Clean Air as a Public Health Strategy
What are the priorities?

The Health and Buildings Roundtable

9:00 - 9:30 am

Session Speakers

Cameron Oskvig
National Academies of Science, Engineering and Medicine
Director, Board of Infrastructure and the Constructed Environment

Audience Introductions

Please turn to your neighbor,
or use chat, to introduce yourself
(name, org, title)

Audience Poll

What is your
personal area of expertise?

Today's Agenda

- Introducing the HiBR
- Linking human health to better operations and maintenance
- KPIs that improve ventilation and energy performance
- Lunch
- Standards and guidelines that improve air quality
- GSA's ventilation verification and ASHRAE Standard 241 study
- What are others doing to improve indoor air in buildings?
- Conclusion

NATIONAL ACADEMIES *Sciences Engineering Medicine*

Clean Air as a Public Health Strategy: What are the Priorities?

Health in Buildings Roundtable: Improving Health with Better Ventilation

Cameron Oskvig, Board on Infrastructure and the Constructed Environment

MAY 2024

Federal Facilities Council

Cooperative association of federal agencies
with the mission of identifying and advancing technologies, processes and management practices that improve the management, operations and evaluation of federal facilities throughout life cycle

Established in 1953
Sponsored by 24+ federal agencies
Large diversity by agency, mission, function, & culture

NATIONAL ACADEMIES Sciences Engineering Medicine

FEDERAL

>250,000 Buildings

>2.7 Billion square feet

500,000 structures

GSA

8,800 assets

370 million square feet of workspace

1.1 million federal employees

Board on Infrastructure and the Constructed Environment (BICE)

Capital Assessment, Funding & Prioritization	• Assessment of Capital Facility Requirements • Cross sector Infrastructure Planning • Innovative Financing of Public Infrastructure (ESPC, P3, Asset Recycling, Public Bldg Fund) • Infrastructure and Critical Services & Cascading Failures
Safety & Environment	• Physical Security of Federal Buildings • Structural Safety / Forensic Engineering of Structures • Construction Safety and Occupational Safety of Facilities Workforce • Healthy Buildings / Indoor Air Management • Building Design for Improved Productivity and Health • Applications and Technology for Building Utilization
Sustainable Design and Construction	• Resilience and Adaptability • New Workspace Paradigm • Building Innovation (materials, design, technology, operations) • High Performance Building Standards • Social Equity in Planning and Design
Economic & Workforce Development	• Stimulus Effects of Infrastructure Investment • Building the Facilities and Construction Profession • Recruiting, Training, and Retaining Infrastructure Workers

FEDERAL FACILITIES COUNCIL

- Cyber Security of OT
- Physical Security
- New Workspace Paradigm
- Measuring Utilization
- Facilities Engineering and Skilled Trades Workforce
- Facility Condition Prediction Modeling
- Sustainment, Restoration, and Modernization Cost
- Disposition of Assets
- Implementing Federal Mandates for Real Property

NATIONAL ACADEMIES *Sciences Engineering Medicine*

Current Focus Areas

Program Development in Blue

1 **Resilience and Sustainability**

Assessment of highest value approaches
- *Meeting Carbon and Electrification Goals in Buildings*
- *Designing Resilient and Sustainable Embassies of the Future*

2 **Health and Safety of Buildings**

Research gaps, technology, and improvement
- *Health in Buildings Roundtable*
- *GUV and FAR UV – Effectiveness, Standards and Regulation*

3 **Construction Innovation**

Priorities for R&D to improve productivity
- *Construction Safety Culture in Undergraduate Ed*
- *Well plugging technology and innovation*

4 **Managed Retreat**

Engineering aspects for critical service systems
- *Public Infrastructure for Effective Climate Change Adaptation*

5 **Addressing Shifting Infrastructure Paradigms**

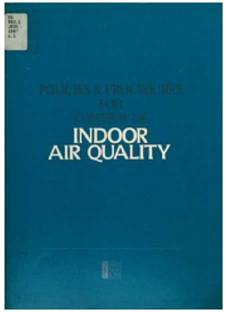
Assessment of emerging system changes – e.g., remote work
- *Utilization of Office Space and Future Workspace Design*
- *Future of the Built Environment using Digital Twins*

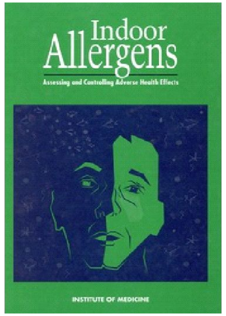
The National Academies Cross-disciplinary Network of Boards and Ongoing Environmental Health Initiatives

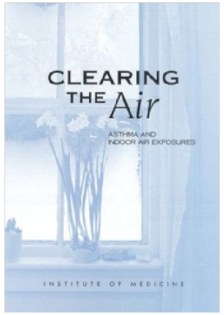
- Roundtable on Environmental Health Sciences Research and Medicine
  - interested in sensitive and difficult environmental health issues from research perspectives
- Environmental Health Matters Initiative
  - seeks to enhance the nation's ability to alleviate harmful environmental impacts on human health
- Related National Academies Boards
  - Board on Environmental Studies and Toxicology
  - Board on Energy and Environmental Systems
  - Board on Infrastructure and Constructed Environment
  - Board on Population Health and Public Health Practice
  - Board on Life Science
  - Board on Human System Integration
  - Board on Chemical Sciences and Technology

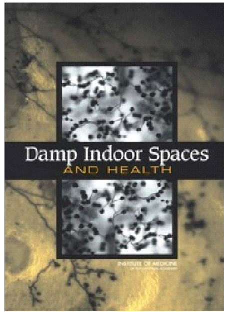
Environmental Health, Healthy and Sustainable Building Design, and Facility Management Practices at the National Academies

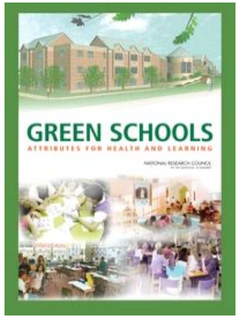
High quality, objective, evidence-based advice on science, engineering, and health matters

