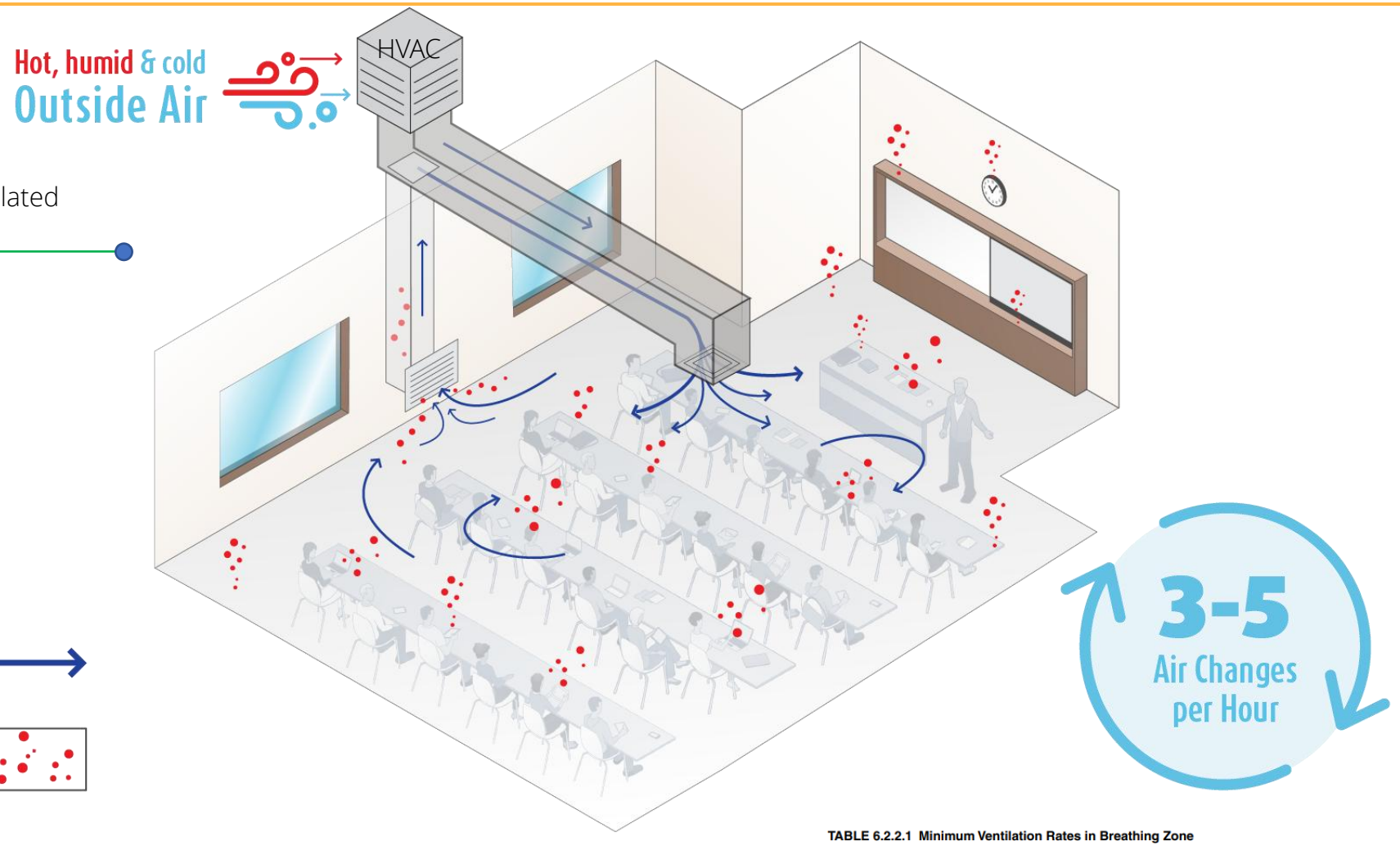
Challenges with the traditional ventilation approach to IAQ

The challenge for designers, owners and operators

“How to enhance indoor air quality and resilience while minimizing energy impact and project first cost?”

The old paradigm: More outside air for better indoor air quality

Large volumes of outside air mixed with recirculated air to dilute indoor generated contaminants



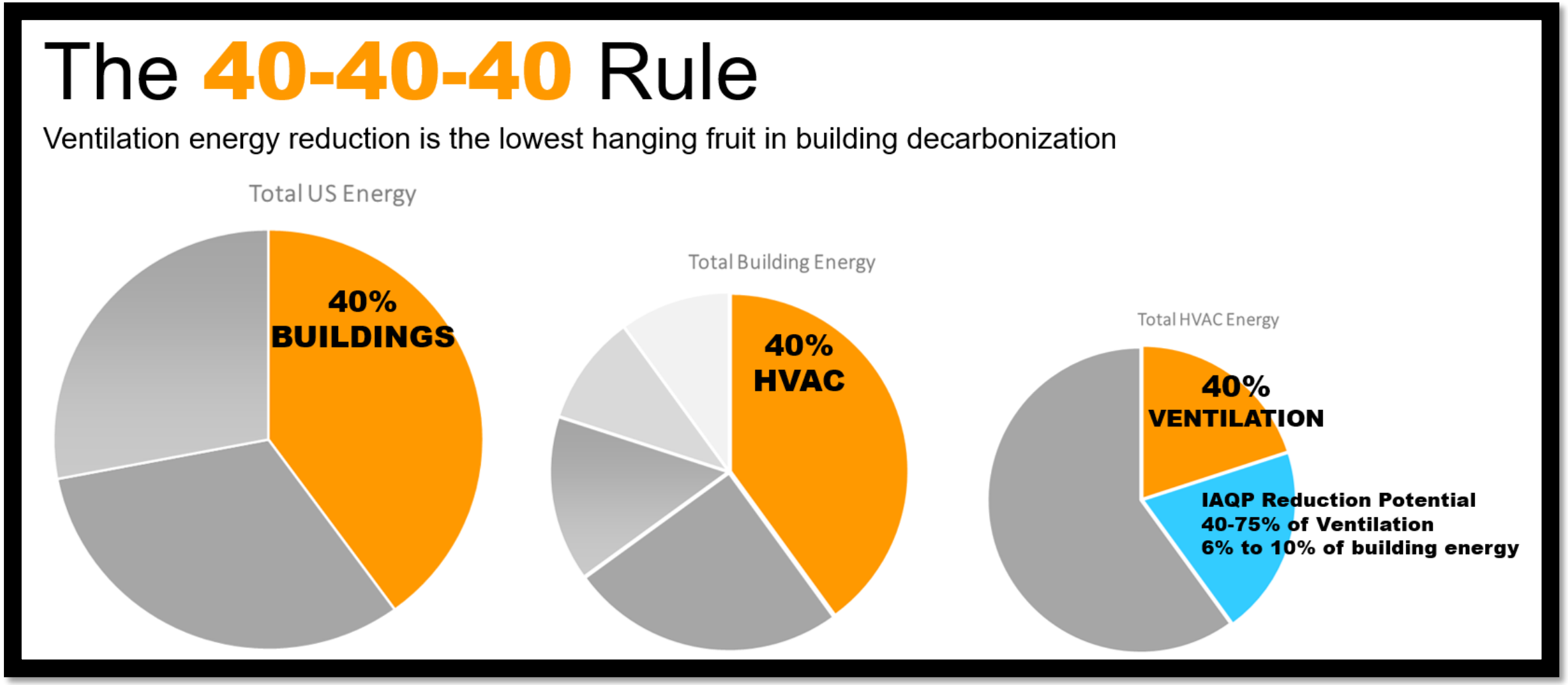
Conditioned air

Contaminated air generated by people and the building

TABLE 6.2.2.1 Minimum Ventilation Rates in Breathing Zone
(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

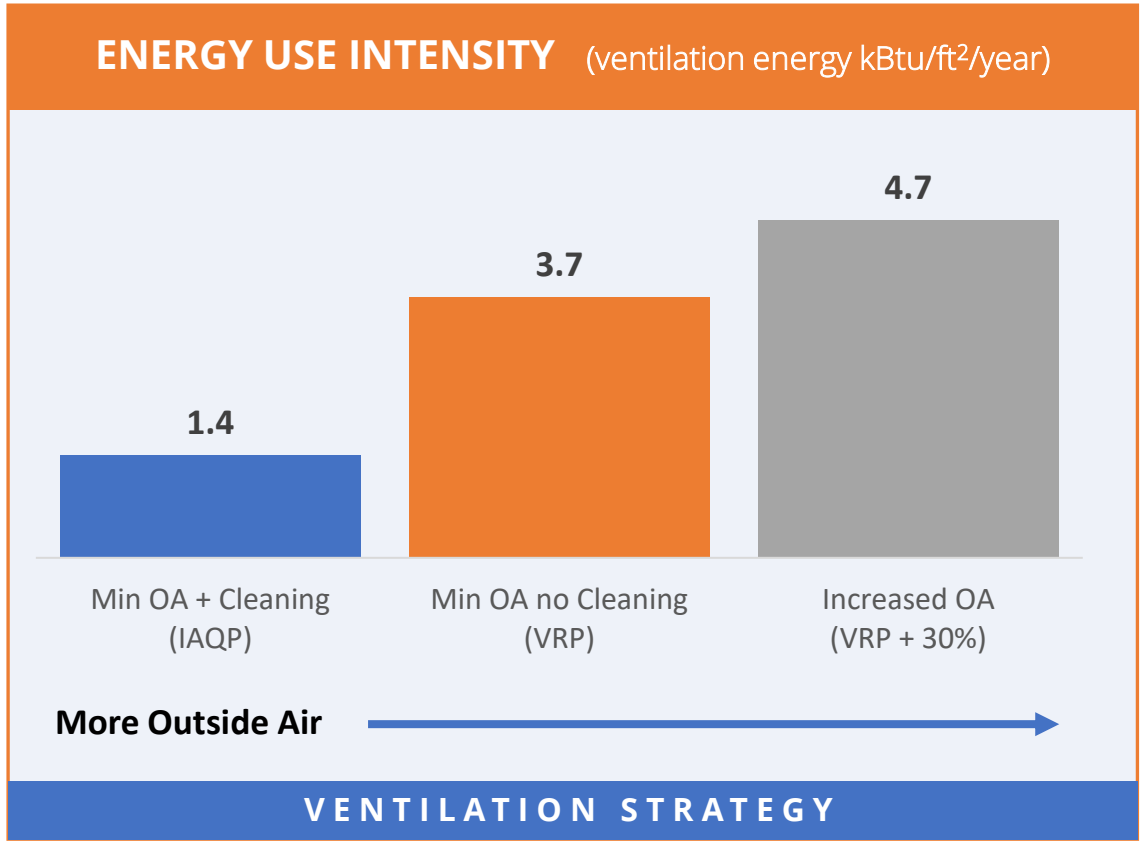
Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values			Air Class
						Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		
	cfm/ person	L/s· person	cfm/ft^2	L/s·m^2		#/1000 ft^2 or #/100 m^2	cfm/ person	L/s·person	

