

Enhanced Ventilation for Cleaner Air in Buildings



July 27, 2023

Today's Speakers



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Welcome Poll



[Slido.com](https://www.slido.com): #cleanair to access polls and Q&A

2023 Summer Buildings and Health Series

Sessions run the 4th week of each month through September

- May 23: Health in Buildings Partnerships
- June 27: Circadian Lighting
- **July 27: Enhanced Ventilation for Cleaner Indoor Air**
- Aug 31: Wellbuilt for Wellbeing
- Sept 26: The Health in Buildings Roundtable Scoping Session

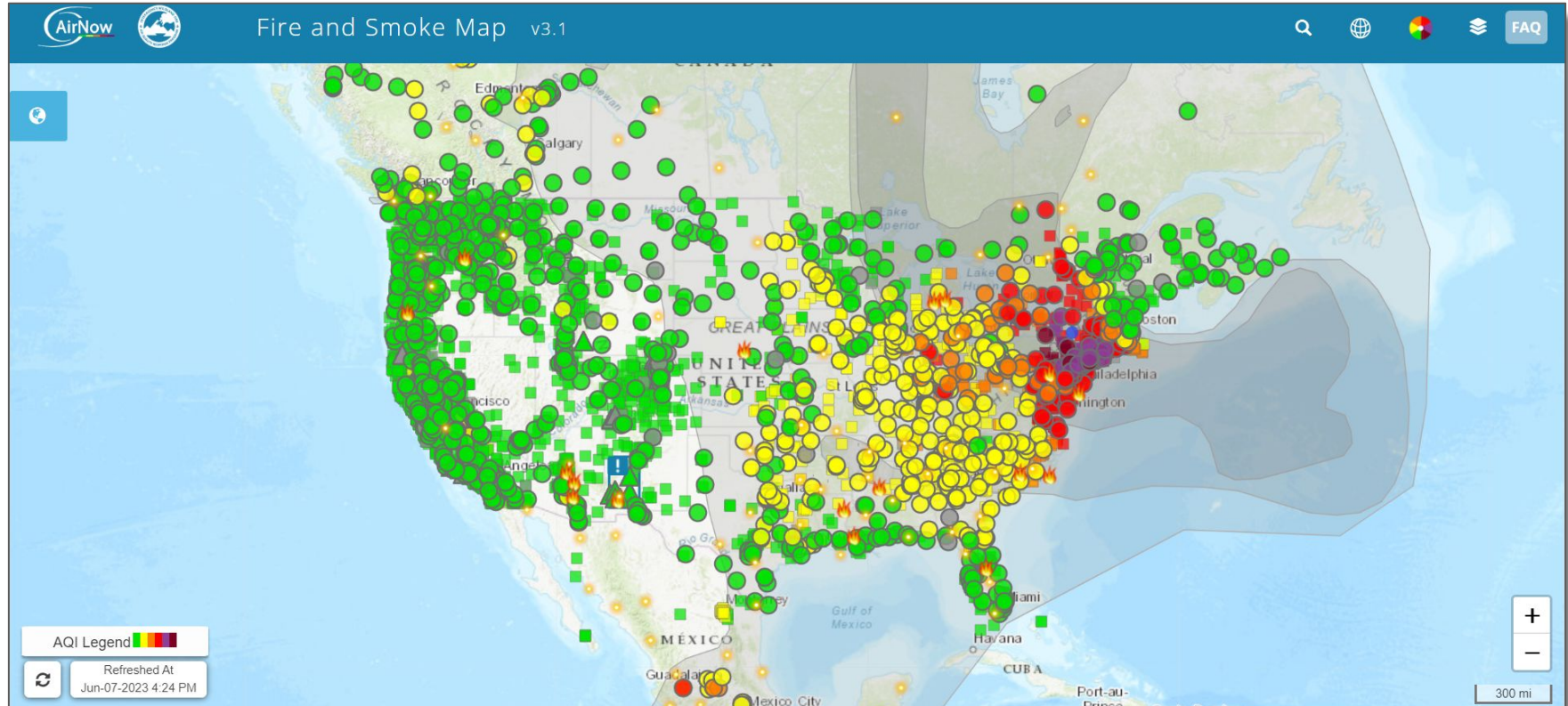
This series is a call for co-sponsors - Health in Buildings Roundtable!

- Government agencies, companies, research organizations, non-profits, etc
- Pilot, measure, and evaluate health-enhancing strategies
- To learn more or to join scoping meeting - email coskvig@nas.edu

Today's Agenda

- **Introduction**
- **Ensuring existing ventilation standards at GSA**
- **ASHRAE Standard 241**
- **Future field research on strategies to improve IAQ**
- **Estimating the value of better indoor air**
- **Breakout session!**
- **Final Q&A**

Ensuring clean indoor air remains important



Pre-COVID: “levers” to improve IAQ

- [Enhancing health with \(better\) indoor air](#) suggests good, enhanced, stringent levels:
 - Clean, fresh air (30 CFM / person)
 - Better filtration (MERV 13)
 - Managing dry air (RH 40-60%)
- Increasing ventilation rates to 30CFM/person could bring \$38B/year in benefits
- More field research is needed to better define replicable, scalable actions



Lever 1
Provide More
Fresh Air



Lever 2
Remove Outdoor
Pollutants



Lever 3
Manage Thermal
Conditions



Lever 4
Eliminate Indoor
Contaminants

Improve ventilation and meet climate goals?

- Better ventilation takes more energy?
- Commissioning can save 5-20% energy in almost any building (PNNL)
- Improved controls saved \$7M/year in energy (GSA Smart Buildings)
- Deep energy retrofits reduce energy use by 38% (GSA ESPC PMO)
- The investments needed to achieve climate goals can also improve IAQ

Clean Air in Buildings Challenge

GSA commits to be an “exemplar” of innovation and implementation

- National program to verify ventilation in federally-owned buildings
- Convene experts to suggest improvements to the P100
- Partner with experts and researchers on “real-world research”
- Share leading practices from research in training resources