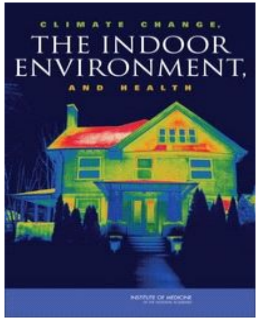


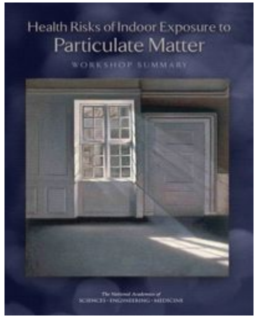


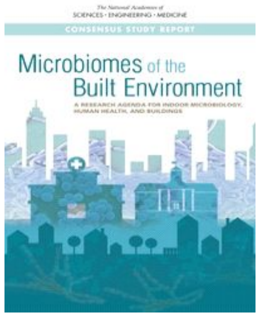


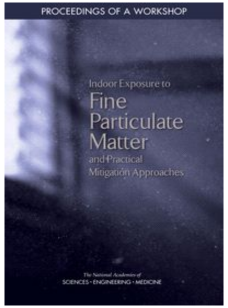


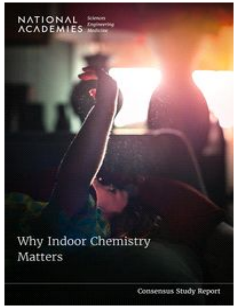


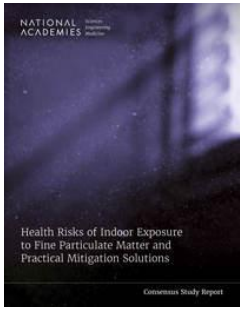




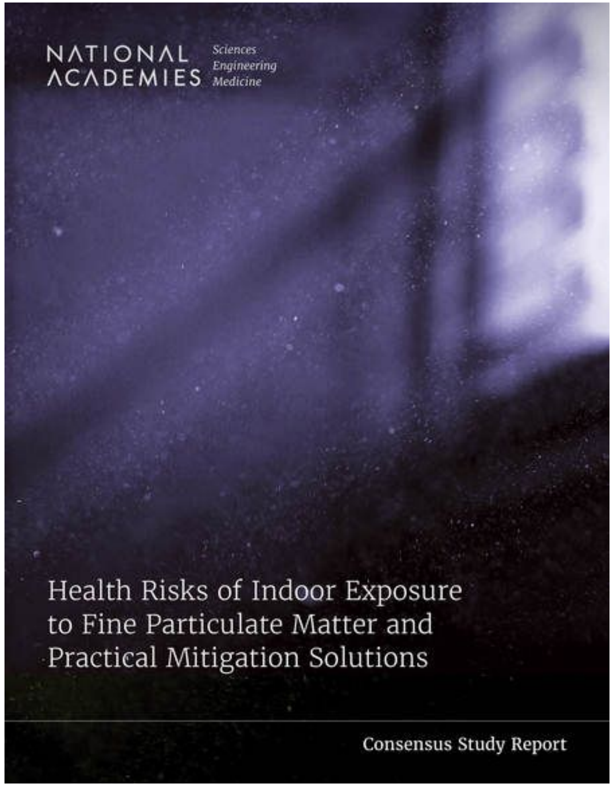








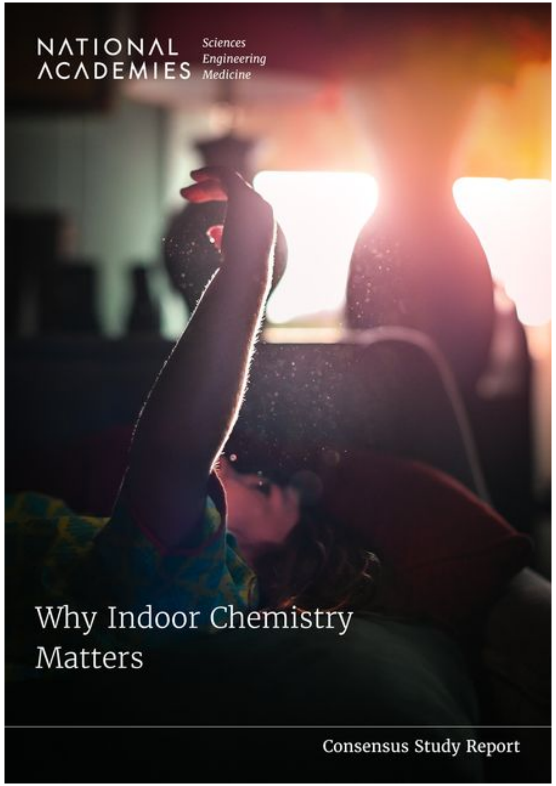
Health Risks of Indoor Exposure to Fine Particulate Matter and Practical Mitigation Solutions



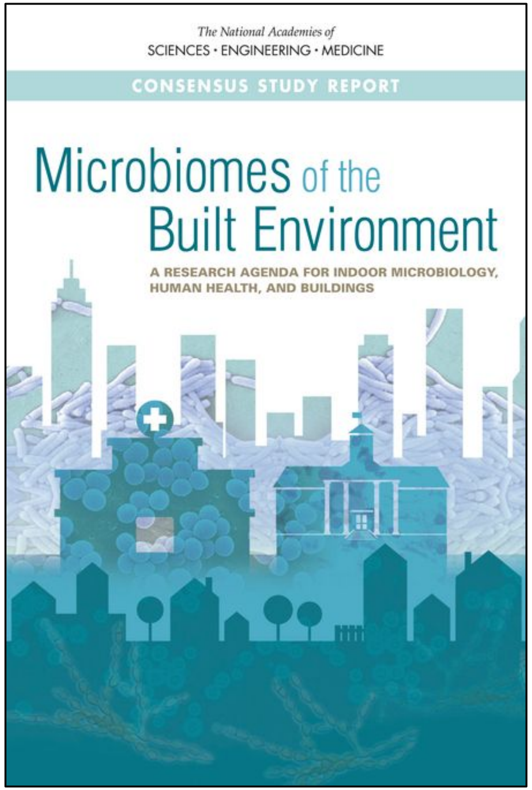
- https://doi.org/10.17226/27341.
- Large-scale clinical trials to **build the evidence base** concerning the health impacts of indoor PM mitigation
- Characterize building factors in studies of PM mitigation to appropriately contextualize findings and add to the existing knowledge on **strategies to mitigate adverse effects**
- Consider **behavioral factors in their development of control strategies** to assure effective implementation and to maximize impact
- Consider the effects of composition and other particle attributes and use this knowledge to harness **mitigation options that may be more practical** in some settings than reduction of PM2.5 defined in conventional, mass terms
- **Optimize existing air cleaning and ventilation technologies and develop new that are more effective, energy-efficient, quieter, easier to maintain, and more intuitive to operate**

Why Indoor Chemistry Matters

- https://doi.org/10.17226/26228
- Devote resources to **creating emissions inventories specific to building types** and to identifying indoor transformations that impact outdoor air quality
- Integrate **indoor chemistry considerations into their building system design** and mitigation approaches
- Further the development of knowledge on the fundamental aspects of complex **indoor chemistry and its impact on indoor environmental quality, exposure assessment, and human health**
- **Conduct controlled field experiments to better understand the fundamental chemistry of emerging air-cleaning technologies,** as well as mold and smoke remediation schemes



Microbiomes of the Built Environment



- https://doi.org/10.17226/23647
- Characterize **relationships among building** site selection, design, construction, commissioning, operation, and maintenance; building **occupants**; and indoor **microbial communities**
- Incorporate **social and behavioral sciences** to better understand how humans interact with their built environments and how these interactions may impact health.
- Explore **the energy, environmental, and economic impacts of interventions** that aim to modify indoor microbial exposures and integrate this information into frameworks that assesses the impact of potential interventions.
- **Translate research into practice** via efforts that support communication and stakeholder engagement to convey information about the interrelationships among the built environment and the indoor microbiome

A Roundtable (or Forum) is a core and continuing activity that provides a means for representatives of government, industry, private businesses, academia and other stakeholder groups to gather periodically in a neutral setting to identify and discuss issues of mutual concern on a continuing basis.