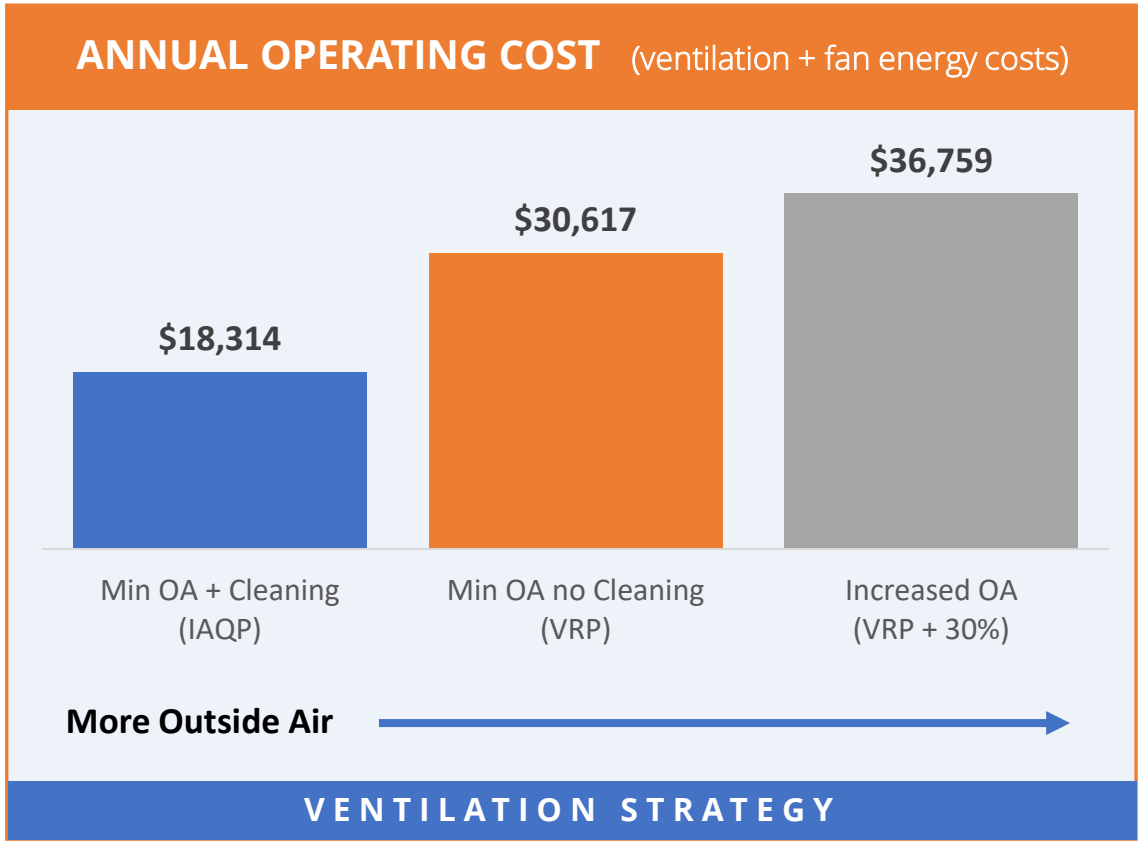
Challenge: High outside air requirements = high energy usage



Challenge: High outside air requirements = high energy usage

More Outside Air = More Energy Used = More Emmissions = More Money Spent





The above scenarios are for a 100,000 ft² all electric office building.
More air changes means higher HVAC system costs, higher HVAC operating costs, and higher total EUI.

Challenge: Outside air is not always “fresh”

Challenge: Larger systems = Larger building footprint, More maintenance

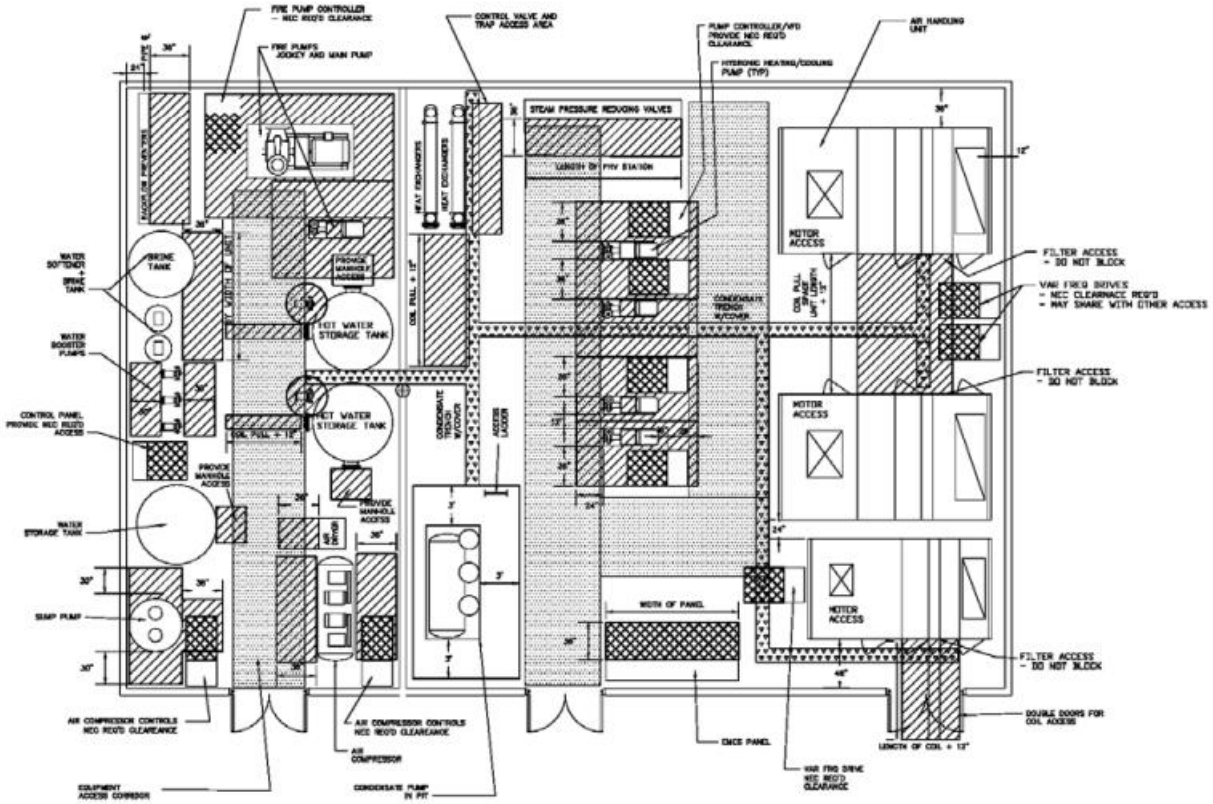
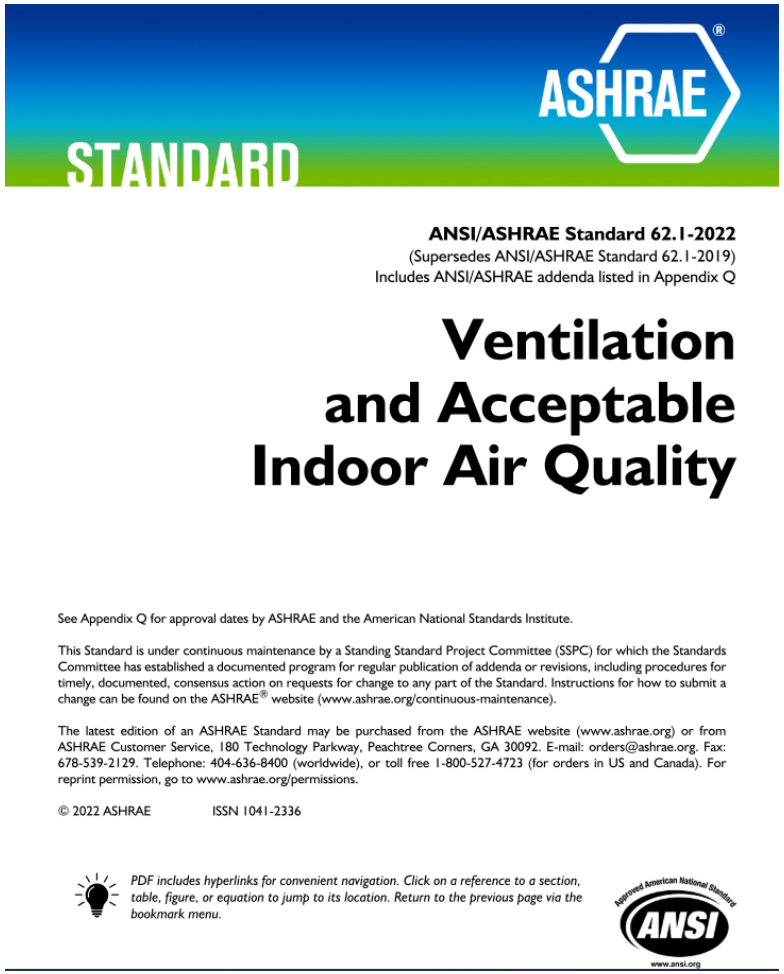


FIGURE 1 - SAMPLE MECHANICAL ROOM LAYOUT

Roles of Codes & Standards – ASHRAE 62.1

ASHRAE Standard 62.1


STANDARD

ASHRAE

ANSI/ASHRAE Standard 62.1-2022
(Supersedes ANSI/ASHRAE Standard 62.1-2019)
Includes ANSI/ASHRAE addenda listed in Appendix Q

Ventilation and Acceptable Indoor Air Quality

See Appendix Q for approval dates by ASHRAE and the American National Standards Institute.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (www.ashrae.org/continuous-maintenance).

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PDF includes hyperlinks for convenient navigation. Click on a reference to a section, table, figure, or equation to jump to its location. Return to the previous page via the bookmark menu.

Approved American National Standard
ANSI
www.ansi.org

Standard 62.1 specifies **minimum ventilation rates** and other measures intended to provide indoor air quality (IAQ) **that is acceptable to human occupants and that minimizes adverse health effects**.

Applies to all commercial applications except critical care healthcare (see ASHRAE Standard 170) and laboratories with hazardous materials.

ASHRAE 62.1 is for the design of commercial buildings in standard operation. Other ASHRAE standards exist with design recommendations for specialized scenarios (i.e. ASHRAE 241 Control of Infectious Aerosols).

Latest version is 62.1-2022 (Released September 30th, 2022)

Compliance: Ohio Mechanical Code

2024 Ohio Mechanical Code

Adoption Info

Effective dates	March 1, 2024 - Present
Adopts with amendments	International Mechanical Code 2021 (IMC 2021)

Section 403.2:

403.2 Outdoor Air Required

The minimum outdoor airflow rate shall be determined in accordance with Section 403.3.

Exceptions:

1. Where the *registered design professional* demonstrates that an engineered ventilation system design will prevent the maximum concentration of contaminants from exceeding that obtainable by the rate of outdoor air ventilation determined in accordance with Section 403.3, the minimum required rate of outdoor air shall be reduced in accordance with such engineered system design.

2. The registered design professional may use ASHRAE 62.1 or ASHRAE 62.2, as applicable, as an alternative engineered ventilation system design provided that the registered design professional demonstrates compliance with all applicable sections of the ASHRAE standard.