First Impressions Poll



[Slido.com](https://www.slido.com): #cleanair to access polls and Q&A

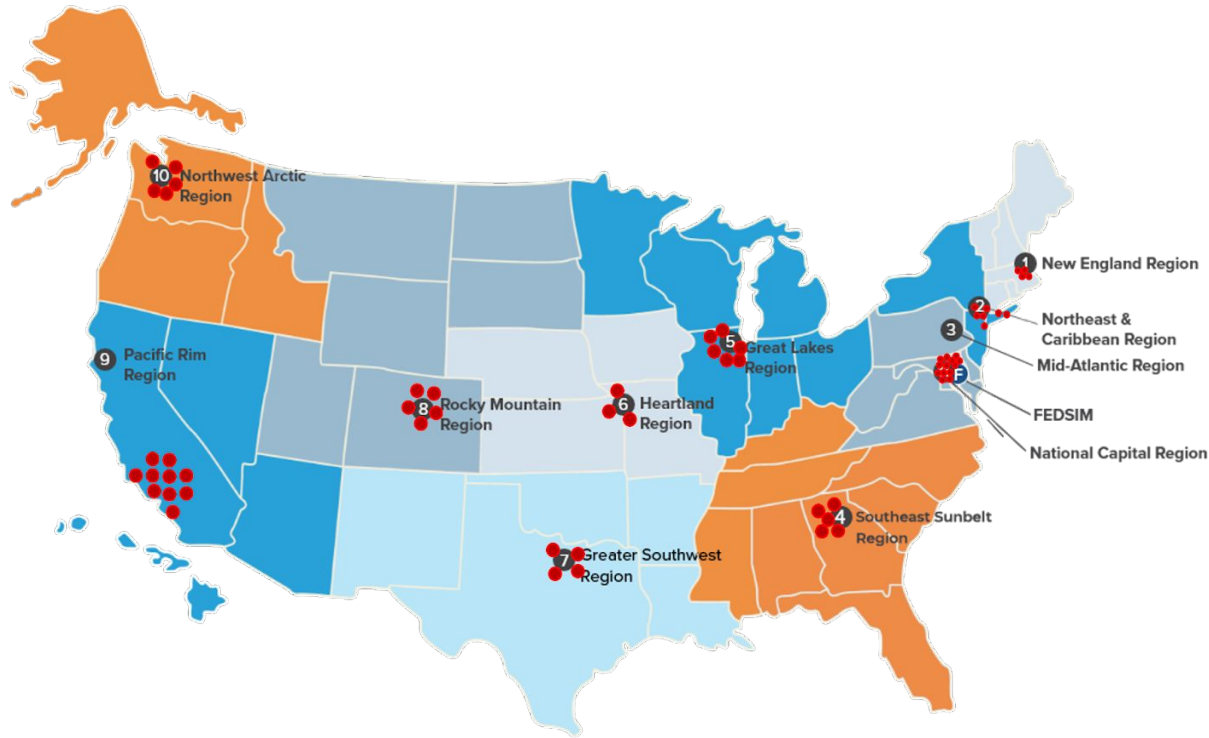


Ensuring Ventilation

A Field Study of 62 Buildings

July 27, 2023

GSA Evaluated 1756 air handling units in 62 buildings



Key data collected at each AHU

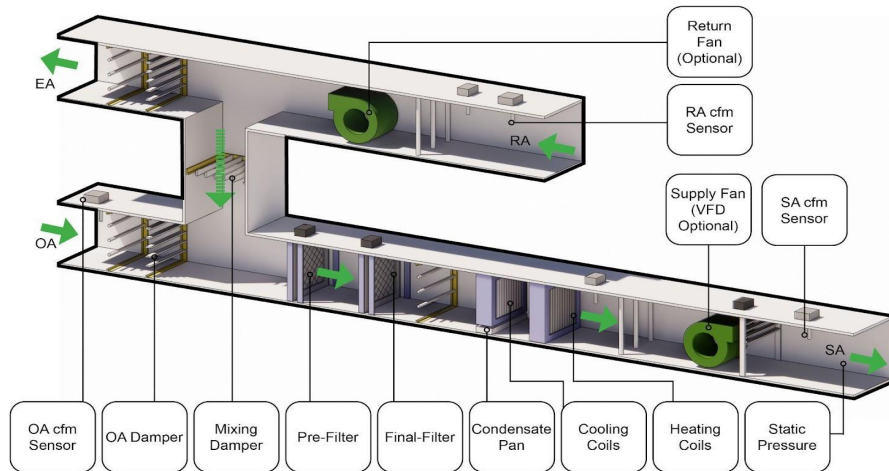
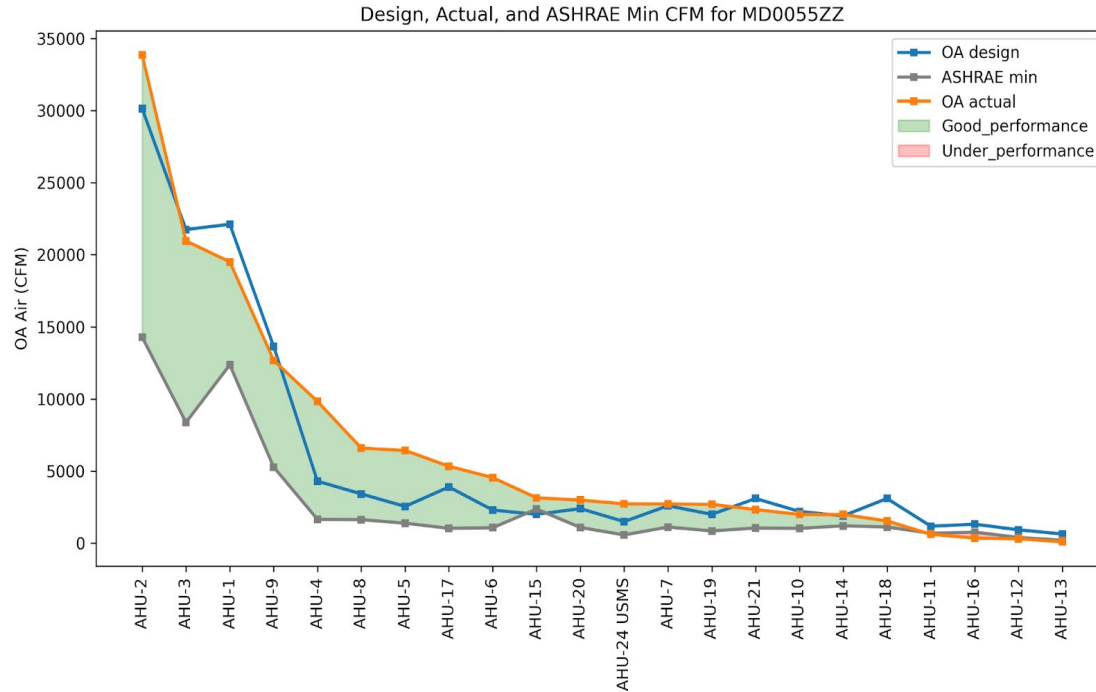


Figure 3.1 Field data records for 1756 AHU in 62 buildings

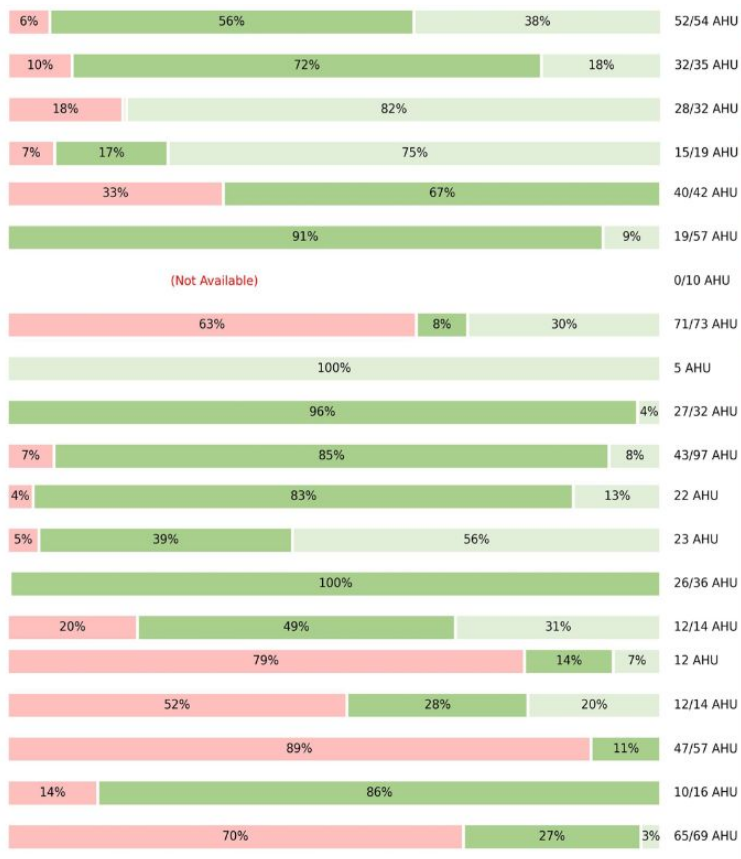
1. **Outdoor Air (OA) minimums:** Measured vs. Initial Design and Field-Calculated ASHRAE Default
2. **OA intensity:** calculated cfm/sqft served
3. **OA Damper** condition/position (min and max)
4. **Filter type/condition** (pre-filter and final filter)
5. **Coil and condensate pan** condition
6. **Supply Fan VFD** in place/operational (Y/N)
7. **Economizer** in place/operational (Y/N)
8. **Airflow Sensors** condition
9. **TAB Assessment** needed (Y/N)
10. **DCV disabled** (Y/N)
11. **Operating hours extended** Y/N

Measured Outdoor Air vs. thresholds: typical building



63% of the 1312 AHUs with both measured (orange line) and field-calculated ASHRAE min (grey line) exceeded the field-calculated ASHRAE default minimum requirements

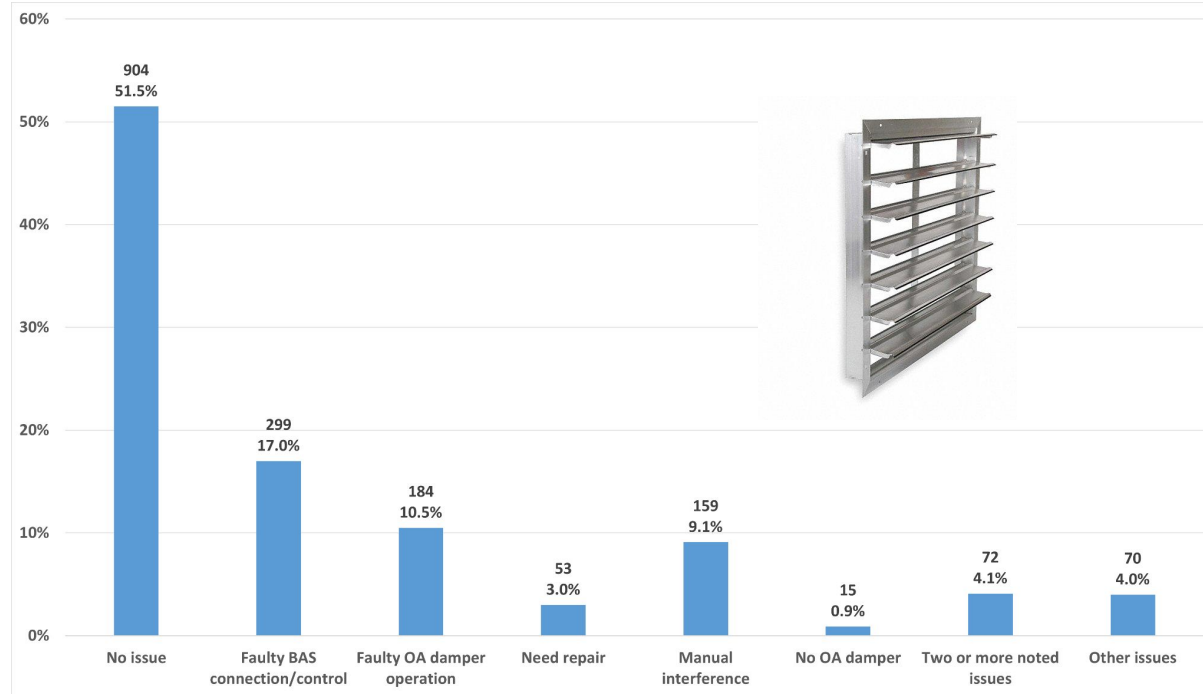
Measured Outdoor Air vs. thresholds: a new dashboard



Percentage of each individual building's floor-space served by an AHU with measured outdoor air:

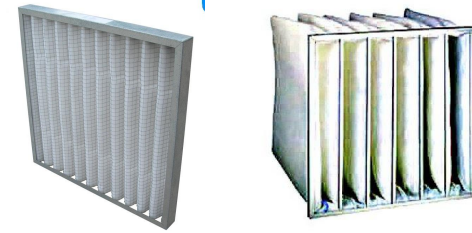
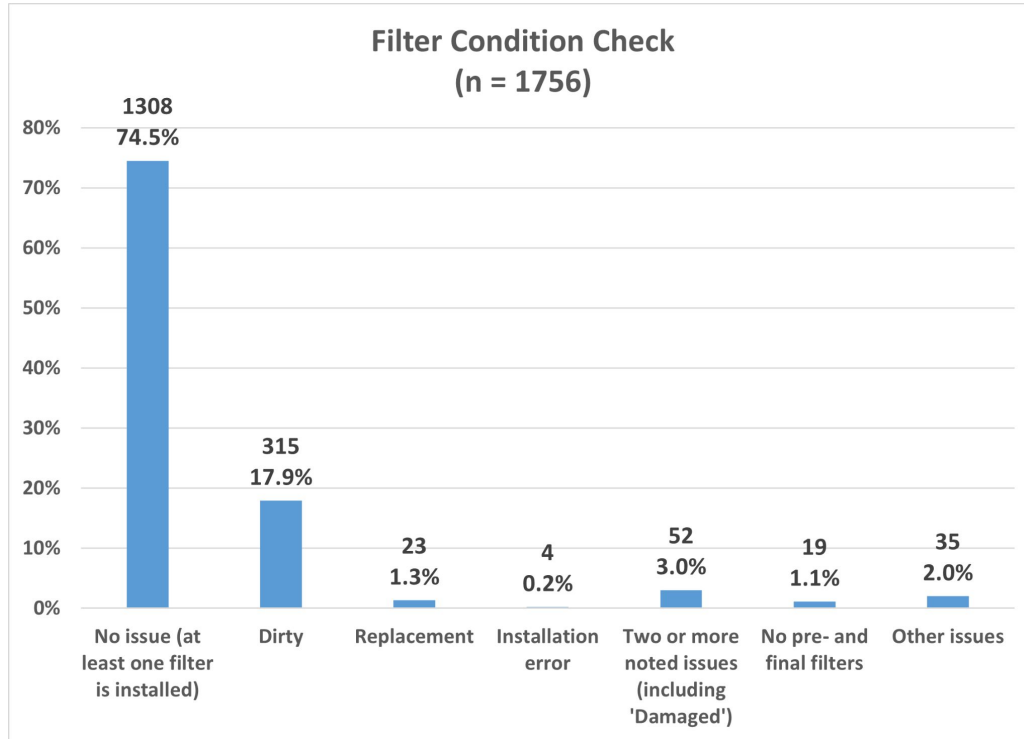
- Below field-calculated ASHRAE min OA
- Above field-calculated ASHRAE min OA
- 60% over ASHRAE min OA

Outdoor Air Damper Condition



**52% of the OA Dampers for 1756 AHU were in good working condition,
27% need software updates, 12% need hardware updates**

Pre/Final filter condition, MERV Rating



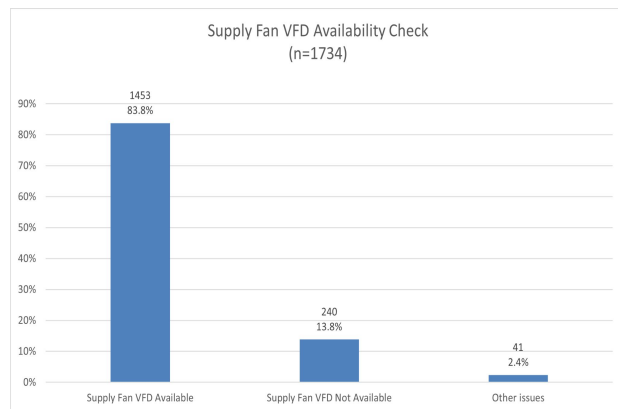
GSA has been a leader in moving to MERV 13 or higher, replacing over 65% of the filters.