Health in Buildings Roundtable

To identify issues, research, and best practices that address building impacts on human health, and to apply health-enhancing strategies and technologies in the planning, design, and management of buildings and the built environment.

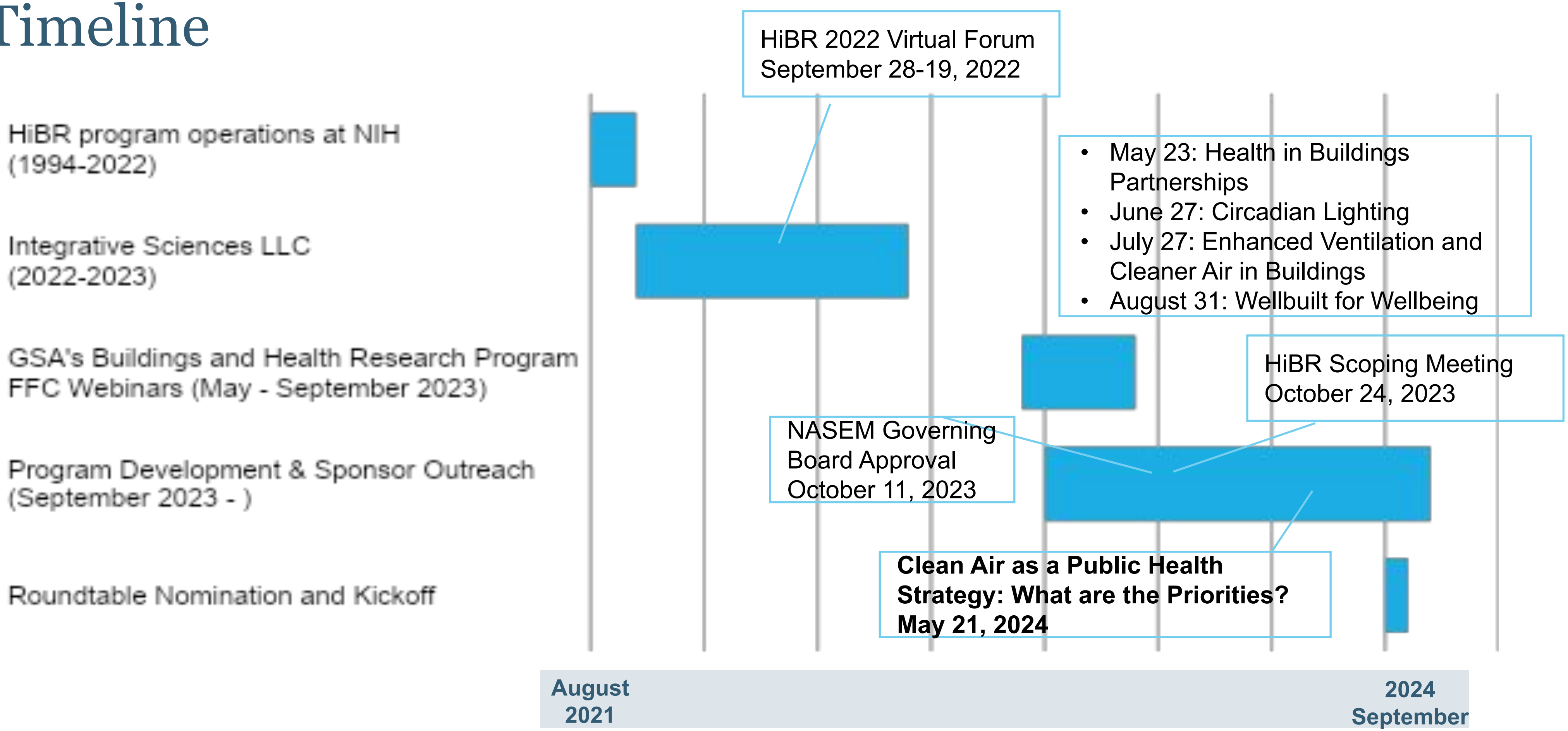
- **Convene with experts and stakeholders across disciplines and sectors, to share knowledge and improve the coherence of efforts by the roundtable member organizations.**
- **Annual symposium on supporting emerging issues and opportunities in health-enhancing strategies and technologies**
- **Opportunities to discuss health-enhancing strategies for upcoming construction and renovation projects and ongoing building management, propose data-gathering plans, and share the results among roundtable members.**
- **Highlight researchers and technology applications that improve health and wellness**
- **Propose topics for deeper analysis and research**

Composition

Cross-section from academia, industry, federal and regulatory agencies, and the commercial sector including facility owners and managers and technical experts in:

- architecture, building design
- construction management
- sustainability
- environmental health (toxicology, exposure science, epidemiology)
- public health, industrial hygiene
- building science
- building information technology and automation
- sociology (human activity patterns, occupational psychology)
- social geography
- engineering
- energy efficiency
- urban planning