Chapter 15 (Reference Standards):

ASHRAE

ASHRAE
1791 Tullie Circle NE
Atlanta, GA 30329

15-2022	Safety Standard for Refrigeration Systems	1101.6, 1105.8, 1108.1
34-2022	Designation and Safety Classification of Refrigerants	202, 1102.2.1, 1103.1
62.1-19	Ventilation for Acceptable Indoor Air Quality in Low-Rise Residential Buildings	401.2, 403.3.1.1.2.3.2
90.1-19 (Not referenced)	Energy Standard for Buildings Except Low-rise Residential Buildings	401.2
170-2021	Ventilation of Health Care Facilities	407

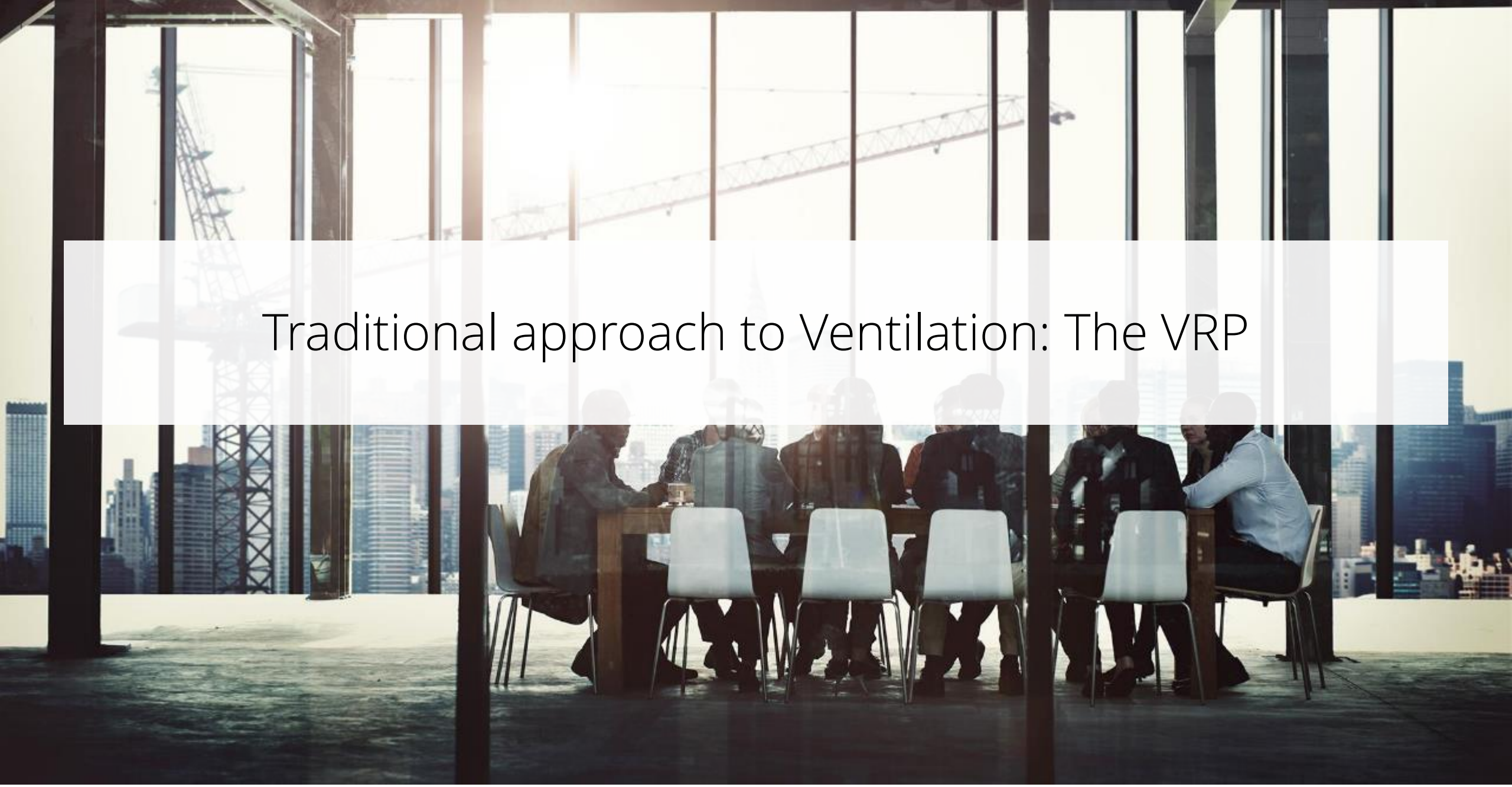
ASHRAE 62.1-2019 - Outdoor Airflow Procedures

The Ventilation Rate Procedure (VRP), the Indoor Air Quality Procedure (IAQP), the Natural Ventilation Procedure, or a combination thereof shall be used to meet the requirements of this section of the code.

Ventilation Rate Procedure. Prescriptive design procedure presented

Indoor Air Quality Procedure. Engineered approach procedure

Natural Ventilation Procedure. Outdoor air is provided through openings to the outdoors**.**



Traditional approach to Ventilation: The VRP

The Prescriptive Approach - VRP

Standardized, well known calculations

Based on air pollution research, ASHRAE determined ideal ventilation rates in **table 6.2.2.1**

TABLE 6.2.2.1 Minimum Ventilation Rates in Breathing Zone
(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values			Air Class
						Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		
	cfm/ person	L/s·person	cfm/ft²	L/s·m²		#/1000 ft² or #/100 m²	cfm/ person	L/s·person	
Correctional Facilities									
Cell	5	2.5	0.12	0.6		25	10	4.9	2
Dayroom	5	2.5	0.06	0.3		30	7	3.5	1
Guard stations	5	2.5	0.06	0.3		15	9	4.5	1
Booking/waiting	7.5	3.8	0.06	0.3		50	9	4.4	2
Educational Facilities									
Daycare (through age 4)	10	5	0.18	0.9		25	17	8.6	2
Daycare sickroom	10	5	0.18	0.9		25	17	8.6	3
Classrooms (ages 5–8)	10	5	0.12	0.6		25	15	7.4	1
Classrooms (age 9 plus)	10	5	0.12	0.6		35	13	6.7	1
Lecture classroom	7.5	3.8	0.06	0.3	H	65	8	4.3	1
Lecture hall (fixed seats)	7.5	3.8	0.06	0.3	H	150	8	4.0	1
Art classroom	10	5	0.18	0.9		20	19	9.5	2
Science laboratories	10	5	0.18	0.9		25	17	8.6	2
University/college laboratories	10	5	0.18	0.9		25	17	8.6	2
Wood/metal shop	10	5	0.18	0.9		20	19	9.5	2
Computer lab	10	5	0.12	0.6		25	15	7.4	1
Media center	10	5	0.12	0.6	A	25	15	7.4	1
Music/theater/dance	10	5	0.06	0.3	H	35	12	5.9	1
Multiuse assembly	7.5	3.8	0.06	0.3	H	100	8	4.1	1
Food and Beverage Service									
Restaurant dining rooms	7.5	3.8	0.18	0.9		70	10	5.1	2
Cafeteria/fast-food dining	7.5	3.8	0.18	0.9		100	9	4.7	2
Bars, cocktail lounges	7.5	3.8	0.18	0.9		100	9	4.7	2
Kitchen (cooking)	7.5	3.8	0.12	0.6		20	14	7.0	2
General									
Break rooms	5	2.5	0.06	0.3	H	25	7	3.5	1

Minimum Ventilation Rates in Breathing zones

- Correctional facilities
- Education
- Food/beverage
- Generic spaces
- Hospitality (hotels/resorts)
- Office Buildings
- Misc Retail/Manufacturing
- Public Assembly
- Residential
- Retail
- Sports/Entertainment

*Must know square footage and occupant design (typically from architect or owner) for each space or use default occupant density if occupant design unknown.

VRP Defined: What it does

The **VRP method** utilizes a prescriptive approach to determine the quantity of outdoor air required to achieve “acceptable air quality” based on use of zone.

Air quality is maintained by flushing contaminants in “stale” air with “fresh” outside air.

$$Vbz = (Rp * Pz) + (Ra * Az)$$

Vbz = breathing zone outdoor airflow rate

Rp = outdoor airflow rate required per person via ASHRAE 62.1

Pz = # of people in zone during use (via ASHRAE 62.1 or occupant load design)

Ra = outdoor airflow rate required per unit area via ASHRAE 62.1

Az = net occupied floor area of ventilation zone

Ventilation Effectiveness

Must account for Zone Air Distribution Effectiveness (IMC 2021 table 403.3.1.1.1.2)

TABLE 403.3.1.1.1.2

ZONE AIR DISTRIBUTION EFFECTIVENESS[a,b,c,d]

AIR DISTRIBUTION CONFIGURATION	E_z
Ceiling or floor supply of cool air	1.0[e]
Ceiling or floor supply of warm air and floor return	1.0
Ceiling supply of warm air and ceiling return	0.8[f]
Floor supply of warm air and ceiling return	0.7
Makeup air drawn in on the opposite side of the room from the exhaust or return	0.8
Makeup air drawn in near to the exhaust or return location	0.5

Voz = Vbz / Ez

Voz = zone outdoor airflow

Vbz = breathing zone outdoor airflow rate

Ez* = zone air distribution effectiveness

*some engineers may use Ez = 1.0 for simplicity, but Ez = 0.8 should be used for heating mode. System should be designed for worst case.

VRP Example

Typical Classroom in Heating Mode

- Area?
- Occupants?
- ASHRAE defined values?

$$Vbz = (Rp * Pz) + (Ra * Az)$$
$$Voz = Vbz / Ez$$

VRP Example

Vbz = (Rp * Pz) + (Ra * Az)
Voz = Vbz / Ez

Typical Classroom in Heating Mode

- 900 sq ft
- 30 students

Rp = 10cfm/person
Pz = 30 (defined from owner, default would be 25)
Ra = .12cfm/sq ft
Az = 900 sq ft (defined from architect or existing plan)
Ez = 0.8

Occupancy Category	People Outdoor Air Rate R_p cfm/person	People Outdoor Air Rate R_p L/s-person	Area Outdoor Air Rate R_a cfm/ft^2	Area Outdoor Air Rate R_a L/s·m^2
Classrooms (ages 5–8)	10	5	0.12	0.6
Classrooms (age 9 plus)	10	5	0.12	0.6

Vbz = (10 cfm/person * 30 people) + (.12cfm/sq ft * 900 sq ft)

OA load for people **OA load for floor area**

Vbz = 300 CFM + 108 CFM
Vbz = 408 CFM

TABLE 403.3.1.1.1.2

ZONE AIR DISTRIBUTION EFFECTIVENESS[a,b,c,d]

AIR DISTRIBUTION CONFIGURATION	E_z
Ceiling or floor supply of cool air	1.0[e]
Ceiling or floor supply of warm air and floor return	1.0
Ceiling supply of warm air and ceiling return	0.8[f]

Voz = 408 CFM / 0.8

Voz = 510 CFM

Paradigm Shift: the IAQP

ASHRAE 62.1-2019 allows for less outside air with compliant air cleaning

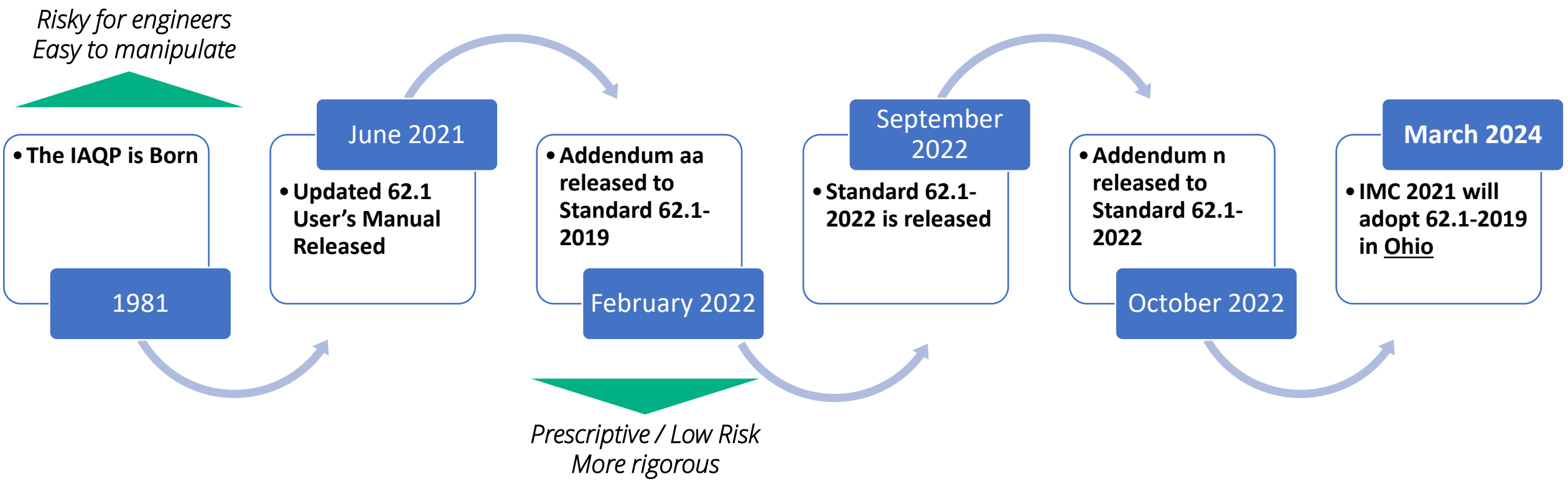
ASHRAE Standard 62.1-2019 includes two mechanical ventilation procedures

	Ventilation Rate Procedure (VRP)	Indoor Air Quality Procedure (IAQP)
Methodology	**Prescriptive:** Outside air based on area and occupancy without accounting for air cleaning.	**Performance-based:** Outside air based on IAQ design targets and source-control and removal measures.
Indoor Air Quality	Depends on quality of outside air and any unusual indoor air contaminates.	Equivalent or better than VRP, especially when outside air is polluted or unusual contaminants.
Energy Intensity	Higher in many climate zones because IAQ is achieved using only outside air.	Often lower because a portion of the outside air may be replaced with cleaned indoor air.