Filter condition records for 1756 AHUs identified 75% in good condition.



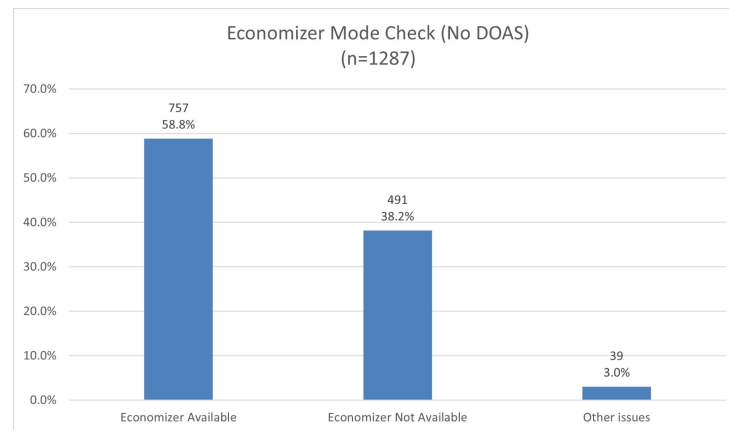
Variable Frequency Drives (VFDs) and Economizers

VFDs for Supply Air Fans



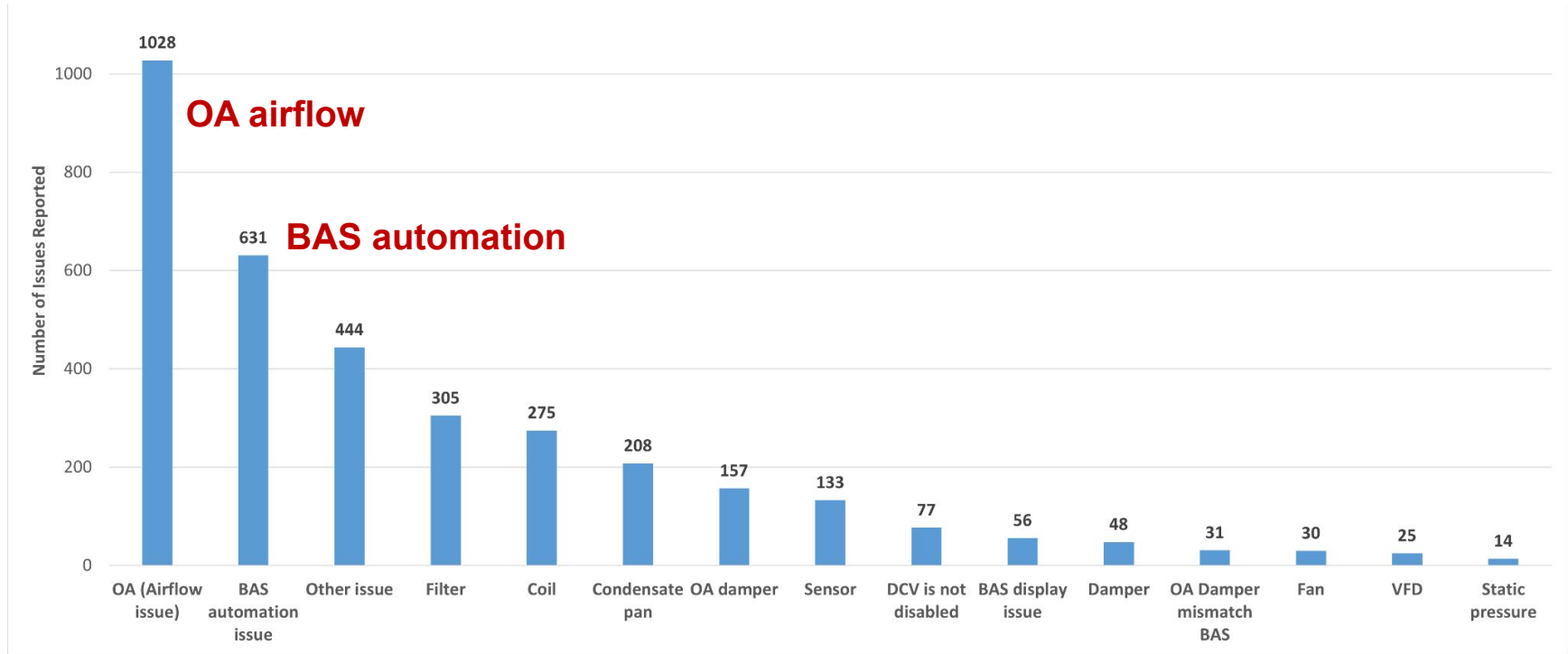
84% of the air handling units had a VFD on supply air fans, with 96% in good condition.

Economizers and OA airflow sensors

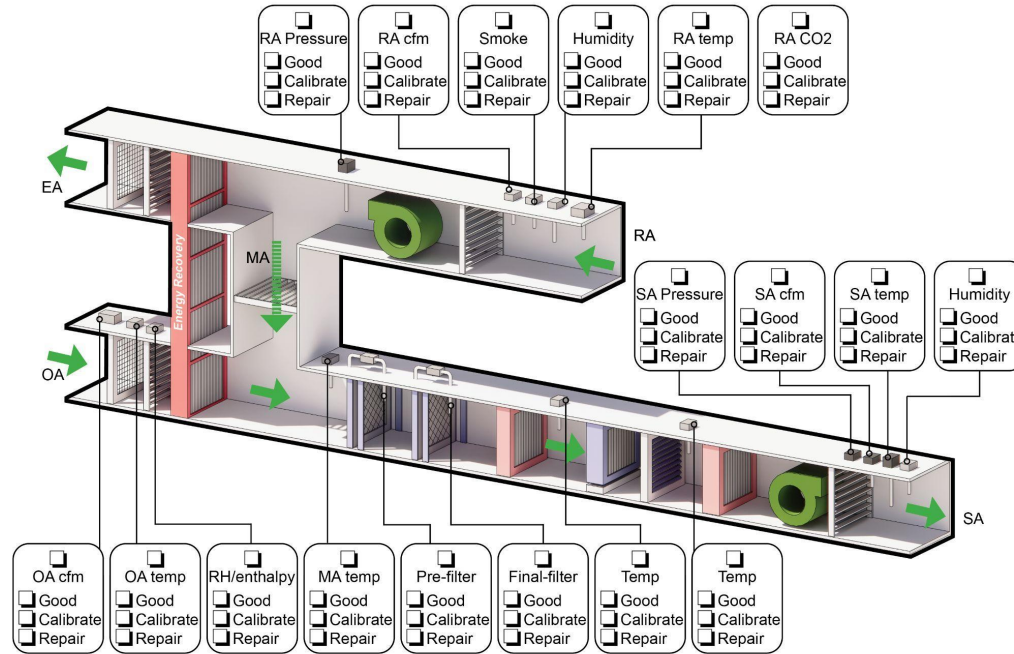


In 1287 AHU units, 59% of the air handling units had economizer operations available. 37% of the OA airflow sensors were considered adequate.

Issues identified across all 62 buildings

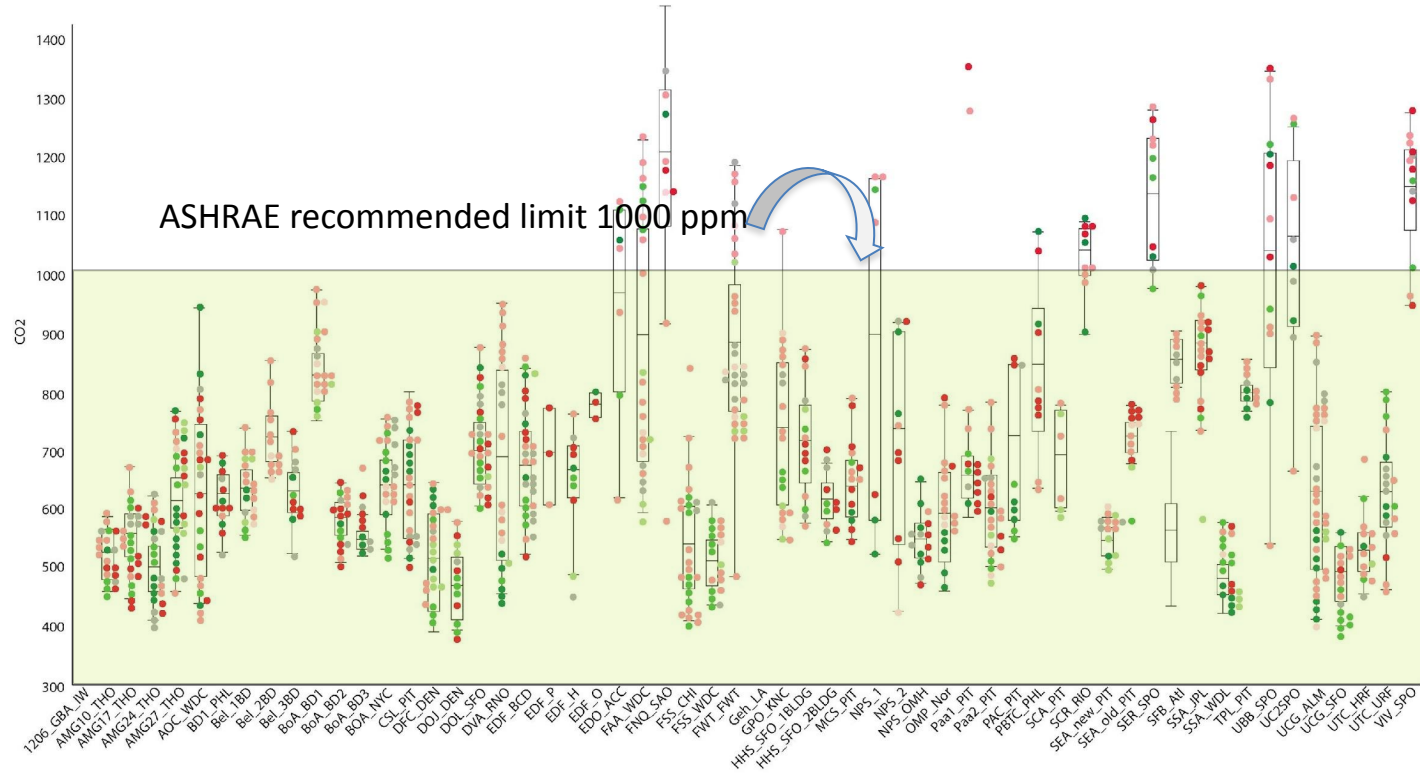


What sensor data is available for FDD and controls?