Timeline

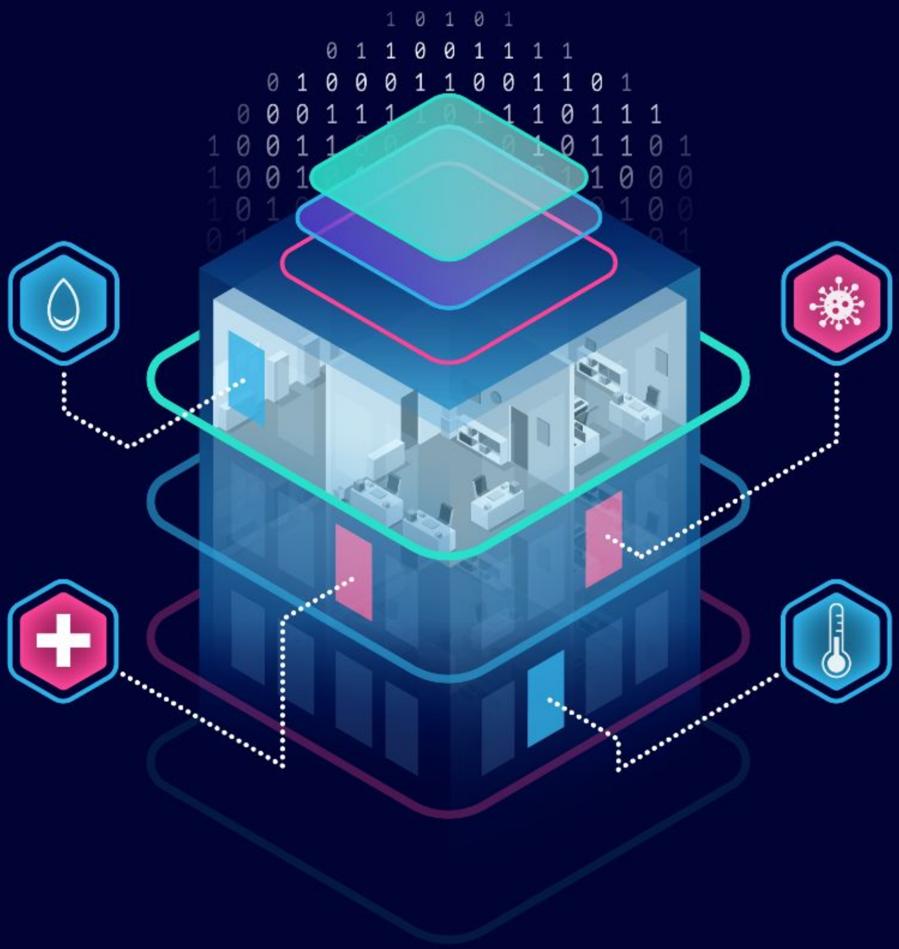

HiBR program operations at NIH (1994-2022)
Integrative Sciences LLC (2022-2023)
GSA's Buildings and Health Research Program FFC Webinars (May - September 2023)
Program Development & Sponsor Outreach (September 2023 -)
Roundtable Nomination and Kickoff
HiBR 2022 Virtual Forum September 28-19, 2022
May 23: Health in Buildings Partnerships
June 27: Circadian Lighting
July 27: Enhanced Ventilation and Cleaner Air in Buildings
August 31: Wellbuilt for Wellbeing
HiBR Scoping Meeting October 24, 2023
NASEM Governing Board Approval October 11, 2023
Clean Air as a Public Health Strategy: What are the Priorities? May 21, 2024
August 2021
2024 September

Goals

- Build an effective and interdisciplinary body to support paradigm-shifting research, education, and policy on human-centered architecture and engineered health-enhancing strategies for health and wellness in the built environment
- Cross-sector engagement
- **Exchange of relevant real-world, operational and health data with owners, technology developers, policy-makers and researchers**
- **Support health and wellness incorporation into codes, building standards and criteria, and performance guidance**
- **Develop useful public engagement, including relevant and simple communication tools, and outreach**
- **Study of health outcomes tied to current and emerging building design and operational practices**

BREATHE

Building Resilient Environments for Air and Total HEalth



Health and Buildings Roundtable

GSA // National Academies of Science, Engineering and Medicine

May 21, 2024

Jessica Green, Ph.D (ARPA-H, Resilient Systems Office)

ARPA-H

ARPA-H Mission

Accelerate better health outcomes for everyone.

ARPA-H

Approved for Public Release: Distribution Unlimited

ARPA-H's Program Portfolio Snapshot: What if…?

NITRO
What if we could make our joints heal themselves?

PSI
What if surgeries fixed problems flawlessly, the first time?

DIGIHEALS
What if we could strengthen the nation's digital health infrastructure to protect against cyberattacks?

BDF
What if next generation tools can synthesize and speed the use of health research data?

REACT
What if your body could make its own medicine?

BREATHE
What if indoor air was always safe and healthy?

APECX
What if we could eliminate viruses as current and future health burdens?

HEROES
What if we could create a sustainable national healthcare market that rewards prevention?

THEA
What if we could restore vision to those who are blind?

PARADIGM
What if we could deliver advanced hospital-level care to every rural county in America?

ADAPT
What if we could adapt cancer treatments as tumors mutate and change?

PRINT
What if we could bioprint any organ on demand?

What if indoor air was always safe and healthy?

Building Resilient Environments for Air and Total Health (BREATHE)
Advanced Research Projects Agency for Health (ARPA-H)

Jessica Green, Ph.D., Program Manager
Resilient Systems Office (RSO), Mission Office (MO)

ARPA H

Program Launch!

Building Resilient Environments for Air and Total HEalth (BREATHE)

Vision: A future with healthy indoor air for everyone.

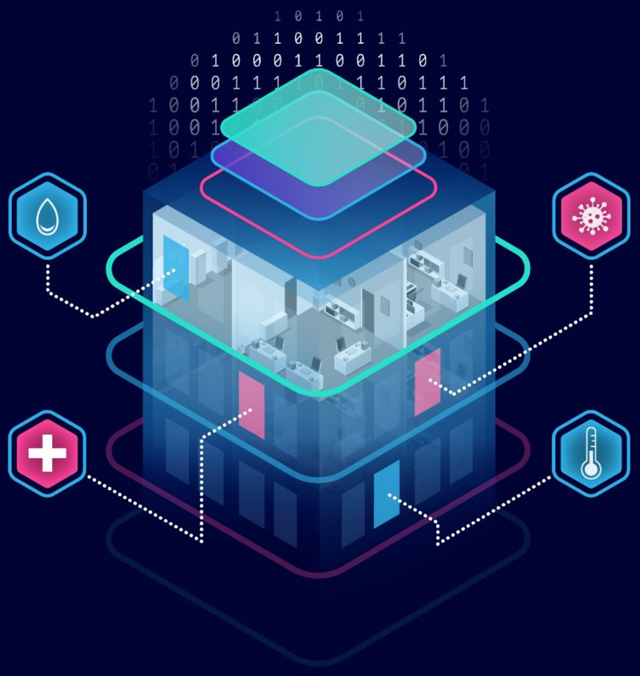
Technology focus areas:
- Indoor Air Biosensors (TA1)
- Respiratory Risk Assessment Software (TA2)
- Healthy Building Controls and System Integration (TA3)
- Real-world efficacy trial (TA1 + TA2 + TA3)

How to apply

- Submit solution summary (encouraged)
- Submit full proposal
- Visit arpa-h.gov for more information about BREATHE and applying to the PS or email: BREATHE@arpa-h.gov

Key Dates (note: dates have been updated)

- Matchmaking Webinars on May 22nd and May 29th, 2024
- Solution summary due on June 21st, 2024
- Program solicitation due on August 26th, 2024