"one size fits all"

tailored to application

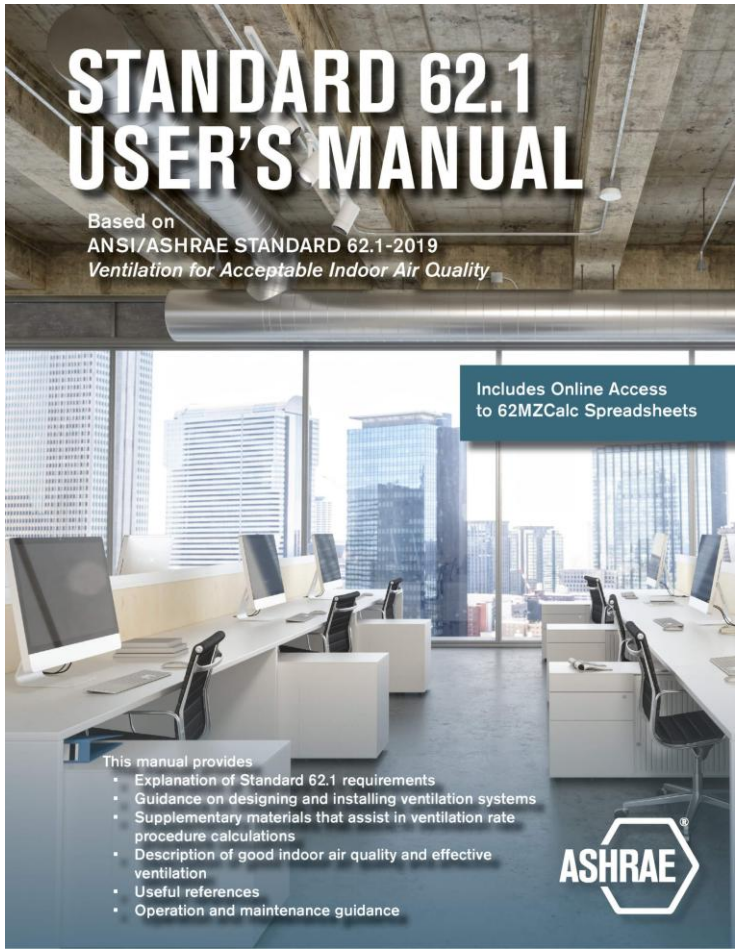
A Brief History of the IAQP in ASHRAE Standard 62.1



Changes to the IAQP in ASHRAE 62.1-2019

Item	Standard 62.1-2010/2013	→	Standard 62.1-2019
1a. Identifying contaminants of concern	Up to design engineer to decide list of contaminants	→	List of Design Compounds (DCs) and Mixtures of Compounds that are regulated (Table 6-5 & 6-6)
1b. Identifying Concentration Limit and Exposure Period	Up to design engineer to decide appropriate limits and exposure periods	→	Limit listed for each Design Compound (Table 6-5 & 6-6)
2. Indoor Emission Rates	Up to design engineer to find references	→	Information in User's Manual & Appendix N
3a. Perceived IAQ Requirement	No explicit requirements	→	Guidance for Subjective Evaluation (80% or more of the people exposed do not express dissatisfaction with the quality of the air during survey)
3b. Verification	No guidance in the Standard	→	Guidance for Objective Evaluation (IAQ testing methods, instrument specifications, number of testing locations)

ASHRAE: Benefits of IAQP + air cleaning approach



"The IAQP may allow for a **more cost-effective solution** to providing good air quality, as all design strategies may be considered…" (Pg. 100)

"The IAQP may also be used to achieve **better air quality** than the VRP…." (Pg. 101)

"**If outdoor air is deemed to be unacceptable** for general ventilation, consider using air cleaning and the IAQP in lieu of the VRP for the ventilation system design." (Pg. 20)

"**If a ventilation zone will have unusual contaminant sources** or sources where emissions will be unusually high, additional ventilation or air cleaning must be included in the design…**The additional ventilation or air cleaning required must be designed using the IAQP** or based on environmental safety standards where there is an environmental health and safety professional responsible to the owner who has determined appropriate criteria." (Pg. 76)

Not in ASHRAE User's Manual* - Can be used when LEED points, WELL points or other green building certification is desired

THE SOLUTION: Reduce outside air by CLEANING the air.

62.1-2019 Addendum aa: Design Compounds & Limits (Published - Feb 2022)

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ADDENDA

ANSI/ASHRAE Addendum aa to
ANSI/ASHRAE Standard 62.1-2019

Ventilation for Acceptable Indoor Air Quality

Approved by the ASHRAE Standards Committee on October 19, 2021, the ASHRAE Board of Directors on November 10, 2021, and the American National Standards Institute on January 21, 2022.

This addendum was approved by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. Instructions for how to submit a change can be found on the ASHRAE® website (https://www.ashrae.org/continuous-maintenance).

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Table 6-5 Design Compounds, PM2.5, and Their Design Limits

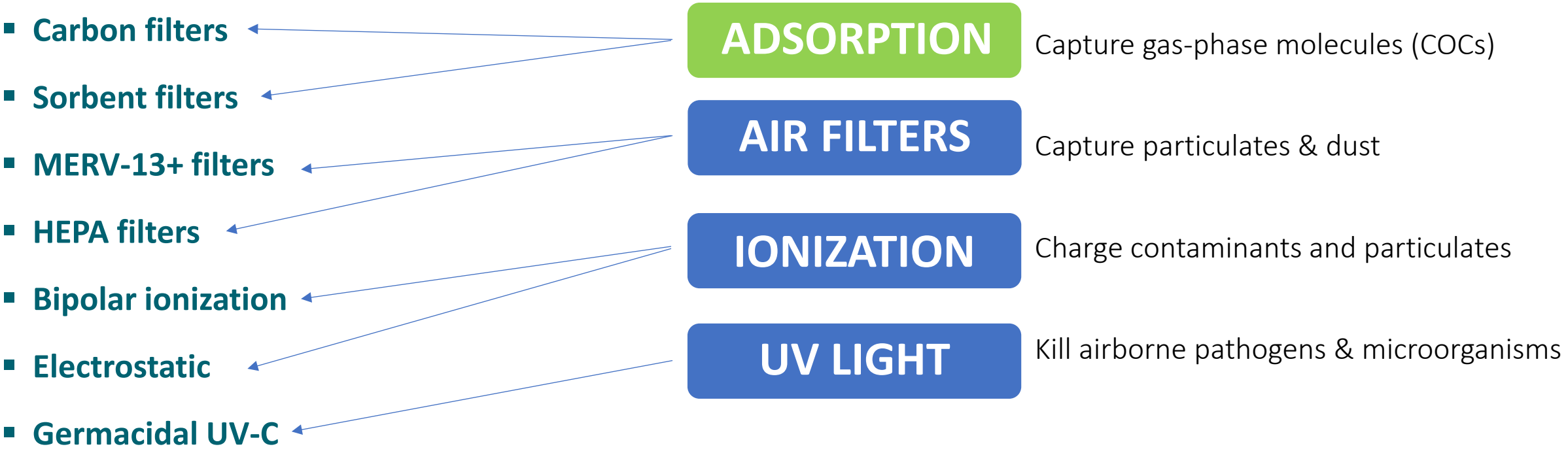
Compound or PM2.5	Cognizant Authority	Design Limit
Acetaldehyde	Cal EPA CREL (June 2016)	140 µg/m^3
Acetone	AgBB LCI	1,200 µg/m^3
Benzene	Cal EPA CREL (June 2016)	3 µg/m^3
Dichloromethane	Cal EPA CREL (June 2016)	400 µg/m^3
Formaldehyde	Cal EPA 8-hour REL (2004)	33 µg/m^3
Naphthalene	Cal EPA CREL (June 2016)	9 µg/m^3
Phenol	AgBB LCI	10 µg/m^3
Tetrachloroethylene	Cal EPA CREL (June 2016)	35 µg/m^3
Toluene	Cal EPA CREL (June 2016)	300 µg/m^3
1,1,1-trichloroethane	Cal EPA CREL (June 2016)	1000 µg/m^3
Xylene, total	AgBB LCI	500 µg/m^3
Carbon monoxide	USEPA NAAQS	9 ppm
PM2.5	USEPA NAAQS (annual mean)	12 µg/m^3
Ozone	USEPA NAAQS	70 ppb
Ammonia	Cal EPA CREL (June 2016)	200 µg/m^3

Table 6-6 Mixtures of Compounds

Upper Respiratory Tract Irritation	Eye Irritation	Central Nervous System
Acetaldehyde	Acetaldehyde	Acetone
Acetone	Acetone	Dichloromethane
Xylene, total	Formaldehyde	Xylene, total
Ozone	Xylene,total	1,1,1-trichloroethane
	Ozone	Toluene

Informative Note: *Source: ACGIH, 2017 (See Informative Appendix M, "Informative References").*

Air Cleaning Technologies for Improving Indoor Air Quality



Each technology has its own selectivity and efficiency for capturing contaminants…
Indoor Air Quality Verification Testing required when utilizing the IAQP to verify system contaminant removal efficiency

ASHRAE Standard 145.2 Laboratory Test Method for Assessing the Performance of Air-Cleaning Devices
ASHRAE Standard 52.2 Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size

How to utilize the IAQP in design

IAQP Defined

C_{bz} = contaminant concentration in space
N = emissions of new contaminants
V_{ot} = volume of outdoor air
C_o = contaminant concentration in outdoor air
Q_f = volume of treated/filtered air
E_f = efficiency of filtration device

$$VdC_{bz} = Ndt - (V_{ot}\, C_o\, dt) - (Q_f\, E_f\, C_{bz} dt)$$

Contaminant threshold defined

C_{bz} = contaminant concentration in space
N = emissions of new contaminants
V_{ot} = volume of outdoor air
C_o = contaminant concentration in outdoor air
Q_f = volume of treated/filtered air
E_f = efficiency of filtration device

$$VdC_{bz} = Ndt - (V_{ot}\, C_o\, dt) - (Q_f\, E_f\, C_{bz} dt)$$

the amount of contaminants (COCs) in the space = contaminants being emitted into the space − contaminants being flushed out of space with "fresh air" (but adding in contaminants already in the "fresh air") − contaminants being "trapped" or removed by filtration devices

Utilizing the IAQP for your project

How to apply the IAQP with air cleaning can be summarized in four steps:

Step 1:
Confirm Design Compounds & Limits

Defined in ASHRAE 62.1–2019 Addendum aa

Step 2:
Apply emissions rates

Defined in the updated 62.1 User's Manual & Appendix N

Step 3:
Apply air cleaning efficiency

Test Standards defined in ASHRAE 62.1-2022 addendum n. ASHRAE 145.2 and 52.2 testing.