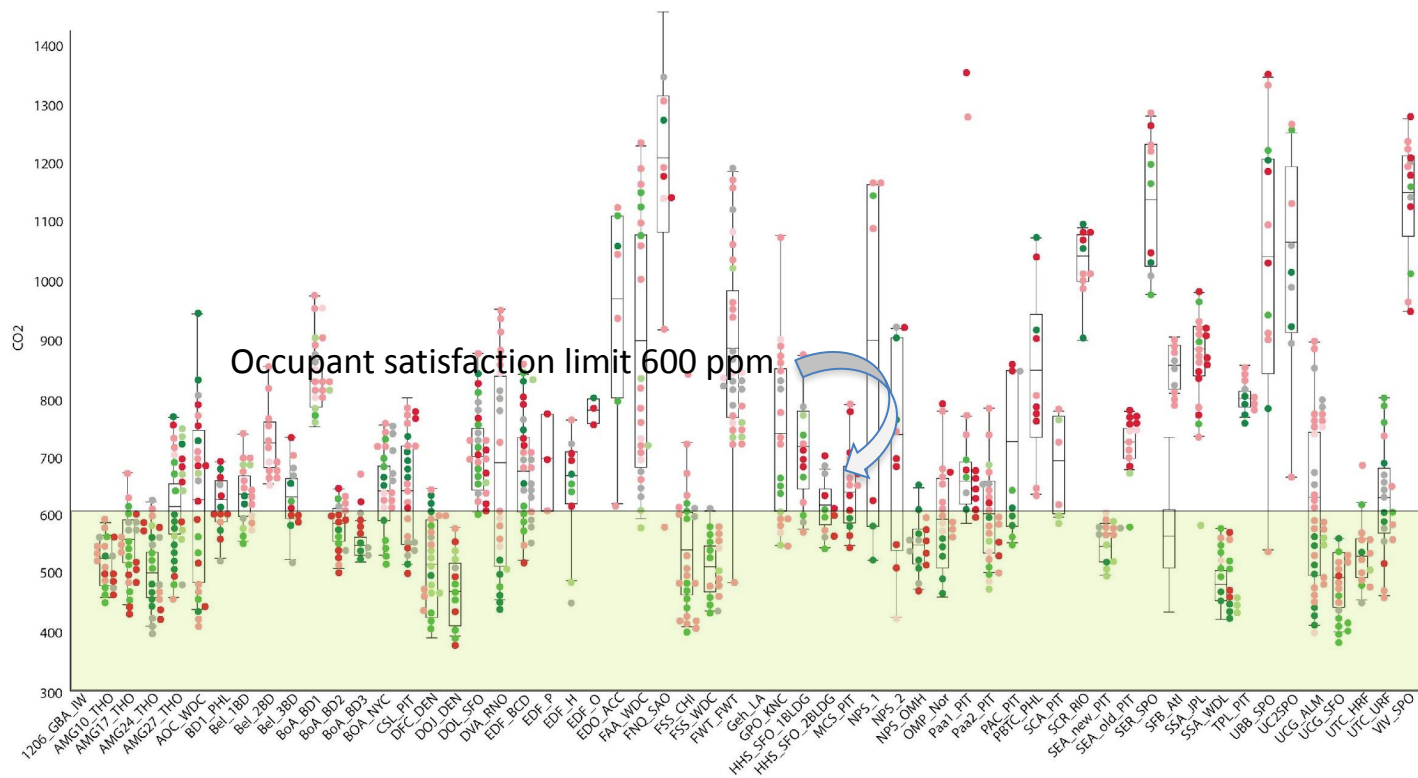
Beyond Air Handling Unit Field Assessments: Sensors and Working Conditions

Cross-sectional analyses: CO2 levels at 1282 desks



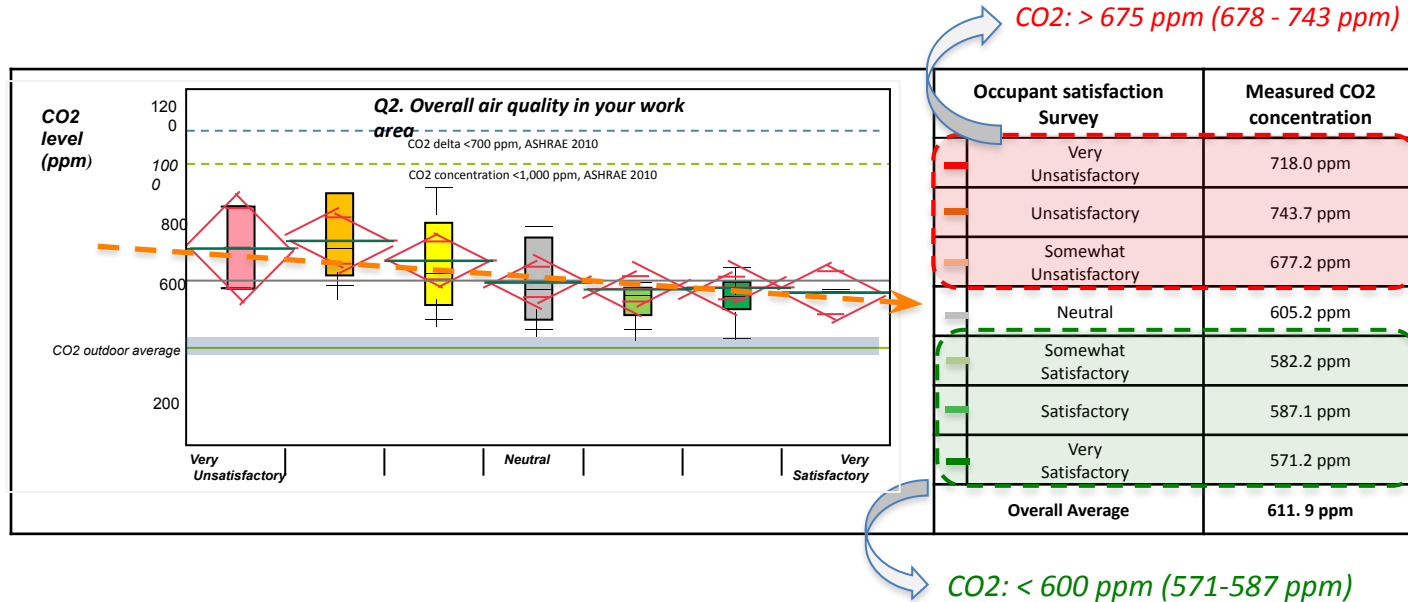
n=1282 workstations, 64 buildings

CO2 levels at desk compared to occupant AQ satisfaction



n=1282 workstations, 64 buildings

Workstation CO2 and satisfaction with overall air quality



Occupant Satisfaction with overall air quality is strongly linked to CO2 levels, with significant shifts to satisfaction when CO2 < 600 ppm (n=1282 in 64 buildings, p < 0.05).



ASHRAE Standard 241

July 27, 2023

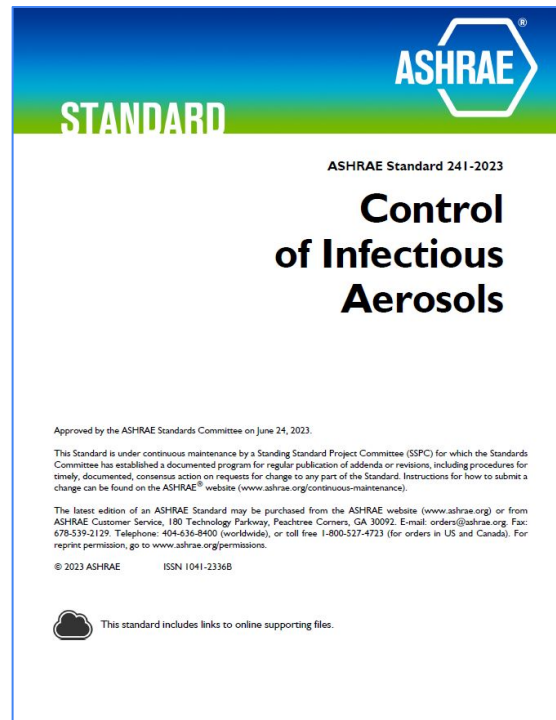
Standard 241 Poll



[Slido.com](https://www.slido.com): #cleanair to access polls and Q&A

Overview of ASHRAE Standard 241

- Written in response to COVID-19 pandemic experience
- White House COVID-19 Response Team encouraged fast-track development of an airborne pathogen control standard
- Timeline:
 - Nov. 2022 – ASHRAE/White House discussions
 - Dec. 6, 2022 – ASHRAE BOD orders development in six months with waiver of some ANSI procedures
 - Dec. 2022 – open call for members
 - Jan., 2023 – title/purpose/scope and roster approved
 - Feb. 28, 2023 – first project committee meeting
 - May 11, 2023 – public review draft approved
 - June 15, 2023 – draft recommended for publication
 - June 24, 2023 – ASHRAE approves publication



Purpose and Scope

Purpose

- Establish minimum requirements for control infectious aerosols to reduce risk of disease transmission in occupiable space of new and existing buildings and major renovations
- Requirements cover outdoor air systems, air cleaning systems
 - Design
 - Installation
 - Commissioning
 - Operation
 - Maintenance
- Specifies equivalent clean airflow to be provided in infection risk management mode