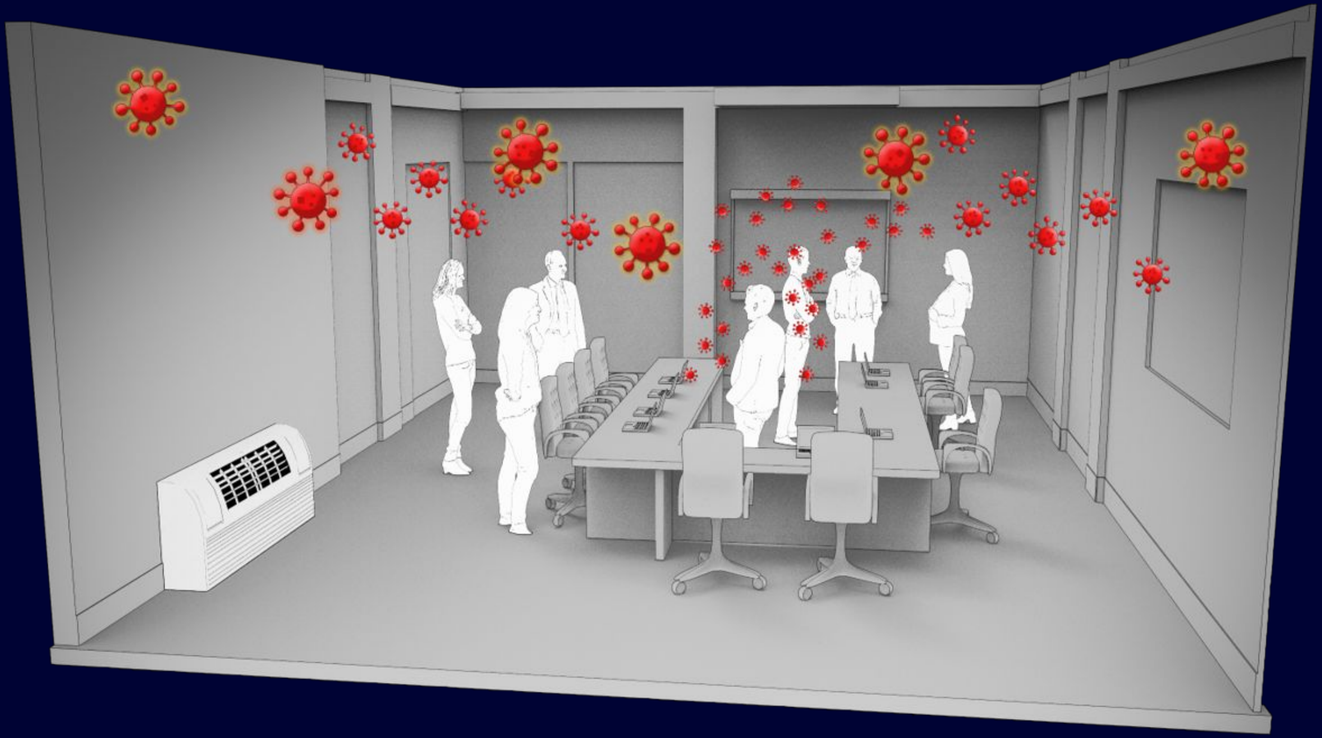
>50 years ago, we improved the outdoor air we breathe ...

Particulate matter reduction reduces child asthma diagnoses by 20%[1] and lung cancer risk by 18%[2].

[1] Garcia et al., 2019.
[2] Raaschou-Nielsen et al., 2013.

But what about indoor air?

Americans spend 90% of their lives indoors with airborne viruses, bacteria, mold & allergens.



Indoor air technologies are not optimized for health, speed, or scale

BREATHE will target these gaps

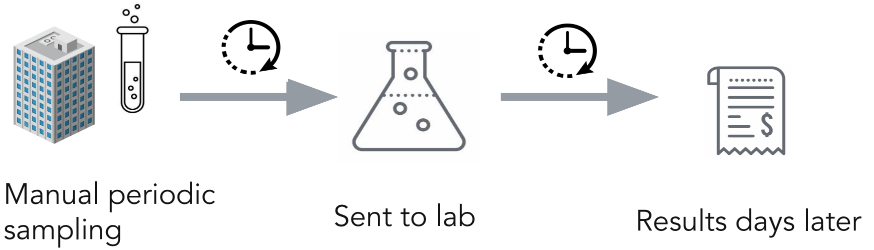
Current State

- Sensors focus on chemical & particle detection
- No standardized measurement for air biology
- Bioaerosol detection requires manual intervention
- Time-lagged results arrive too late to respond to threats

BREATHE

- Indoor biosensors to detect a wide range of viruses, bacteria, molds, allergens
- Routine assessment of indoor air quality & risks
- Smart & energy-efficient interventions tailored for health

Time-delayed biosensors



Continuous real-time measurement & assessment loop

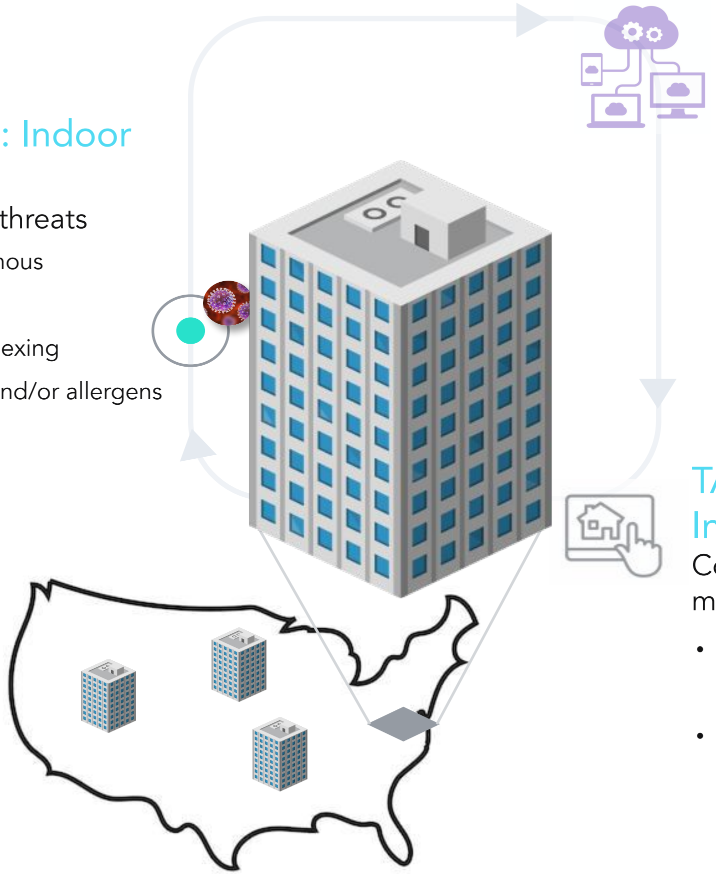
BREATHE will deliver healthy indoor air

A closed-loop diagnostic, therapeutic building ecosystem + nationwide efficacy trial