Step 4:
Perform mass balance analysis

Utilize a validated IAQP calculator using the ASHRAE defined inputs

Step 1: Confirm Design Compounds & Design Limits

62.1-2019 Addendum aa: Design Compounds & Limits (Published - Feb 2022)

ANSI/ASHRAE Addendum aa to
ANSI/ASHRAE Standard 62.1-2019

Ventilation for Acceptable Indoor Air Quality

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Formaldehyde	Cal EPA 8-hour REL (2004)	33 µg/m^3
Naphthalene	Cal EPA CREL (June 2016)	9 µg/m^3
Phenol	AgBB LCI	10 µg/m^3
Tetrachloroethylene	Cal EPA CREL (June 2016)	35 µg/m^3
Toluene	Cal EPA CREL (June 2016)	300 µg/m^3
1,1,1-trichloroethane	Cal EPA CREL (June 2016)	1000 µg/m^3
Xylene, total	AgBB LCI	500 µg/m^3
Carbon monoxide	USEPA NAAQS	9 ppm
PM2.5	USEPA NAAQS (annual mean)	12 µg/m^3
Ozone	USEPA NAAQS	70 ppb
Ammonia	Cal EPA CREL (June 2016)	200 µg/m^3

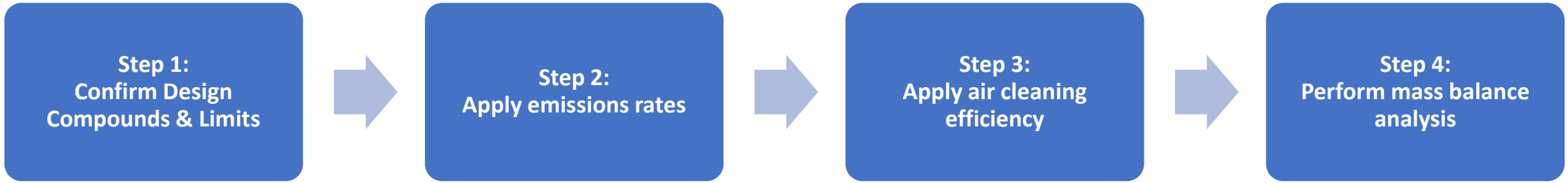
Table 6-6 Mixtures of Compounds

Upper Respiratory Tract Irritation	Eye Irritation	Central Nervous System
Acetaldehyde	Acetaldehyde	Acetone
Acetone	Acetone	Dichloromethane
Xylene, total	Formaldehyde	Xylene, total
Ozone	Xylene,total	1,1,1-trichloroethane
	Ozone	Toluene

Informative Note: *Source: ACGIH, 2017 (See Informative Appendix M, "Informative References").*

Utilizing the IAQP for your project

How to apply the IAQP with air cleaning can be summarized in four steps:



Defined in ASHRAE 62.1–2019 Addendum aa

Defined in the updated 62.1 User's Manual & Appendix N

Test Standards defined in ASHRAE 62.1-2022 addendum n. ASHRAE 145.2 and 52.2 testing.

Utilize a validated IAQP calculator using the ASHRAE defined inputs

Step 2: Determine Indoor Emission Rate & Outdoor Concentrations

Step 2 ➡Determine indoor emission rates and outdoor concentrations for the COCs in project location.

The updated User's Manual provides a list of emission rates and outdoor concentrations for a typical office space.

ASHRAE points to peer-reviewed papers **(Appendix N of Standard 62.1),** containing the emission rates for other applications and building types.

Mechanical engineer should confirm or update outdoor concentrations based on the **specific location** of the project.

Data for specific sites can be obtained from the local air quality board, fire department, emergency management agency or the EPA Data Site (publicly available).

Generation Rates and Outdoor Air Concentrations
(from ASHRAE 62.1-2019 User's Manual pg. 106)

Contaminant	Generation Rate ($\mu g/h\text{-}m^2$)	Concentration in Outdoor Air (ppb)	Concentration in Outdoor Air ($\mu g/m^2$)
Acetaldehyde	17.45	0.98	1.77
Acetone	37.7	2.4	5.70
Benzene	0.57	1.2	3.83
Dichloromethane	1.18	0	0
Formaldehyde	37.5	3.02	3.71
Naphthalene	0.38	0.4	2.10
Phenol	6.25	0.6	2.31
Tetrachloroethylene	0.14	0.6	4.07
Toluene	146	1.1	4.15
1,1,1-trichloroethane	.12	0	0
Xylene, total	3.13	0.6	2.16
Carbon monoxide	17.45	0.98	1.77
PM2.5	37.7	–	5.70
Ozone	0.57	1.2	3.83

Utilizing the IAQP for your project

How to apply the IAQP with air cleaning can be summarized in four steps:

Step 1:
Confirm Design Compounds & Limits

Defined in ASHRAE 62.1–2019 Addendum aa

Step 2:
Apply emissions rates

Defined in the updated 62.1 User's Manual & Appendix N

Step 3:
Apply air cleaning efficiency

Test Standards defined in ASHRAE 62.1-2022 addendum n. ASHRAE 145.2 and 52.2 testing.

Step 4:
Perform mass balance analysis

Utilize a validated IAQP calculator using the ASHRAE defined inputs

Step 3: Apply Air Cleaning Efficiency

62.1-2022 Addendum n: Test standards for air cleaners (Published - Oct 2022)

Addendum n to Standard 62.1-2022

Add New Section 6.3.4 as shown below. Renumber other sections as appropriate.

6.3.4 Air Cleaning. Where particulate matter or gas-phase air cleaning is included in the design, the removal efficiencies shall be specified as follows. Particulate matter filters shall report an efficiency reporting value (MERV) in accordance with ASHRAE Standard 52.2 or reporting in accordance with ISO 16890. Gas-phase air cleaners shall report an efficiency test for all compounds included in the design in accordance with any of the following:

a. ASHRAE Standard 145.2
b. ISO 10121-2
c. Testing by methods in Section 6.1.2,10.4, and 10.5 and reported as required in ASHRAE Standard 145.2, Section 11
d. Testing to a national consensus standard approved by the authority having jurisdiction
e. For technologies not covered by any of the above, tests developed to demonstrate the removal efficiency shall be performed by a third party. The custom efficiency test shall be conducted for all compounds included in the design, and shall comply with the following:
    1. Test of the background concentration without the air cleaning in operation
    2. Test of the output concentration with the air cleaning in operation
    3. Be conducted under air cleaning operating conditions that match the IAQP design operating conditions (***Informative Note:*** Air cleaning operating conditions include fan voltage, flow rate, and other settings that are consistent with the manufacturer's operating specifications.)
    4. Be conducted using the relevant laboratory methods for analysis and quantification as specified in Table 7-1. Inorganic compounds and PM2.5 may be measured instead using direct read instruments that are calibrated in accordance with the device manufacturer's recommendations, capable of measuring below the design limit, and consistent with the performance requirements specified in Table 7-2.

Any custom efficiency test description, covering points (a) through (d) above and challenge test concentration shall be documented and approved by the authority having jurisdiction. All test results, along with relevant equipment settings, shall be provided upon request.

Manufacturers required to obtain third party testing to determine contaminant cleaning efficiencies

Efficiencies used in IAQP equation to obtain accurate calculations based on air cleaning technology efficiency

Not yet required by code in Ohio (will likely be adopted soon)

Utilizing the IAQP for your project

How to apply the IAQP with air cleaning can be summarized in four steps:

Step 1:
Confirm Design Compounds & Limits

Defined in ASHRAE 62.1–2019 Addendum aa

Step 2:
Apply emissions rates

Defined in the updated 62.1 User's Manual & Appendix N

Step 3:
Apply air cleaning efficiency

Test Standards defined in ASHRAE 62.1-2022 addendum n. ASHRAE 145.2 and 52.2 testing.

Step 4:
Perform mass balance analysis

Utilize a validated IAQP calculator using the ASHRAE defined inputs

Step 4: Perform Mass Balance Analysis

The updated IAQP defines inputs to the mass balance equation; making IAQP easier to apply and more robust.

Breathing Zone Outdoor Airflow CFM

$$V_{bz} = \frac{N - V_c E_f C_{bz}}{C_{bz} - C_o}$$

V_{bz}: Calculated for a defined list of compounds (Table 6-5)

N: Indoor Emissions — Compound Emission Rate (Appendix N)

$V_c E_f C_{bz}$: Air Cleaning — Air Cleaning Volume x Efficiency (Addendum n); Compound Design Limit (Table 6-5)

C_{bz}: Compound Design Limit (Table 6-5)

C_o: Outdoor Concentration (EPA & NAAQS)

Outside Air Dilution

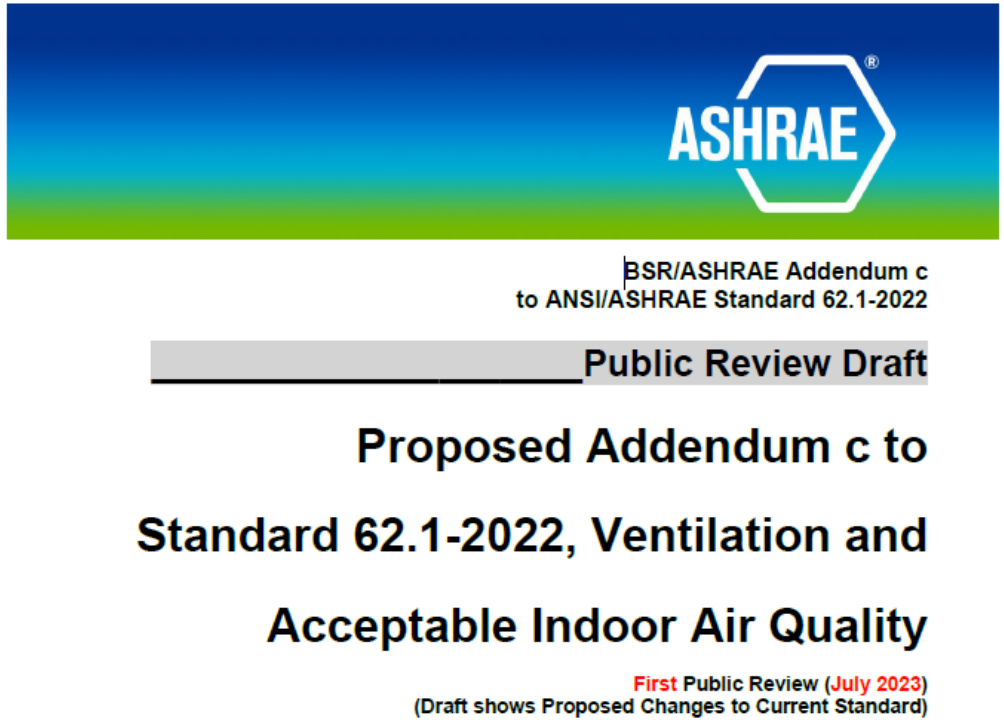
Minimum inputs needed to run preliminary IAQP calculation:

- **Building location/Space Type**
- **Floor Area (ft^2)**
- **Occupancy (max and avg)**

62.1-2022 Addendum c: ASHRAE IAQP Calculator

ASHRAE has developed a tool to help engineers use the IAQP.