Scope

- Does NOT establish overall requirements for acceptable indoor air quality
- Based on control of long range transmission, i.e., outside close proximity to an infector

Compliance - Prerequisites

Meet requirements of applicable standard or approved equivalent

- ANSI/ASHRAE Standard 62.1
Ventilation and Acceptable Indoor Air Quality
- ANSI/ASHRAE Standard 62.2
Ventilation and Acceptable Indoor Air Quality in Residential Buildings
- ANSI/ASHRAE/ASHE Standard 170
Ventilation for Health Care Facilities

Significance

- Governing standards for acceptable indoor air quality
- Set minimum outdoor air flow rates
- Set minimum particulate filtration requirements
- Cover anything not addressed in Standard 241

Infection Risk Management Mode (IRMM)

The mode of operation in which measures to reduce infectious aerosol exposure documented in a building readiness plan are active

- The standard does not give criteria for activating IRMM
- Possible decision makers
 - Public health authority
 - Owner/operator
 - Occupant
- Why not all the time?
 - Risk varies greatly over time – not always necessary
 - Minimizes incremental energy use and operating cost
 - Standard 241 is not a general IAQ standard

Building Readiness Plan (BRP)

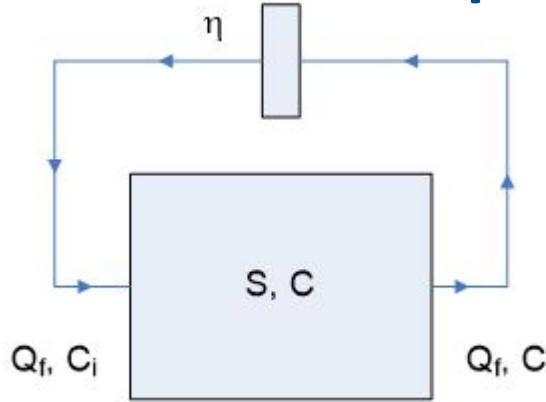
A plan that documents the engineering and non-engineering controls that facility systems will use for the facility to achieve its goals

- Standard 241 includes requirements for assessment and planning to develop a BRP

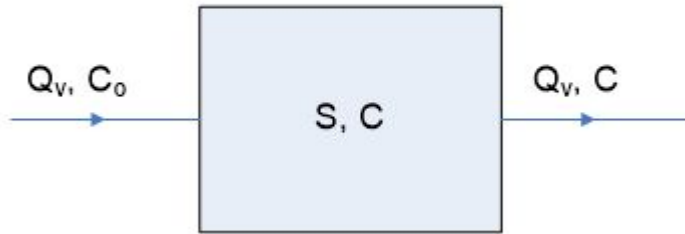
Equivalent Clean Air Flow

The flow rate of pathogen-free air that, if distributed uniformly within the breathing zone, would have the same effect on infectious aerosol concentration as the sum of actual outdoor airflow, filtered airflow, and inactivation of infectious aerosols

Equivalent Clean Air Flow



Actual filtration of recirculated air with efficiency " η " at flow rate " Q_f " controlling source " S " to achieve concentration " C "



For an equivalent dilution process with uncontaminated air: $Q_v = \eta Q_f$

Equivalent clean airflow can be determined for any technology and system configuration

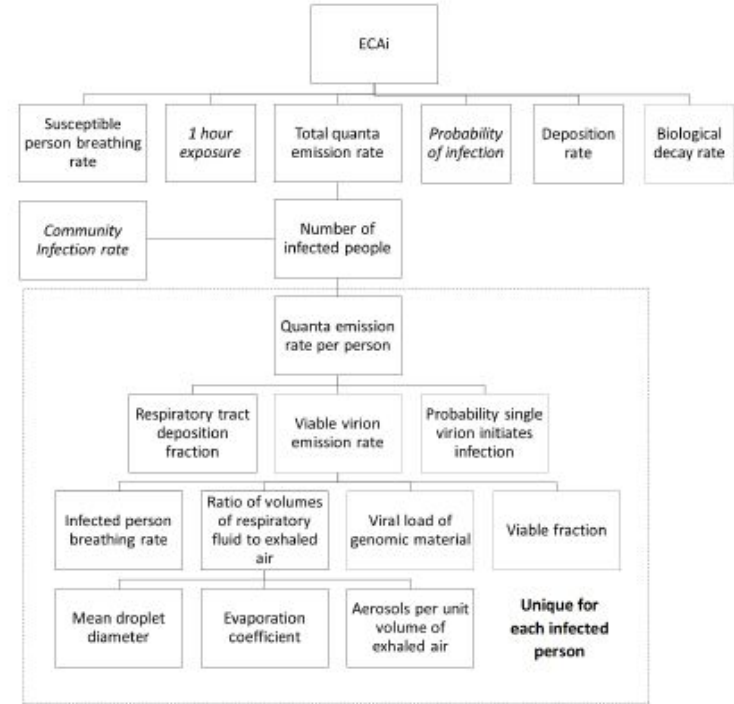
Equivalent Clean Air Flow Requirement (ECAi)

- Specified as equivalent clean air flow for infection control per person, ECAi (cfm/pers or L/s-pers)
- Based on probabilistic risk assessment incorporating many factors
- Wells-Riley infection model
- Goal is same risk per hour across all space types
- ECAi and number of occupants, $P_{Z,IRMM}$ determine requirement for a given space, V_{ECAi}

$$V_{ECAi} = ECAi \times P_{Z,IRMM}$$

- Alternatively, achievable V_{ECAi} and ECAi determine maximum number of occupants in IRMM

$$P_{Z,IRMM} = V_{ECAi} / ECAi$$



EACi Values

- Compared with ASHRAE Standard 62.1 rates at default occupancy ECAi values are substantially higher:
 - Office: 17 vs. 30 cfm/pers
 - Classroom (age 9+): 13 vs. 40 cfm/pers
 - Restaurant: 10 vs. 60 cfm/pers
- Constant risk ECAi values do not give constant air change rate. For 8' ceiling, default occupancy
 - Office: 1.1 ACH
 - Classroom: 10.5 ACH
 - Restaurant: 31.5 ACH*

* IRMM occupancy can be reduced if not possible

Table 5-1 Minimum Equivalent Clean Airflow per Person in Breathing Zone in IRMM

Occupancy Category	ECAi	
	cfm/person	L/s/person
Correctional Facilities		
Cell	30	15
Dayroom	40	20
Commercial/Retail		
Food and beverage facilities	60	30
Gym	80	40
Office	30	15
Retail	40	20
Transportation waiting	60	30
Educational Facilities		
Classroom	40	20
Lecture hall	50	25
Industrial		
Manufacturing	50	25
Sorting, packing, light assembly	20	10
Warehouse	20	10
Health Care		
Exam room	40	20
Group treatment area	70	35
Isolation room	70	35

Meeting the Equivalent Clean Air Requirement

- V_{EACi} can include
 - Outdoor airflow – mechanical and natural ventilation
 - Equivalent clean air from multizone air cleaning systems
 - Air cleaning systems serving individual spaces
- Air cleaning systems capture and remove or inactivate airborne pathogens
 - Mechanical filters
 - Germicidal ultraviolet
 - Reactive species
- Approach allows maximum flexibility to user

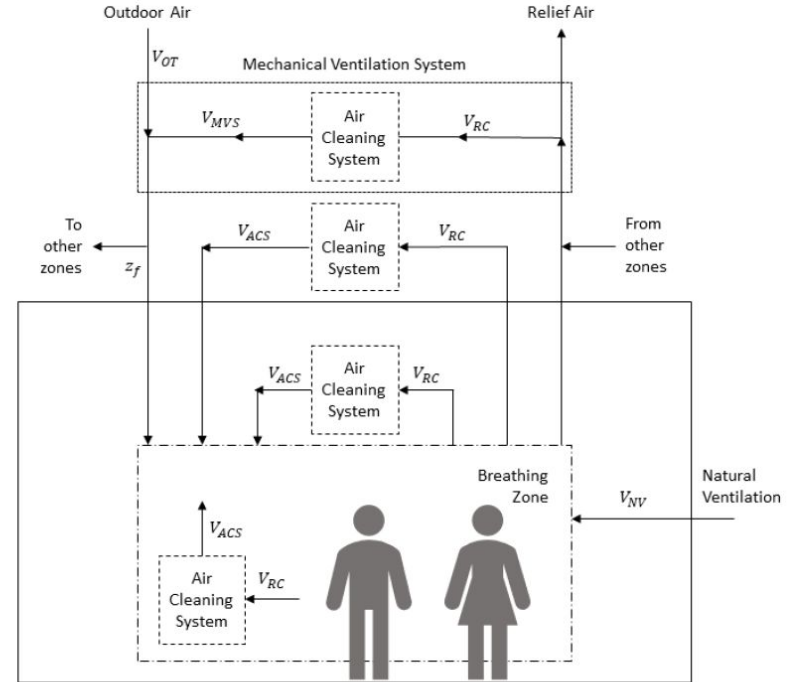


Figure 6-1 Sources of outdoor and clean air (for V_{RC} , see Section 7).

Requirements for use of air-cleaning systems

- Must pass requirements for effectiveness and safety testing
- Effectiveness
 - Single pass
 - Equivalent clean air flow rate
- Safety
 - PM > 0.3 μm
 - Formaldehyde
 - Ozone
- Available test methods aren't entirely sufficient
- Several new standards are under development

Assessment, planning, and implementation

- Builds extensively on ASHRAE Epidemic Task Force Building Readiness guidance
- Provides requirements for developing the Building Readiness Plan
- Guidance for field tests to measure equivalent clean air flow rate
- Supporting information includes
 - Equivalent outdoor air calculator
 - Guidance on assessing energy recovery ventilators
 - Guidance on preventing re-entry of contaminated air