Technical Area 1 (TA1): Indoor Air Biosensors

Rapidly detect airborne bio-threats

- Develop cost-effective autonomous sensors for >25 targets
- Demonstrate 100-target multiplexing
- Detect viruses, bacteria, fungi and/or allergens



TA2: Respiratory Risk Assessment Software

Determine whether health impacts are likely

- Develop Indoor Air Quality Index
- Demonstrate model generalization across facilities, geographies, and seasons

TA3: Healthy Building Controls & System Integration

Cost-optimize use of building interventions to mitigate threats

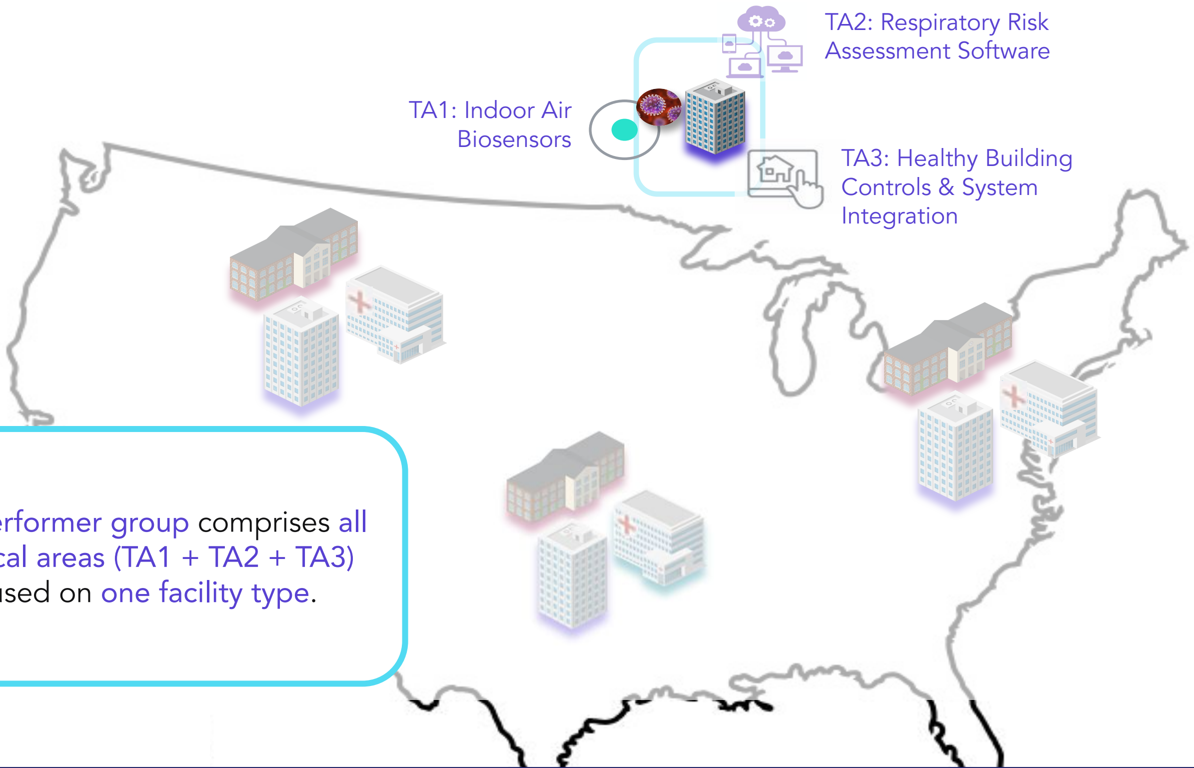
- Optimize facility control systems for indoor air quality, energy and cost
- Demonstrate real-time response to exposure risk using existing interventions (e.g. ventilation, filtration, disinfection)

Real-word testing and evidence

Conduct nation-wide efficacy trial

- Integrate and install BREATHE systems (TA1 + TA2 + TA3) across selected facilities
- Demonstrate a reduction of indoor respiratory incidence by at least 25% at a 10% return of investment

Evaluation through real-world efficacy trials



Each performer group comprises all technical areas (TA1 + TA2 + TA3) focused on one facility type.

BUILDING & OCCUPANT TYPES

Trial facilities require controlled testing and statistically linking transmission incidence to in-building exposure.

- Non-ambulatory care facilities (skilled nursing facilities, inpatient hospice, convalescent homes)
- Hospitals
- Schools
- Homes

ENVIRONMENTAL VARIATIONS

- Climate zone
- Outdoor air quality
- Local infectious disease outbreaks

ARPA-H

Next Steps

Submit Your Teaming Profile & Review Other Profiles

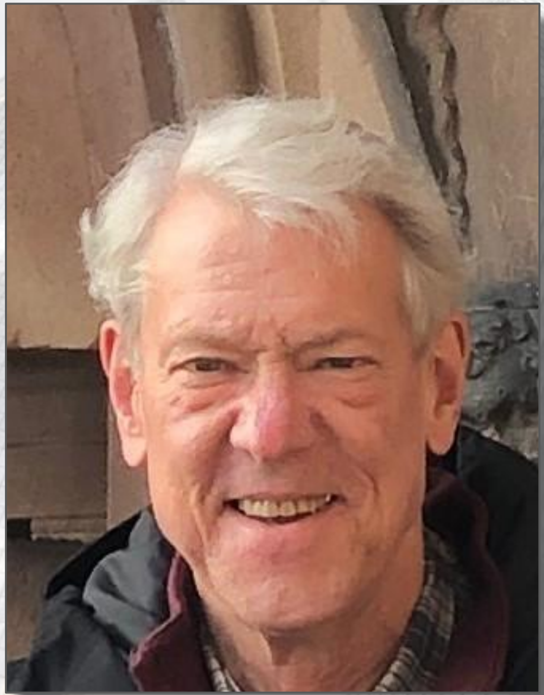
Register to Attend or Present at the Matchmaking Sessions