"This proposed addendum provides a calculator for mass balance equations used with the revised indoor air quality procedure."

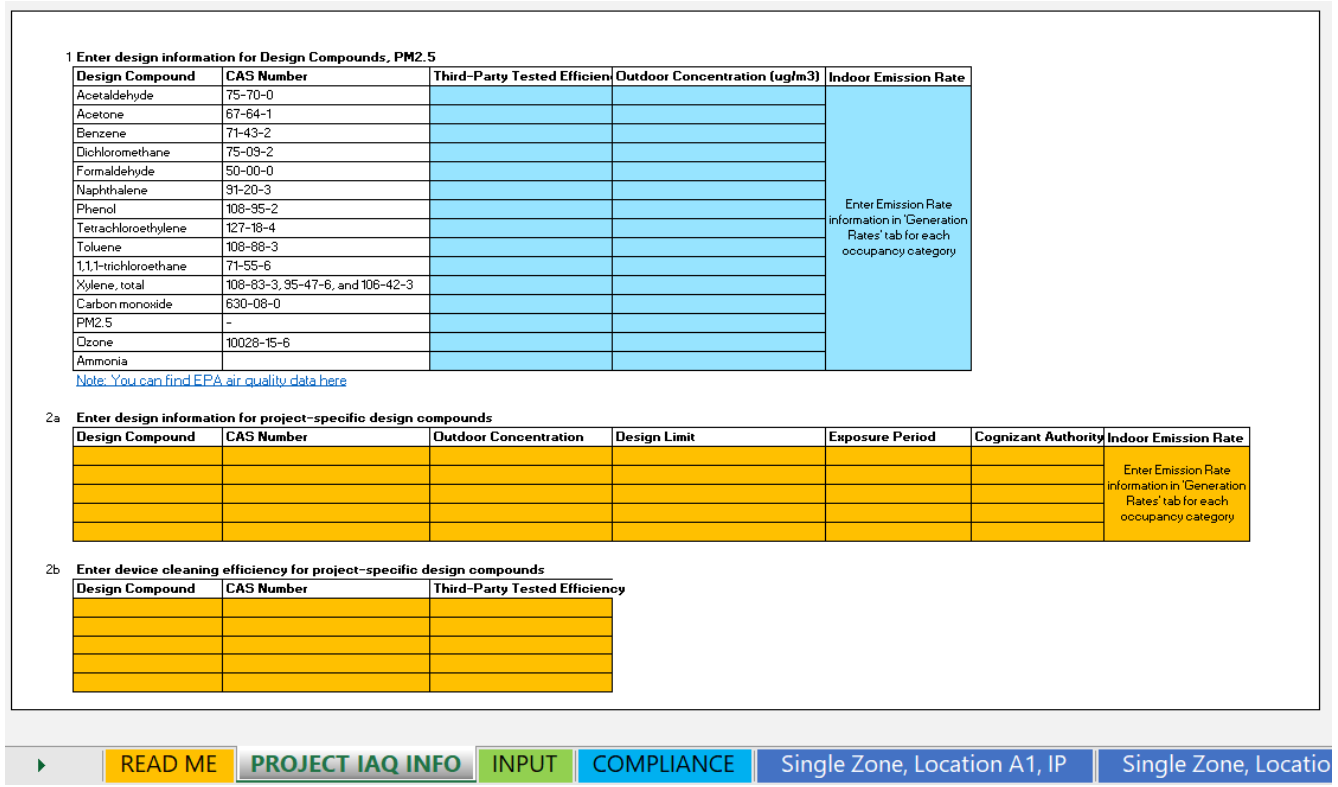


BSR/ASHRAE Addendum c
to ANSI/ASHRAE Standard 62.1-2022

Public Review Draft

Proposed Addendum c to Standard 62.1-2022, Ventilation and Acceptable Indoor Air Quality

First Public Review (July 2023)
(Draft shows Proposed Changes to Current Standard)



1 Enter design information for Design Compounds, PM2.5

Design Compound	CAS Number	Third-Party Tested Efficien	Outdoor Concentration (ug/m3)	Indoor Emission Rate
Acetaldehyde	75-70-0			Enter Emission Rate information in 'Generation Rates' tab for each occupancy category
Acetone	67-64-1			
Benzene	71-43-2			
Dichloromethane	75-09-2			
Formaldehyde	50-00-0			
Naphthalene	91-20-3			
Phenol	108-95-2			
Tetrachloroethylene	127-18-4			
Toluene	108-88-3			
1,1,1-trichloroethane	71-55-6			
Xylene, total	108-83-3, 95-47-6, and 106-42-3			
Carbon monoxide	630-08-0			
PM2.5	-			
Ozone	10028-15-6			
Ammonia				

Note: You can find EPA air quality data here

2a Enter design information for project-specific design compounds

Design Compound	CAS Number	Outdoor Concentration	Design Limit	Exposure Period	Cognizant Authority	Indoor Emission Rate
						Enter Emission Rate information in 'Generation Rates' tab for each occupancy category

2b Enter device cleaning efficiency for project-specific design compounds

Design Compound	CAS Number	Third-Party Tested Efficiency

READ ME | PROJECT IAQ INFO | INPUT | COMPLIANCE | Single Zone, Location A1, IP | Single Zone, Locatio

IAQP Example – Air Cleaning + ASHRAE 62.1 IAQP CALCULATOR

Typical Classroom in Heating Mode

- 900 sq ft, 30 students

System Inputs

Design System Population (optional)	30	occupants	Ps	System population, maximum simultaneous # of occupants of space served by system
				System primary airflow from air handler. This may differ from the sum of primary airflow to zones.
System Design Airflow (optional)	1200	cfm	Vps	**REQUIRED ENTRY for Filter Locations A2 and B if no values are entered for zone primary airflows.**
Cleaned Air Rate (Location A1)	350	CFM	Vc	Rated airflow through the installed air cleaning device for filter location A1

Calculation Results

Occupant Diversity	-		D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/∑Pz
	-	CFM	Voz	Zone outdoor airflow (Single Zone Systems)
	-	CFM	Vou	Uncorrected outdoor air intake (Multiple Zone Systems)
	-		Xs	Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps
	-		Ev	System ventilation efficiency, based on method chosen above
Outside Air Intake	-	**CFM**	**Vot**	**Minimum outside air** Calculated Vot satisifies IAQP requiremen
Critical Zone	-			This zone has the highest calculated ventilation efficiency

Mixtures Check

Outside Air Intake Override	0	**CFM**	**Voz**	Increase Voz if doesn't pass mixtures check
Mixed Exposure Sum	0.03		**Em**	Upper Respiratory Tract Irritation
Mixed Exposure Sum	0.47		**Em**	Eye Irritation
Mixed Exposure Sum	0.01		**Em**	Central Nervous System
Pass Mixtures Check?	Yes		**Em < 1**	Yes | No

Required Zone Information								Optional Zone Information		Results	
Zone Name	Room Number	Space Type	Use Default Occupancy?	Zone Floor Area	Zone Population	Zone Air Distributio	Primary Zone	Zone Discharge Airflow	Zone Secondary Recirculation Fraction	Zone Recirculation Air	Uncorrected IAQP OA
				A_z [ft²]	P_z [people]	Ez	Vpz [CFM]	Vdz [CFM]	Er	RVr,f [CFM]	Vou [CFM]
IAQP											
Totals:				900	30		1,200			350	-
CLASSROOM		Classrooms (age 9 plus)	No	900	30	0.8	1,200			350	-

IAQP Example – Multiple Zones

Typical (4) Classroom wing in Heating Mode

- 900 sq ft, 30 students

System Inputs

Design System Population (optional)	120	occupants	Ps	System population, maximum simultaneous # of occupants of space served by system
				System primary airflow from air handler. This may differ from the sum of primary airflow to zones.
System Design Airflow (optional)	4800	cfm	Vps	**REQUIRED ENTRY for Filter Locations A2 and B if no values are entered for zone primary airflows.**
Cleaned Air Rate (Location A1)	350	CFM	Vc	Rated airflow through the installed air cleaning device for filter location A1

Calculation Results

Occupant Diversity	**1.00**		D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/∑Pz
	-	CFM	Voz	Zone outdoor airflow (Single Zone Systems)
	150	CFM	Vou	Uncorrected outdoor air intake (Multiple Zone Systems)
	0.031		Xs	Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps
	0.750		Ev	System ventilation efficiency, based on method chosen above
Outside Air Intake	**200**	**CFM**	**Vot**	**Minimum outside air** Calculated Vot satisifies IAQP requiremen
Critical Zone	CLASSROOM 1			This zone has the highest calculated ventilation efficiency

Mixtures Check

Outside Air Intake Override	150	**CFM**	**Vou**	Increase Vou if doesn't pass mixtures check
Mixed Exposure Sum	0.07		**Em**	Upper Respiratory Tract Irritation
Mixed Exposure Sum	0.96		**Em**	Eye Irritation
Mixed Exposure Sum	0.03		**Em**	Central Nervous System
Pass Mixtures Check?	Yes		**Em < 1**	Yes|No

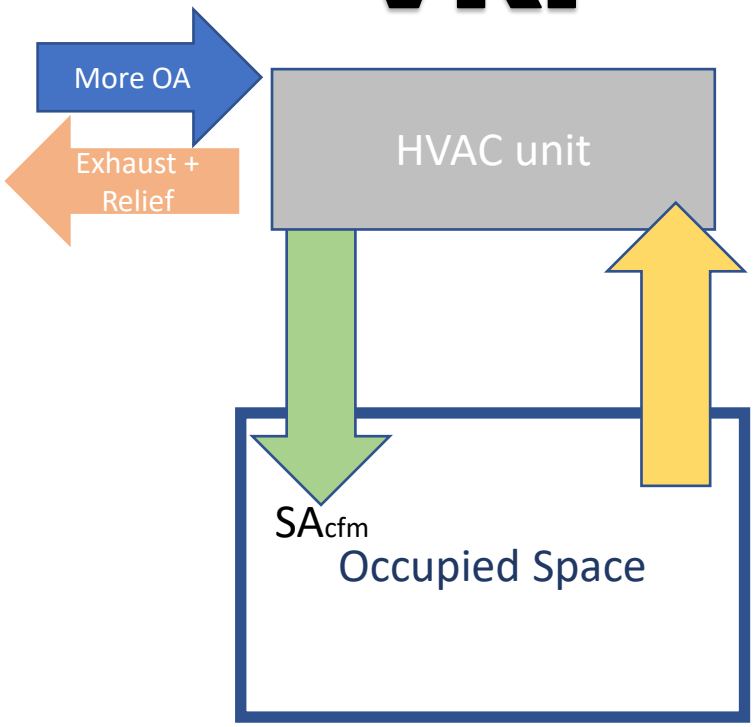
Required Zone Information								Optional Zone Information		Results	
Zone Name	Room Number	Space Type	Use Default Occupancy?	Zone Floor Area	Zone Population	Zone Air Distributio	Primary Zone	Zone Discharge Airflow	Zone Secondary Recirculation Fraction	Zone Recirculation Air	Uncorrected IAQP OA
				A_z [ft²]	P_z [people]	Ez	Vpz [CFM]	Vdz [CFM]	Er	RVr,f [CFM]	Vou [CFM]
IAQP											
Totals:				3,600	120		4,800			350	150
CLASSROOM	1	Classrooms (age 9 plus)	No	900	30	0.8	1,200			88	38
CLASSROOM	2	Classrooms (age 9 plus)	No	900	30	0.8	1,200			88	38
CLASSROOM	3	Classrooms (age 9 plus)	No	900	30	0.8	1,200			88	38
CLASSROOM	4	Classrooms (age 9 plus)	No	900	30	0.8	1,200			88	38

VRP vs IAQP

The **IAQP method** reduces the amount of outside air required by **cleaning the air** and reducing contaminants in the air.