Assessment, planning, and implementation

Phase of the Process		Assessment	Planning	Planning	Planning	Planning	Implement
Name of Space / AHU / Building	Units	EXISTING	Option 1	Option 2	Option 3	Option 4	FINAL SYSTEM
Description of system or Option		AHU with X,Y,Z	Description	Description	Description	Description	Description
Space Type from Standard 241	Type	Office	Office	Office	Office	Office	Office
Target ECAI from Standard 241 (See Instructions for Table)	CFM / Person	30	30	30	30	30	40.0
Area	Sq Ft	2,000	2,000	2,000	2,000	2,000	2,400
Average Ceiling Height	Ft	9	9	9	9	9	9
Volume	Cu Ft	18,000	18,000	18,000	18,000	18,000	21600
Total Supply Air	CFM	1,800	1,800	1,800	1,800	1,800	1800
Total Outdoor Air	CFM	240	240	240	240	240	272
Occupancy - Design (Pz)	Quantity	12	12	12	12	12	12
Occupancy - IRMM Target (Pz,IRMM)	Quantity	8	8	8	8	8	12
VECAI,t,Des Airflow Target - Design Occupancy	CFM	360	360	360	360	360	480
VECAI,t,IRMM Airflow Target - IRMM Target Occ.	CFM	240	240	240	240	240	480
Central AHU Filter MERV Rating	MERV	12	13	13	13	13	13
Method for Rating Filter	241 or DNFE	241	241	DNFE	241	241	241
Filter Pathogen Removal Efficiency	ϵ_{PR}	71.0%	77.0%	67.0%	77.0%	77.0%	77.0%
UV in HVAC - Single Pass Inactivation	%	0.0%	35.00%	50.00%	0.00%	0.00%	0.00%
Air Treatment in HVAC (Impacts Space)	CFM	400	100	0	0	0	0
Air Treatment Device in Space	CADR	0	4	0	0	0	0
Number of Air Treatment Devices in Space	Quantity	0	1	0	0	0	0

Operations and maintenance

- Operational requirements are derived from Epidemic Task Force Core Recommendations, e.g.,
 - Operating hours
 - Demand control modifications
 - Exhaust modifications
- Maintenance requirements are built on requirements in ASHRAE Standard 62.1
 - IRMM frequency may be higher
 - New items for engineering controls added to reduce risk

Potential impact of Standard 241-2023

- Innovations
 - Use of equivalent clean air (ECAi)
 - Resilient operating modes in IAQ standards (IRMM)
 - Effectiveness and safety requirements for air cleaners
- Building stock better prepared to meet future airborne infectious disease outbreaks
- Framework for making building occupants less vulnerable to indoor respiratory disease transmission while addressing cost and energy concerns
- Model for future IAQ standards



Expert Panel Prioritizing GSA's Real World Research

July 27, 2023

Real World Research Poll



[Slido.com](https://www.slido.com): #cleanair to access polls and Q&A

GSA's Real World Research Program

Expert Workshop to identify research for advancing IAQ and Health

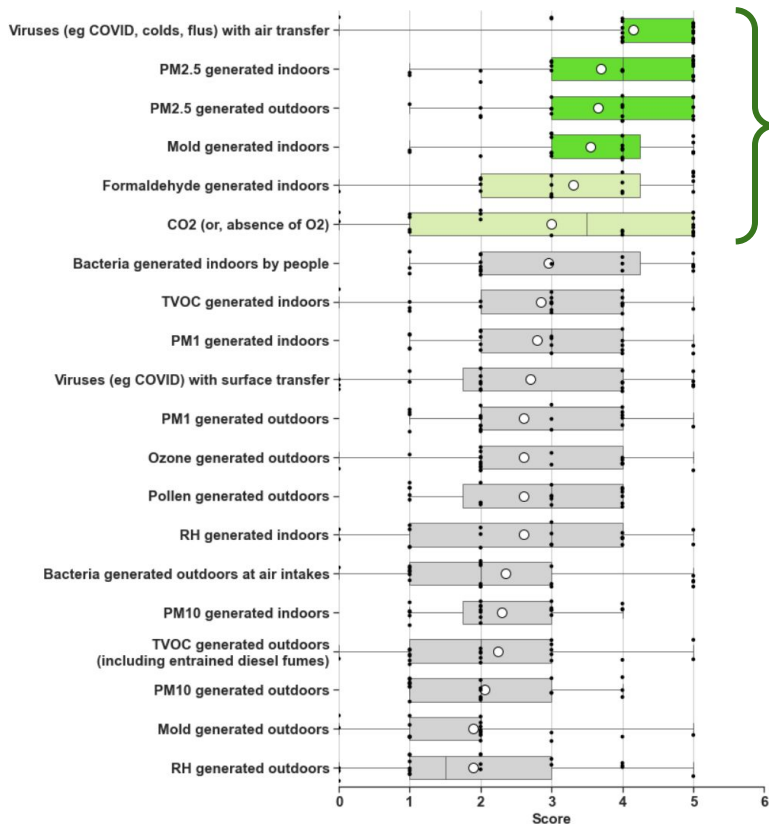
- Measures of health outcomes and air quality critical to future research
- Attributes of HVAC systems and controls believed to influence health
- A common corrective action list for HVAC systems in federal buildings
- Criteria for selecting buildings to pilot interventions
- An approach to a future long-term epidemiological study

An Expert Panel of diverse perspectives

- Whitney Austin Gray, PhD, IWBI
- William Bahnfleth, PE, PhD, Penn State University
- Ruairí Barnwell, HBDP, DLR Group
- Liam Bates, CEO, Kaiterra
- Sara Coefield, Missoula City
- Ian Cull, CIH, PE, Indoor Science
- Seema Bhangar, PhD, USGBC
- Maria Fara, Facility Engineering
- Elliott Gall, PhD, Portland State University
- Brian Gilligan, PE, GSA
- Diann Herrick, Rivion
- Kevin Kampschroer, GSA
- Kevin Keene, PNNL
- Mark Kutchi, PE, GSA
- Roger Lautz, PE, AEI Engineering
- Luke Leung, PE, SOM
- Linsey Marr, PhD, Virginia Tech
- Meghan McNulty, PE, Servidyne
- David Michaels, PhD, MPH, GWU
- Shona O'Dea, SOM
- David Okada, Engineering Economics, Inc.
- Cameron Oskvig, National Academies of Science Engineering and Medicine
- Jovan Pantelic, PhD, Well Living Lab
- Andrew Persily, NIST
- Maureen Roskoski, Facility Engineering Associates
- Peter Rumsey, PE, Point Energy Innovations
- Phillip Salvatore, MD, CDC
- Brett Singer, PhD, LBNL
- Jelena Srebric, PhD, University of Maryland
- Esther Sternberg, MD, University of Arizona
- Stephanie Taylor, MD, Building4Health
- Steve Taylor, PE, Taylor Engineering
- Martin Weiland, PE, GSA

Prioritize Pollutants by Short-Term Impacts to Health and Performance

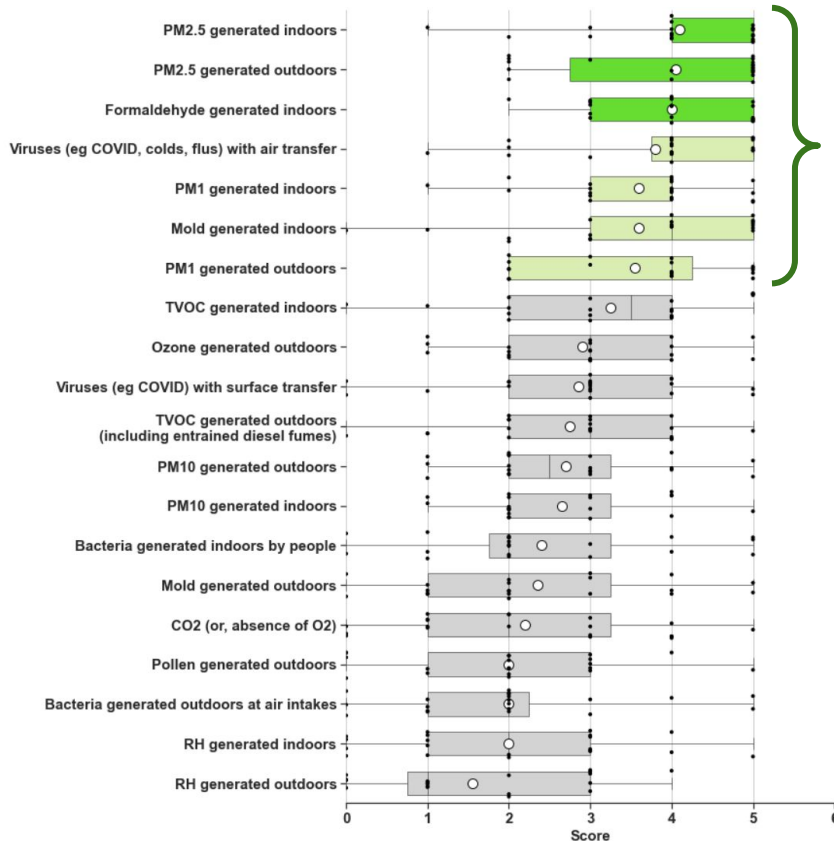
Survey 1 (n=20)



- Viruses
- PM2.5 (generated indoors)
- PM2.5 (generated outdoors)
- Mold (generated indoors)
- Formaldehyde (generated indoors)
- CO2 (or absence of O2)

Prioritize Pollutants by Long-Term Impact to Health and Performance

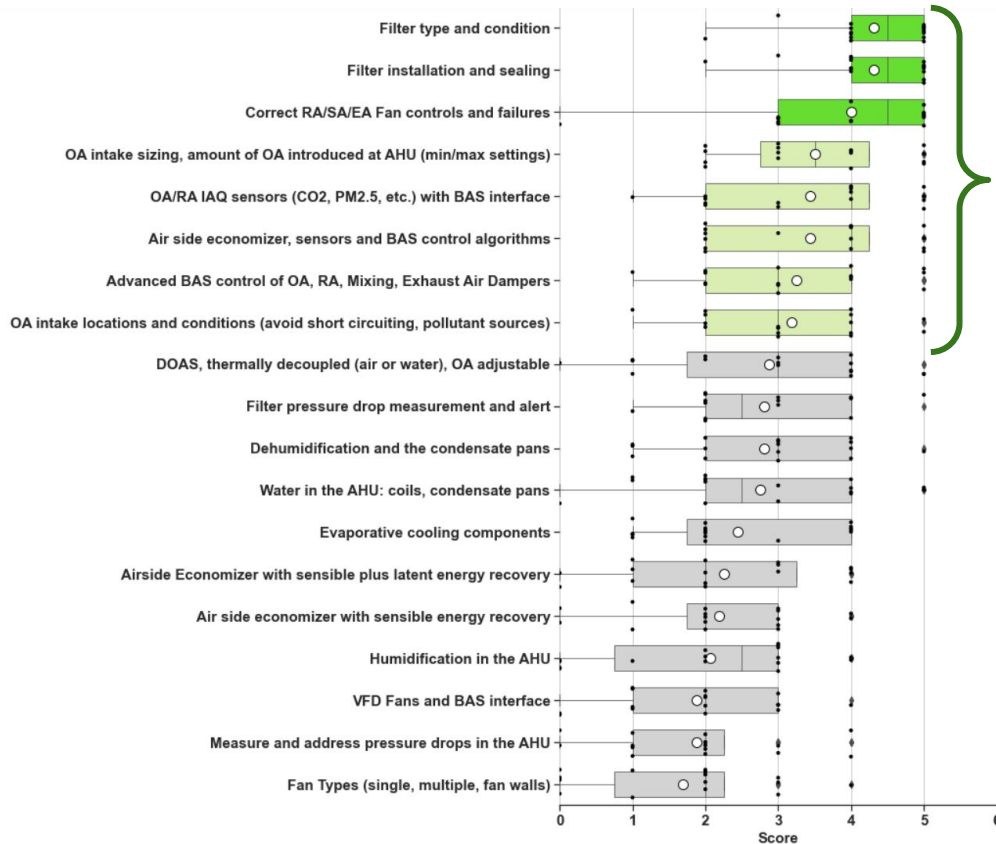
Survey 1 (n=20)