Linking human health to improved operations and maintenance

9:30 - 10:30 am

Session Speakers

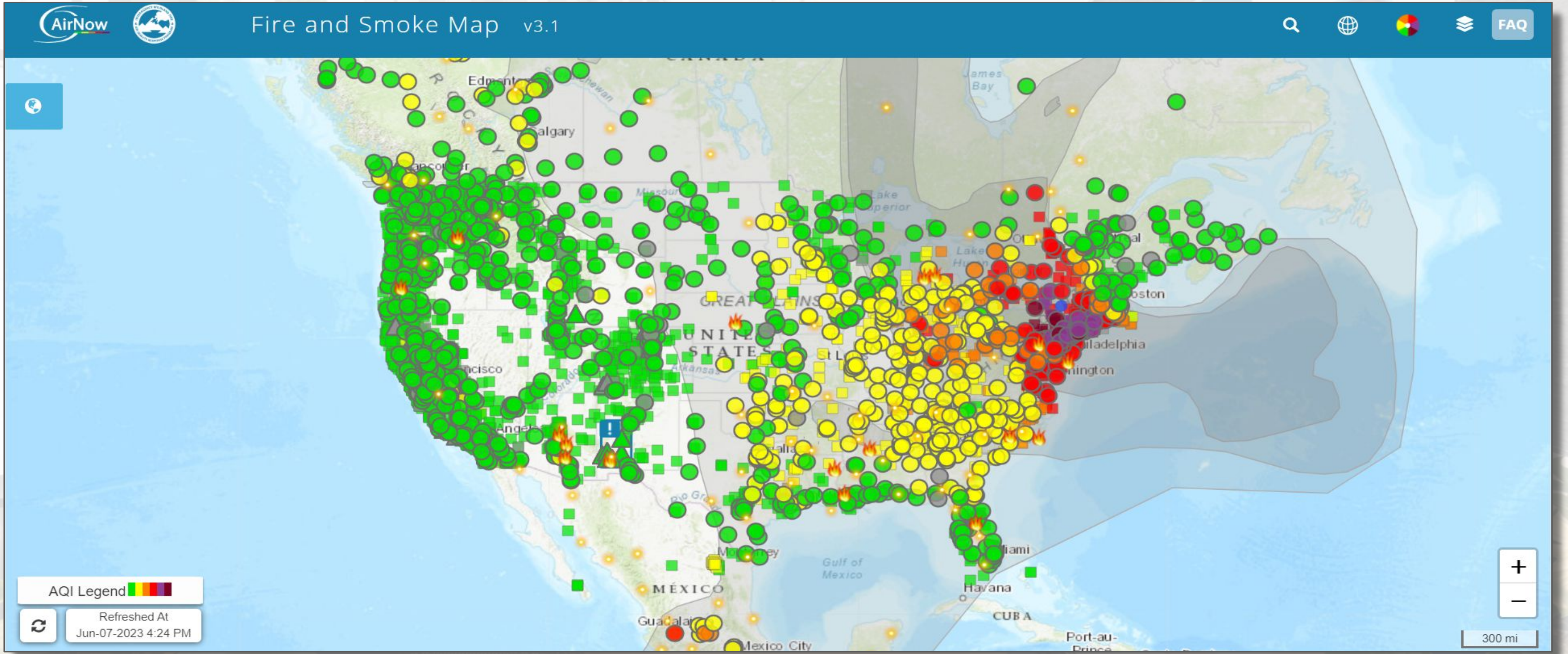
Brian Gilligan, PE
US General Services Administration
Acting Director,
Office of Federal High-Performance Green Buildings



Kevin Kampschroer
US General Services Administration
Chief Sustainability Officer,
Office of Federal High-Performance Green Buildings

Vivian Loftness, FAIA
Carnegie Mellon University
Professor of Architecture
Center for Bldg Performance & Diagnostics

Ensuring clean indoor air remains important



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


Administration Priorities The Record

DECEMBER 08, 2022

FACT SHEET: DEPARTMENTS AND AGENCIES COMMIT TO CLEANER INDOOR AIR ACROSS THE NATION

OSTP ▸ NEWS & UPDATES ▸ PRESS RELEASES

Audience Poll

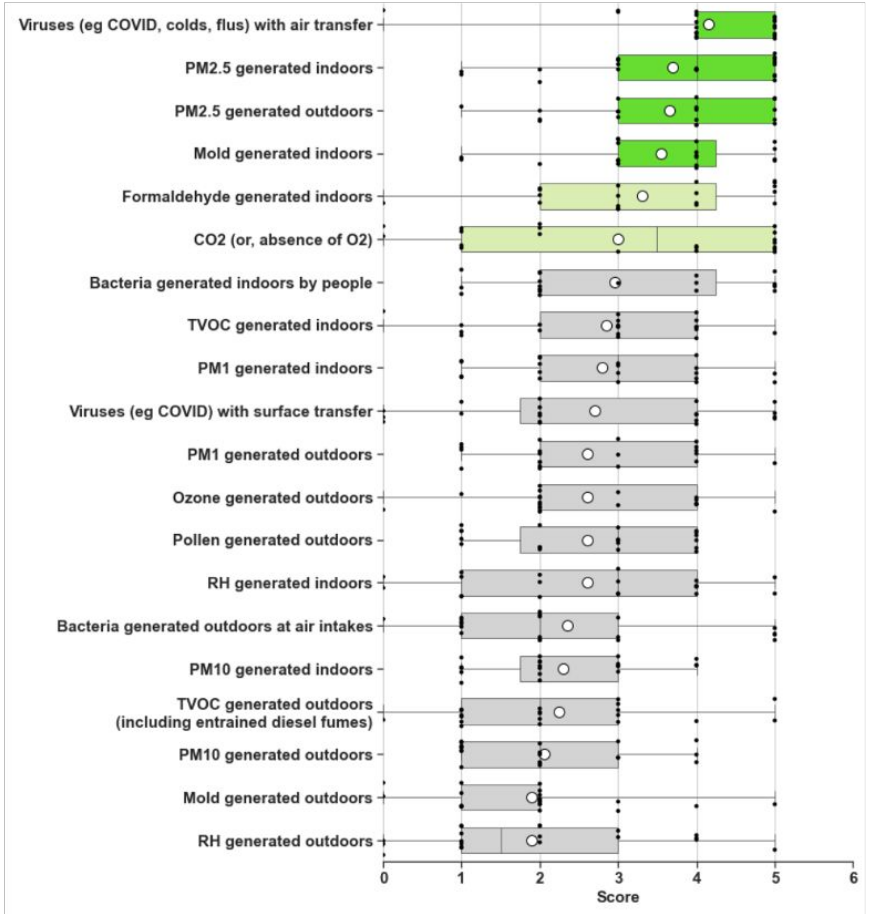
What would drive you to try strategies for enhancing health with indoor air?

Improve ventilation and meet climate goals?

- What pollutants matter?
- What building systems matter?
- Is O&M the biggest challenge for better IAQ?
- Is Zone or Room air delivery the biggest challenge for IAQ?
- Is the Central Air Handler the biggest challenge for IAQ?
- What improvements should we be prioritizing?
- What research and innovations are needed?