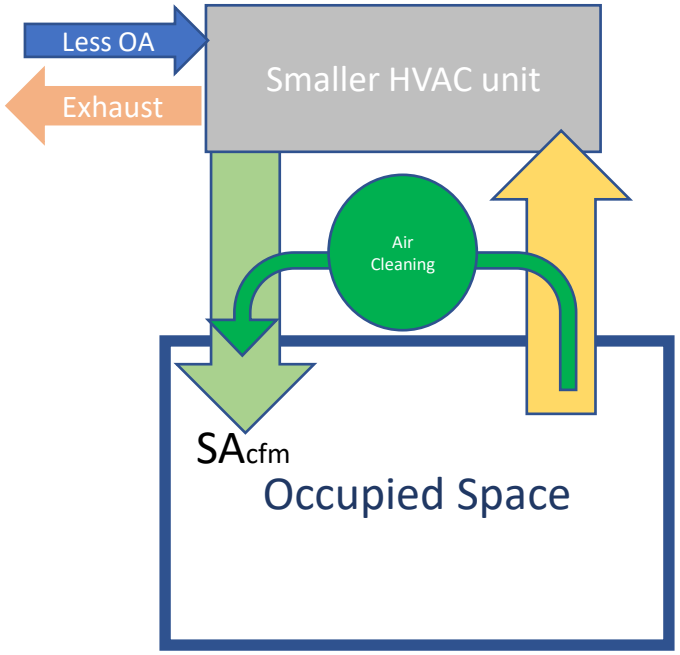
In return, the overall energy usage of the building is reduced while maintaining air quality.

VRP



SAcfm
Remains Constant
Heating/Cooling
load decreased

IAQP



The Target Application - IAQP

- IAQP can be applied to any space defined under ASHRAE 62.1. Common Applications include:
  - Office buildings (Including Medical Office Space)
  - K-12 schools / Childcare Centers
  - Colleges / universities / libraries
  - Assembly halls, theatres, concert venues, indoor arenas
  - Airports / Retail / Conditioned Warehouses

Great for Green / LEED buildings / Net Zero / Decarbonization

May be applied to the entire building or *just targeted at specific spaces*

- Low Hanging Fruit: Systems with High occupancy, low exhaust above 10,000 sqft

Generally, not good candidates:

- Multi Family Residences & Hotel guestrooms – Exhaust Driven (exception: retail/amenities/common areas are good candidates)
- Kitchens & Labs – Exhaust Driven
- Critical Care and Negative Pressure Hospital Spaces – Governed by ASHRAE 170 (exception: MOB/Outpatient are good candidates)

Cost effective, energy efficient

- Decrease size of system components (equipment, piping, ductwork, electrical load, structural, etc)
- Decreased upfront equipment and maintenance cost
- Decrease equipment footprint in mechanical rooms
- Decrease energy expenditure and carbon footprint
- Increase indoor air quality
- IAQP can be applied to remove energy recovery wheels in large air handling equipment
  - Simplifies design and maintenance
  - Eliminates risk of cross contamination from dirty exhaust air
- Decrease annual operating costs
  - Some applications see a 10+ ton reduction in peak cooling load by incorporating just (1) IAQP device

TABLE 6.5.6.1-1 Exhaust Air Energy Recovery Requirements for Ventilation Systems Operating Less than 8000 Hours per Year

Zone	% Outdoor Air at Full Design Airflow Rate							
	≥10% and <20%	≥20% and <30%	≥30% and < 40%	≥40% and < 50%	≥50% and < 60%	≥60% and < 70%	≥70% and < 80%	≥80%
	Design Supply Fan Airflow Rate, cfm							
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	NR	NR	NR	NR
1B, 2B,5C	NR	NR	NR	NR	≥26000	≥12000	≥5000	≥4000
6B	≥28,000	≥26,500	≥11000	≥5500	≥4500	≥3500	≥2500	≥1500
1A, 2A, 3A, 4A, 5A, 6A	≥26,000	≥16,000	≥5500	≥4500	≥3500	≥2000	≥1000	>0
7,8	≥4500	≥4000	≥2500	≥1000	>0	>0	>0	>0

NR—Not required

TABLE 6.5.6.1-2 Exhaust Air Energy Recovery Requirements for Ventilation Systems Operating Greater than or Equal to 8000 Hours per Year

Zone	% Outdoor Air at Full Design Airflow Rate							
	≥10% and <20%	≥20% and <30%	≥30% and <40%	≥40% and <50%	≥50% and <60%	≥60% and <70%	≥70% and < 80%	≥80%
	Design Supply Fan Airflow Rate, cfm							
3C	NR	NR	NR	NR	NR	NR	NR	NR
1B, 2B, 3B, 4C, 5C	NR	≥19,500	≥9000	≥5000	≥4000	≥3000	≥1500	>0
1A, 2A, 3A, 4B, 5B	≥2500	≥2000	≥1000	≥500	>0	>0	>0	>0
4A, 5A, 6A, 6B, 7, 8	>0	>0	>0	>0	>0	>0	>0	>0

NR—Not required

IAQP Helps Easily attain Green and Healthy Building Goals

LEED

- Earn points under IAQ, innovation and/or energy
- Past projects have earned up to 10 points

WELL

- Up to 2 preconditions and 5 optimization points in the Air concept category

"Easy Button" to cost effective LEED & WELL points, Plus Many Other Green Building Certifications!

Project Examples Utilizing IAQP

Case Study: Harvard University Science Center – Lecture Halls

HARVARD UNIVERSITY

DOER
Massachusetts Department of Energy Resources

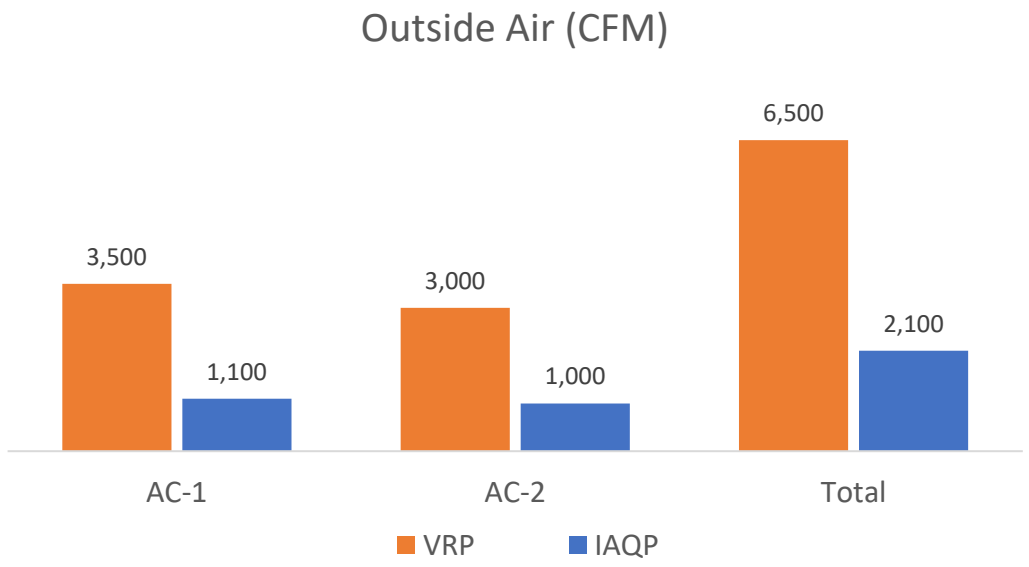
Harvard University Project Report
Innovate Energy Efficiency Grant Program (InnovatEE)
Commonwealth of Massachusetts Department of Energy Resources

Goals		Results
Energy Efficiency	✓	**Recurring annual energy savings from operating smaller capacity system ($3,131 Estimated Savings)**
Enhanced IAQ	✓	**Reduced levels of VOCs, PM2.5, Ozone**
First Cost Savings	✓	**Reduced peak HVAC Load by 14.2 tons**

Project Overview	
Building Type	Auditorium/Lecture Hall
Project Type	P&S Construction - MEP design, existing building
Location	Cambridge, MA
Air Cleaning Modules	Qty 3
Owner/Developer	Harvard University
Consulting Engineer	BR+A

Case Study: Harvard M&V Results for Indoor Air Quality

The IAQP design reduced outside air requirements by 68% from 6,500 CFM to 2,100 CFM

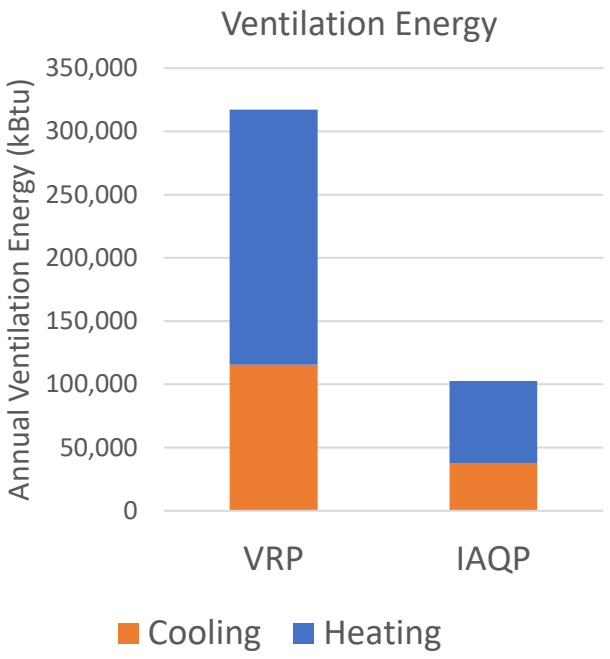


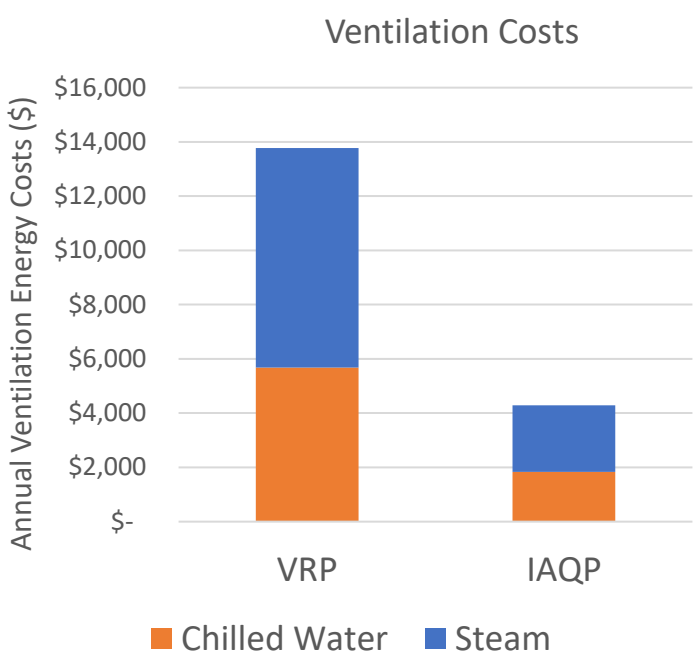
Indoor air contaminant levels were measured in 2 locations and remained well below ASHRAE Limits.