- PM2.5 (generated indoors)
- PM2.5 (generated outdoors)
- Formaldehyde (generated indoors)
- Viruses
- PM1 (generated indoors)
- Mold
- PM1 (generated outdoors)

Prioritize HVAC Interventions at the AHU Level

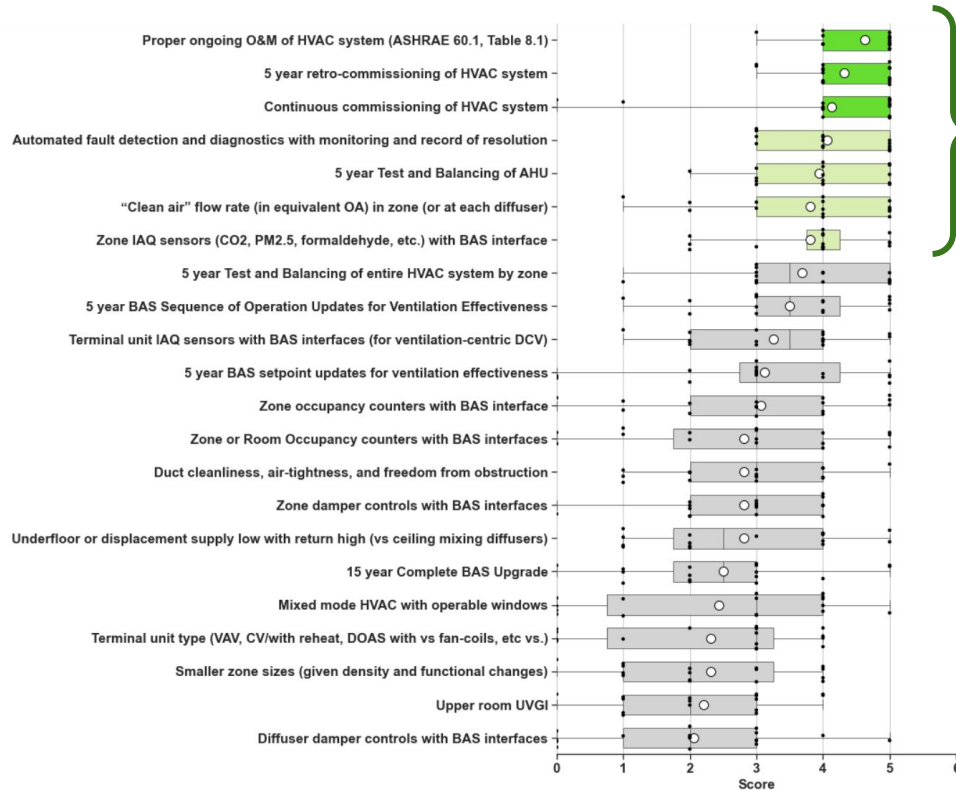
Survey 2 ($n = 16$)



- Filter type and condition
- Filter installation and sealing
- Correct fan controls and failures
- OA intake sizing, amount of OA
- Air side economizer, sensors, BAS interface
- Advanced BAS control of OA
- OA intake locations and conditions

Prioritize HVAC Interventions at the Zone/Room/Terminal Level

Survey 2 (n=16)



- Proper ongoing O&M of HVAC system
- 5-Year retro-commission HVAC system
- Continuous commissioning
- Automate fault detection & diagnostics
- 5 Year Test and Balancing
- Clean air flow rate in zone
- Zone IAQ sensors (CO2, PM2.5, etc.)

Comments on Additional HVAC Interventions

‘Clean air (pandemic or not) does not have to come from outside, though outside air has its benefits. With climate change, outside air can be expensive to operate, an **"equivalent clean air"** procedure can be more important, especially in pandemic times.’

‘**Smaller zones**, ability to supply outdoor air and measure performance and need with sensors distributed across the space. This would be my preferred design concept.’

‘**Actual tracking of air movement in space**. There are different systems out there that can "track" actual air movement and migrations. Helpful to track the building where the air is moving.’

5-year ‘sequence operation and setpoint’ check - similar to continuous commissioning but checking that the latest controls requirements in 62.1 can be met.

“Wisdom of the Room”

Proposed experiments, interventions and portfolio analyses

(breakout rooms to discuss a range of scales and approaches)

1. Improve **O&M** (i.e. frequency of Commissioning, enabling Automated Fault Detection & Diagnostics, workforce training, KPIs)
2. Improve **Clean Air** Flow Rate & Air Quality Sensors **at room/ zone/ terminal units**
3. Improve **Outdoor Air** Hardware/Software and/or Economizers
4. Improve **Filters** (type, efficiency, and installation and sealing) at AHUs
5. Improve **Supply Air / Return Air Fans** and System Balancing at AHUs

Proposed Intervention: **Improve O&M**

Key O&M issues impact indoor air quality

- No standard for **sensing and assessing** IAQ at room / zone level
- No standard **health surveys** to engage occupants as IAQ sensors
- Long-term **under-funding** of facility maintenance (<1.5% of current plant value)

Hypothesis: Reporting on a set of building KPI's would improve O&M and improve IAQ

1. KPI for resolution of specific Fault Detection and Diagnostic faults tied to IAQ
2. IAQ performance KPI against thresholds at the building or zone level (eg CO2, PM)
3. KPI of user health indices surveyed at the building or zone level (eg SBS, infections)
4. Facility Management KPI indices (i.e. budget, manpower, staff training, turnover)

Proposed Intervention: Improve clean air at room/zone

Key issues impact delivery of clean air at the Zone/Room level:

- The adequacy of in-room air delivery is not monitored.
- Changes in space uses and layouts and HVAC hardware are not synchronized.
- The density of occupants in spaces is highly volatile, especially since Covid.

Adjusting controls and equipment would improve conditions at the zone/room level

- 1. Compare ventilation effectiveness strategies** (diffuser types/locations including UFAD, displacement, controls)
- 2. Expand zone ‘thermostat’ controllers to include IAQ and occupancy sensors**
- 3. Introduce in-room air cleaning for equivalent OA** (i.e. portable HEPA, ceiling UVGI)

Proposed Intervention: Improve OA Hardware/Controls at AHU

Key issues impacting delivery of clean air from the Central AHU:

- AHU outside air (OA) and mixing hardware and software is prone to failure.
- Adjusting for changes in seasons, use-type, occupant density need FM training .
- Economizers have mixed success and metrics of performance.

Hypothesis: Improving designs for delivering OA at AHU will improve clean air at zone

- 1. Increase quantity of filtered OA** along with technologies to avoid energy penalty (new damper/sensor/actuator, VFD fans and BAS assemblies, economizer, ERV)
- 2. Improve filter materials**, replacement schedule, and locations
- 3. Introduce DOAS with separate VRF for thermal conditioning**

Expert input on health and performance metrics to pursue

Occupant surveys

- Self reported health / wellness (rethink SBS questionnaire)
- Self reported Stress, Fatigue, Productivity
- Satisfaction (air quality, comfort, IEQ)
- Mood, sleep

Employer records

- Absenteeism, records of Sick days
- Turnover
- Asthma, Allergy and other Health records, short and long term

Expert input on health and performance metrics to pursue

Wearable sensors

- Blood pressure (as an indicator of PM2.5 impacts on building occupants)
- Heart Rate Variability (HRV- stress and relaxation response)
- Sweat biomarkers of stress and immune response
- Physical activity, posture, sleep quality

Productivity testing

- Cognitive performance, next day cognition (relative to to CO2/PM 2.5)

FM records

- Complaint records numbers – thermal, air quality, other
- Fault detection frequency and speed of response relative to air quality
- Energy cost/benefits



Pacific Northwest National Laboratory Healthy Buildings Toolkit

July 27, 2023

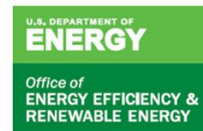
Healthy Buildings Toolkit Poll



[Slido.com](https://www.slido.com): #cleanair to access polls and Q&A

Healthy Buildings and Energy Support Tool (H-BEST)

1. Benchmarks indoor environmental quality performance against acceptable and high-performance targets
2. Estimates the potential financial gains from improving productivity as a result of optimizing IEQ conditions
3. Identifies energy efficiency and health upgrades for buildings



**Healthy Buildings and
Energy Support Tool
(H-BEST)**
Beta Version

<https://www.energy.gov/femp/healthy-buildings-toolkit>

Table 1. Estimated productivity improvement by achieving high-performance target levels.

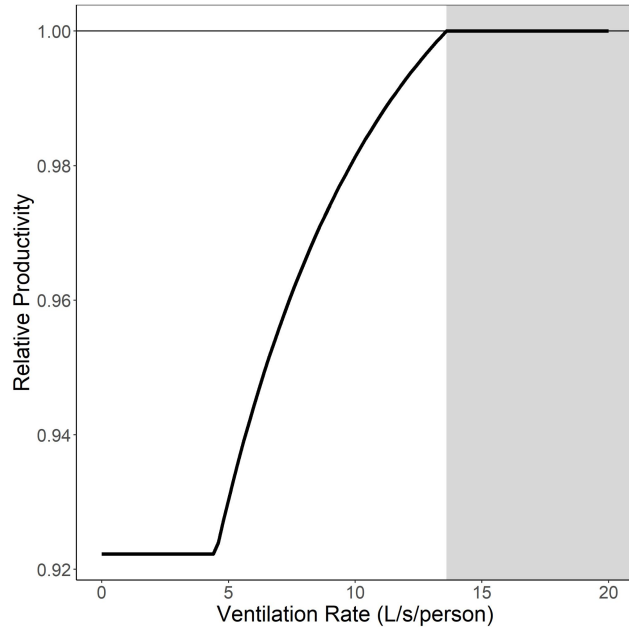
	Correlation Metric	High-Performance Target	Productivity Gain	Performance Rating	Health Savings
Indoor Air Quality	Carbon Dioxide	727 ppm	0.0%	Little improvement potential	\$0
Thermal Comfort	Temperature	20°C to 24.4°C	0.2%	Moderate improvement potential	\$762,000
Lighting	Horizontal Illuminance	500 lux	1.9%	Significant improvement potential	\$2,732,000