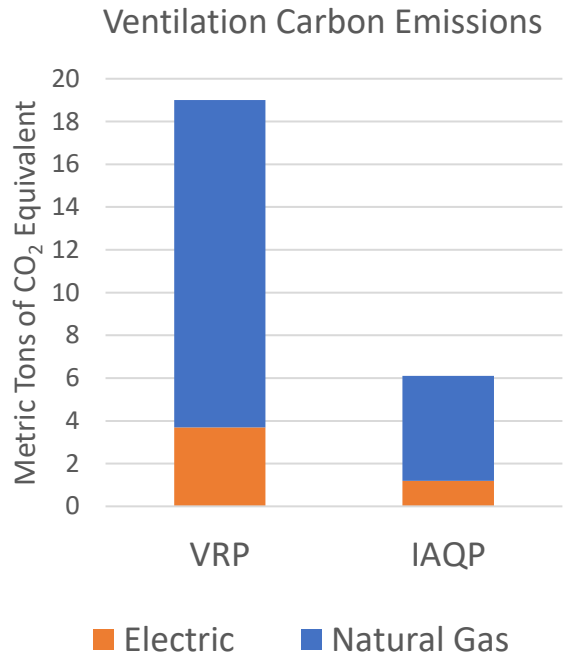
		Proposed Case IAQP + Air Cleaning		Baseline Case VRP	
Design Compounds	ASHRAE Concentration Limit (ug/m3)	Classroom	Office	Classroom	Office
Acetaldehyde 75-07-0	140	12	4	7.9	8.4
Benzene 71-43-2	3	< 1	< 1	< 1	< 1
Toluene 108-88-3	300	< 2	< 2	< 2	< 2
Napthalene 91-20-3	9	<0.4	<0.4	<0.4	<0.4
Xylenes-total 108-38-3, 95-47-6, and 106-42-3	500	< 2	< 2	< 2	< 2
Formaldehyde 50-00-0	**33**	**18**	**16**	**23**	**31**
Acetone	500	< 40	< 40	< 40	< 40
Methylene Chloride	400	< 1	< 1	< 1	< 1
Phenol	10	<0.4	<0.4	0.4	0.5
Tetrachloroethylene	35	<0.2	<0.2	<0.2	<0.2
1,1,1-Trichloroethane	500	<0.2	<0.2	<0.2	<0.2

The project demonstrated that IAQP can be used to provide acceptable indoor air quality with much less outside air.

Case Study: Harvard M&V Results for Energy & Carbon Emissions





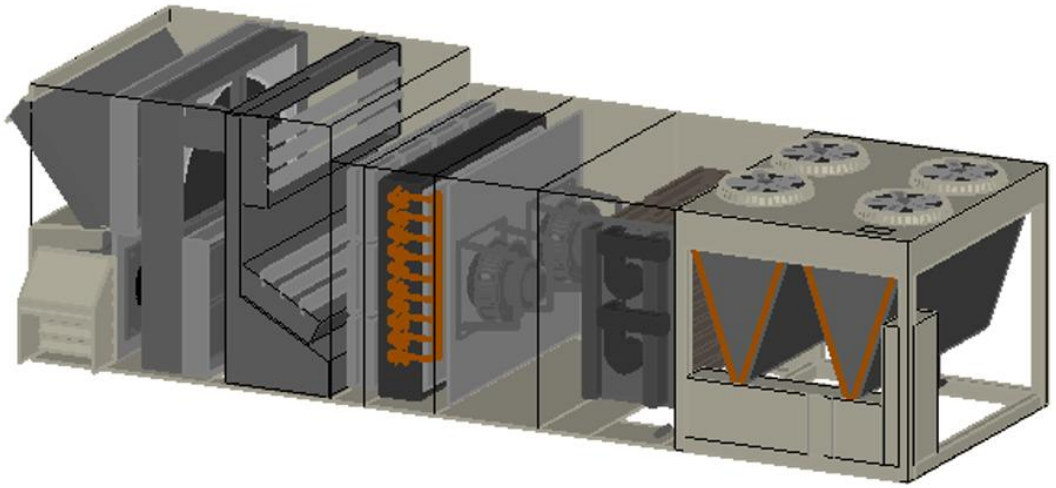


"Based upon the findings, the University would be well served to consider this technology in all new construction projects while also looking for more applications in existing buildings."

Project Example: – Primary School Piketon, OH

Packaged DX RTUs

- (2) 55-ton Rebel Applied RTUs w/ ERWs
- (2) 20-ton Rebel RTU2 with ERWs



Equipment Sizing Using VRP

	Base Package
SVT Units	-
Supply Airflow	43,250 cfm
Cleaned Return Air	-
Outside Air	21,526 cfm
Outside Air Reduction	-
Total Tonnage (DX RTUs)	150-tons
Heating Sizing	2,400 MBH

Project Example: – Primary School Piketon, OH

Table 1 - IAQP Summary - Whole Building

Building Type	**K-12 School**	
Green Building Standard	**N/A**	
Floor Area (ft^2)	**33,631**	Estimated from "SV35 - HVAC SD Set.pdf"
Occupancy	**1,464**	Estimated from "SV35 - HVAC SD Set.pdf"
Baseline Minimum Outside Airflow (CFM)	**21,526**	Estimated from "SV35 - HVAC SD Set.pdf"
System Efficiency (%)	**0.75**	Assumed for typical recirculating air system
IAQP Minimum Outside Airflow (CFM)	**10,958**	Per ASHRAE 62.1 IAQP Calculations
Outside airflow reduced (CFM)	**10,568**	= [VRP – IAQP]
Number of HLR Modules	**4**	Per ASHRAE 62.1 IAQP Calculations

The above analysis is broken out per system in Table 2 below.

Table 2 - IAQP Summary - Breakout

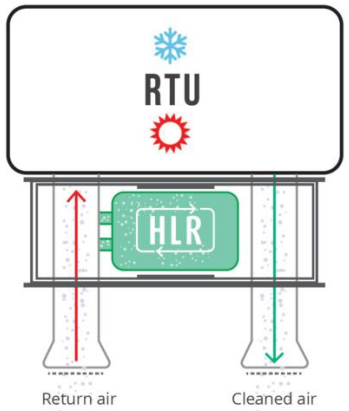
Unit/Tag	Area Served	Area (ft^2)	Occupancy	Baseline Outside Airflow (CFM)	System Efficiency	IAQP Design Outside Airflow (CFM)	Number of HLR Modules	OA Reduction (CFM)
RTU-CAFÉ	Cafeteria	3,721	372	4,614	0.75	2,042	1	2,572
RTU-GYM	Gymnasium	5,436	400	4,435	0.75	1,829	1	2,605
RTU-CR1	Area A Classrooms	13,038	349	6,210	0.75	3,507	1	2,703
RTU-CR2	Area B Classrooms	11,436	343	6,267	0.75	3,579	1	2,688
Total:		**33,631**	**1,464**	**21,526**	**-**	**10,958**	**4**	**10,568**

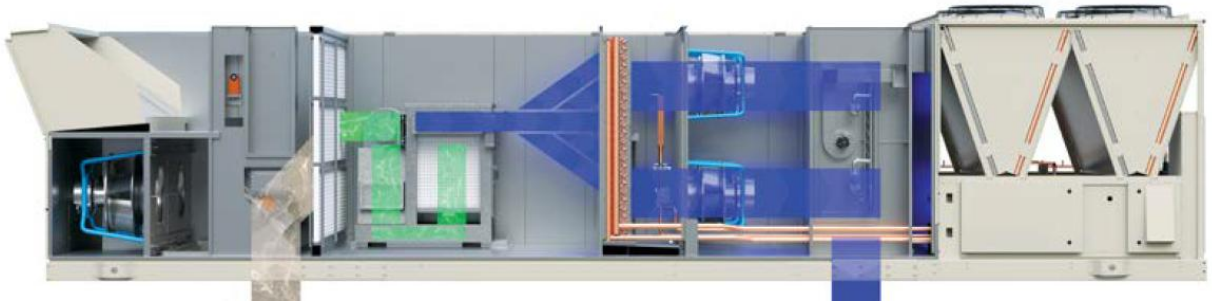
ERW					SVT			
Selection	SA CFM	OA CFM	Tons	HTG MBH	Selection	OA CFM	TONS	HTG MBH
(2) 55-ton Rebel Applied	15,000	12,477	55	800	(2) 40-ton Rebel Applied	7,086	40	450
20-ton Rebel	8,000	4,435	20	400	15-ton Rebel	1,830	15	200
20-ton Rebel	5250	4,614	20	400	15-ton Rebel	2,042	15	200
TOTAL	43,250	21,526	150	2,400		10,958	110	1300

Project Example: – Primary School Piketon, OH

Packaged DX RTUs

- (2) 40-ton RTUs w/ air cleaning
- (2) 15-ton RTUs w/ air cleaning





Equipment Sizing

	Base Package	Daikin Package w/SVT
SVT Units	-	4
Supply Airflow	43,250 cfm	43,250 cfm
Cleaned Return Air	-	4,000
Outside Air	21,530 cfm	10,960 cfm
Outside Air Reduction	-	49%
Total Tonnage (DX RTUs)	150-tons	110-tons
Heating Sizing	2,400 MBH	1,300 MBH

Benefits of IAQP + Air cleaning

- Enhanced Indoor Air Quality design (below LEED limits)
- 6-8 additional LEED points for a performance-based indoor air quality design
- Peak cooling load reduced by 40 tons
- Most robust design with elimination of ERV wheels and associated maintenance/failures
- ~$35k in owner first cost savings (Packaged RTUs)
- Reduced operating costs

Project Example: – Troy Library Renovation, OH

Packaged DX + DOAS

- (1) Packaged AHU + Fan coils (interior load)
- (1) 6-ton DOAS unit (1,250 CFM OA)
- (1) 10-ton DOAS unit (1,750 CFM OA)
- Project over budget and at risk of not moving forward

VE Exercise with IAQP + Air cleaning

- (1) Packaged AHU + Fan coils (interior load)
- (1) 6-ton DOAS to serve entire building (930 CFM OA)
- By utilizing the IAQP + Air cleaning, the project was able to move forward within budget

DOAS Equipment Sizing

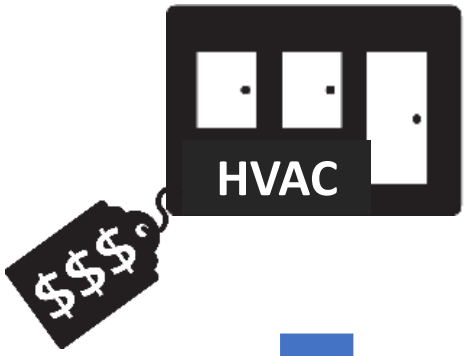
	Base Package	VE Package w/ IAQP
Air cleaning Units	-	1
Supply Airflow	3,000 CFM	1,930 CFM
Cleaned Return Air	-	1,000 CFM
Outside Air	3,000 CFM	930 CFM
Outside Air Reduction	-	69%
Total Tonnage (DX RTUs)	16 tons	6 tons
Heating Sizing	270 MBH	150 MBH

Benefits of IAQP + Air cleaning

- Smaller mechanical footprint, reduced ductwork and equipment sizing
- Enhanced Indoor Air Quality design
- Most robust design with elimination of ERV wheels and associated maintenance/failures
- ~$45k in owner first cost savings (Eliminated DOAS)
- Reduced operating and energy costs

Summary: Benefits of IAQP

Save money on new HVAC equipment



CapEx

Reduce HVAC EUI & energy costs by 40%

OpEx

Lower Carbon Emissions & Improve IAQ

Air Quality

Earn points for LEED & WELL

Green Buildings

IAQP + air cleaning can reduce the OA code requirement by 40% - 80%