Performance targets

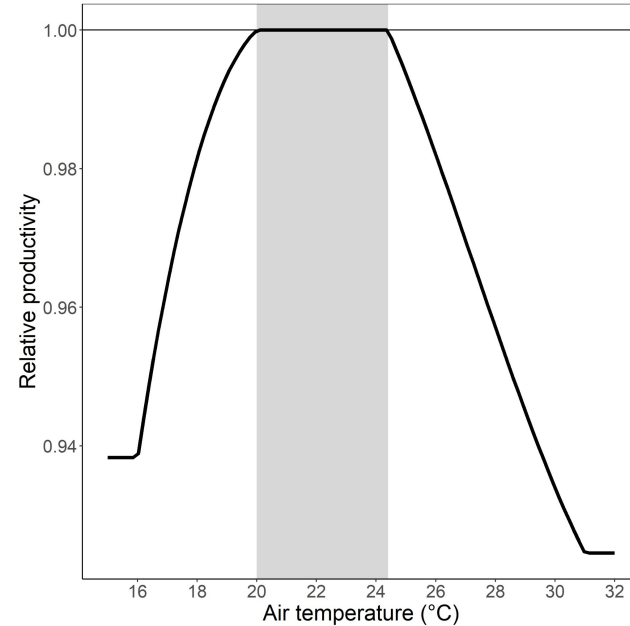
Metric	Acceptable Target	High-Performance Target	Sources
Ventilation Rate (Carbon Dioxide)	8.5 L/s per person (924 ppm steady state)	13.6 L/s per person (727 ppm steady state)	ASHRAE 62.1 WELL
Particulate Matter (PM_{2.5})	25 ug/m ³	15 ug/m ³	WHO
Air Temperature	20 - 24.4 C (68 - 75 F)		OSHA
Predicted Mean Vote	-1.0 to +1.0	-0.5 to +0.5	ASHRAE 55 WELL
Relative Humidity	30 to 65%	40 to 60%	EPA/CDC Recent Research

Lighting metrics and more information about these HVAC-related targets available in H-BEST, which can be found through the link on the previous page.

Regression models for productivity



Increasing ventilation rate from 5 L/s per person to 13.6 would give an estimated 7% productivity gain



Changing temperature from 28 C (82 F) to 24 C (75 F) would give an estimated 4% productivity gain

Improvement recommendations

Indoor Air Quality	Thermal Comfort	Lighting
Demand Controlled Ventilation	Upgrade Heating/Cooling	Clean/Repair Overhead Lights
Ventilation Schedule	Adjust Temperature Setpoint	Upgrade to LED
Re-tune HVAC	Add Window Film	Install Light Diffusers
Test and Balance HVAC	Weatherize	Light-Toned Interior Colors
Increase Outdoor Air Supply	Upgrade Windows/Glazing	De-Lamp or Dimming Controls
Replace or Upgrade AHU	Energy Recovery	Translucent/Lower Cube Partitions
Upgrade to MERV 13	Dehumidification/Humidification	Window Blinds/Shading
Green Cleaning Policy	Hoteling Policy	Daylight Harvesting
Install Economizer	Adjust Air Diffuser Speed	Task Lighting

Case study - Federal office building in Illinois

Environmental Factor	JCK (400 ppl)	
	Total Expected Value (over 10 years)	Improvement Recommendations
Indoor Air Quality (6.2/10) 	\$12,300	Scorecard: Evaluate focus room use and OA rates; disperse CO2 with personal fans Focus: Consider automation for targeted opportunities
Thermal Comfort (3.8/10) 	\$2,025,150	FEMP: Check thermostat locations; adjust temperature setpoints. Scorecard: Comfort-based seat suggestions Focus: Consider automation, and options to address individual comfort

- IAQ data revealed an estimated \$2M 10-year savings potential for thermal comfort, compared to \$12k for air quality (data collected in March, August, and November).
- GSA Scorecard showed similar results (3.8 for thermal comfort and 6.2 for IAQ out of 10).
- Survey results aligned as well, with 72.5% of people too cool year round, and only 13% with IAQ complaints (odors and stuffiness specifically).
- Reducing HVAC cooling load in summer by calibrating sensors and adjusting thermostats could save energy and improve comfort.

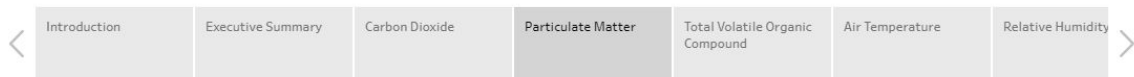
Case study - Federal office building in Texas

- Lighting had the greatest room for improvement (38% of spaces too dim)
- However, occupant surveys found high levels of dissatisfaction (complaints of odor, mold, and dust)
- Research has shown an occupant's perception of air quality can be affected other IEQ factors; they often do not have a good sense of contaminant levels
- Improvements to lighting could benefit perceived IAQ satisfaction

	Percent Worse Than Target	Expected Productivity Improvement	Expected 10-yr NPV Gains
Indoor Air Quality (CO ₂)	1.9%	<0.1%	<\$1k
Thermal Comfort (PMV)	0.0%	0.0%	\$0
Lighting (Horizontal Illuminance)	38.0%	0.6%	\$965k
Combined		0.6%	\$966k ^a

IEQ Measurement	Observations	Recommendations
PMV	• PMV is within comfort range • High levels of dissatisfaction	• Collect PMV data in summer and winter
CO ₂	• Some high CO₂ on Wednesday and Thursday afternoons • Many complaints of odor, dust, and allergens	• Check return air filters • Consider ventilation schedule
PM	• PM levels well below threshold • Many complaints of dust and allergens	• Check return air filters
CS	• High dissatisfaction and lack of window access • CS significantly below target • High cubicle partitions with dark colors block overhead light	• Reduce partition height or incorporate translucent panels and choose partitions with light-toned surface colors or reflective interior finishes
Horizontal Illuminance	• Some dissatisfaction • Some measurements below the target and some much higher • Cubicle layout makes some too bright and others too dim	• Reduce partition height or incorporate translucent panels and choose partitions with light-toned surface colors or reflective interior finishes • Re-calibrate overhead light levels to achieve 400 to 600 lux

Integrating with the Data to Decisions (D2D) platform



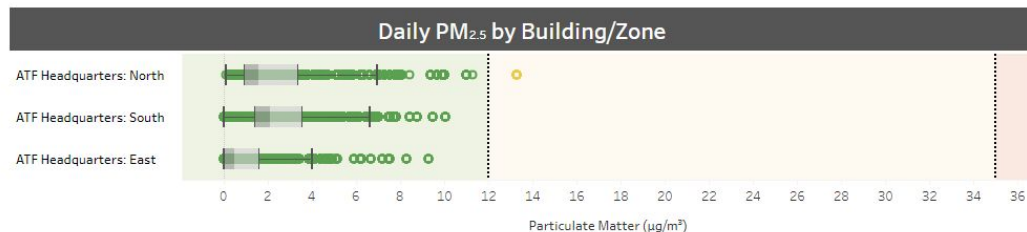
Particulate Matter

Particulate matter is a predominant indoor air pollutant. Small particulates less than 2.5 microns in diameter ($PM_{2.5}$) can enter the lungs and bloodstream when inhaled and pose a significant health risk (EPA, n.d. (a)). Larger particulates than are less than 10 microns (PM_{10}) are less of a health concern but can cause irritation to the eyes, throat, and nose. Particulate matter is produced by vehicles and industrial processes and can be transported indoors if there is not sufficient outdoor air filtration or envelope sealing. Particulate matter can arise from onsite combustion if the ducts are not properly sealed and leak into occupied spaces.

This tool uses the WELL v2 A05 Part 1 one-point threshold and the RESET Standard threshold of $12 \mu\text{g}/\text{m}^3$ or lower for $PM_{2.5}$ and $30 \mu\text{g}/\text{m}^3$ or lower for PM_{10} (WELL Building Standard 2021b)(RESET 2018). For acceptable conditions, the tool uses the RESET Standard acceptable benchmark of $35 \mu\text{g}/\text{m}^3$ or lower for $PM_{2.5}$ and the EPA benchmark of $150 \mu\text{g}/\text{m}^3$ or lower for PM_{10} . GSA's Sustainable Facilities Tool (SFTool) is a resource with more detailed information about particulate matter and targets (GSA, n.d. (a)). Particulate matter data is not correlated to any occupant outcomes in the tool but is used for developing improvement strategies.

There are various potential sources for high particulate matter levels. There could be elevated outdoor levels due to pollution, such as wildfires, industrial buildings, or automobiles. These particulates could enter the building through leaks in the envelope or through the air handler if there is insufficient filtration. The particulates could come from internal combustion or equipment that produces particulates.

Measure: Date of Analysis: Building:



The daily average $PM_{2.5}$ during occupied times are plotted in a boxplot. Compare the charted values to the acceptable conditions ($35 \mu\text{g}/\text{m}^3$) and high-performance target ($12 \mu\text{g}/\text{m}^3$) shown. The values that are within the green zone are days that have no room for improvement. Each value in the yellow zone (acceptable) are days that have some room for improvement, and each value in the red zone has significant room for improvement.

Should we be discussing IAQ at home?



[Slido.com](https://www.slido.com): #cleanair to access polls and Q&A

Breakout Session - 10 min informal discussion

In randomly-assigned groups discuss the following:

- What most impacted you today; did anything surprise you?
- What should agencies prioritize for research and interventions in HVAC?
- What actions should agencies prioritize to improve indoor environments?

When we return, please share a sentence or two in chat with the full group!

What stood out the most from your breakout?



Add a sentence with your biggest takeaway in SLIDO

Final Impressions Poll



[Slido.com](https://www.slido.com): #cleanair to access polls and Q&A

Enhanced Ventilation for Cleaner Air in Buildings



[Slido.com](https://www.slido.com): #cleanair to access polls and Q&A

May 23, 2023

2023 Summer Buildings and Health Series

Sessions run the 4th week of each month through September

- May 23: Health in Buildings Partnerships
- June 27: Circadian Lighting
- July 27: Enhanced Ventilation for Cleaner Indoor Air
- Aug 31: Wellbuilt for Wellbeing
- Sept 26: The Health in Buildings Roundtable Scoping Session

This series is a call for co-sponsors - Health in Buildings Roundtable!

- Government agencies, companies, research organizations, non-profits, etc
- Pilot, measure, and evaluate health-enhancing strategies
- Join scoping meeting planned for this summer
- Email coskvig@nas.edu for more information

Enhanced Ventilation for Cleaner Air in Buildings