GSA Expert Workshop Survey 1:

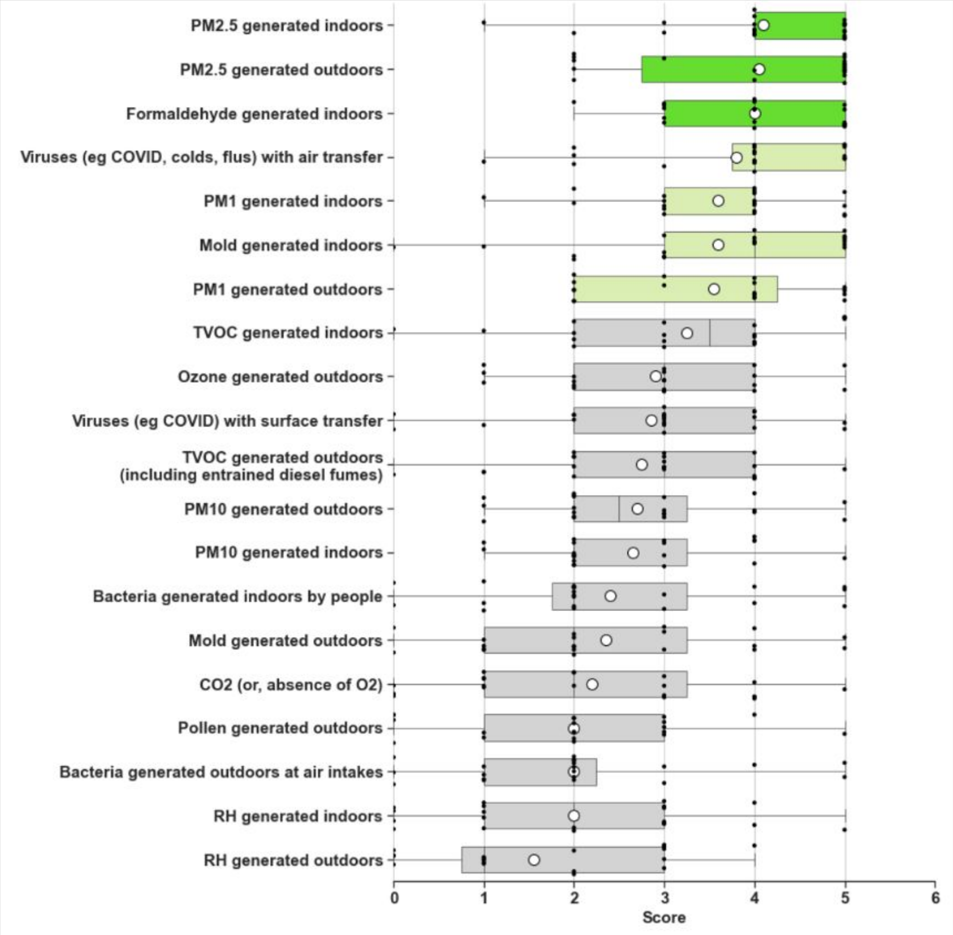
Prioritize Pollutants for <u>Short-Term Impacts</u> to Health and Performance (n = 20)



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

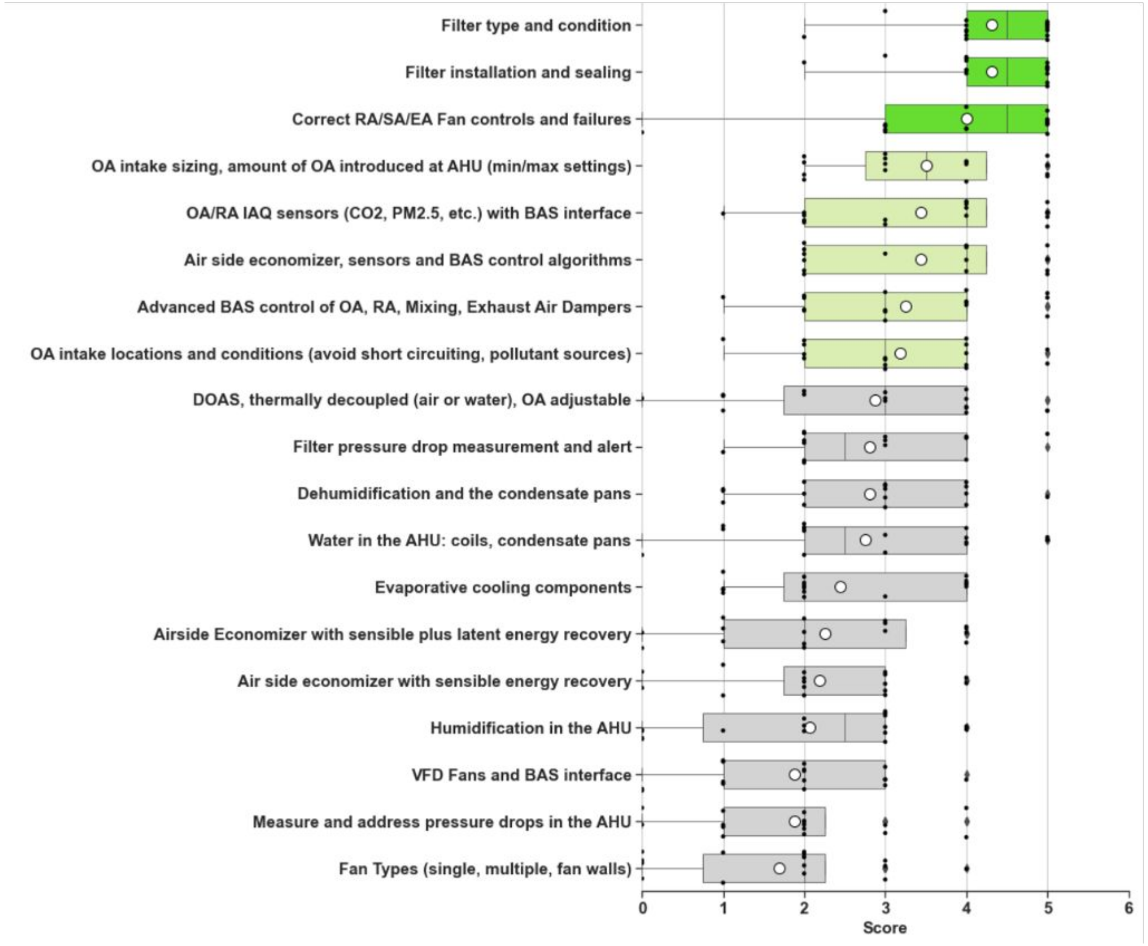
GSA Expert Workshop Survey 1:

Prioritize Pollutants for Long-Term Impact to Health and Performance (n = 20)



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

GSA Expert Workshop Survey 2:
Prioritize HVAC Interventions at the AHU Level (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**

The "Wisdom of the Room"

Top-five interventions for HVAC systems

to improve ventilation and air quality in existing buildings

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

10 Field Research Efforts to Improve IAQ and Health

KPIs for Improving O&M for IAQ

1. **KPI for health** in existing buildings (SBS surveys and health records metrics)
2. **KPI for HVAC condition** assessments (**Fault Detection Diagnostics, Ventilation Verification**)
3. **KPI for IAQ** in existing buildings (zone or room-level monitoring)
4. **KPI for FM investments** in existing buildings (2-4% Current Plant Value)

Room/Zone Investments for IAQ

5. **State of the Room** (Measuring ventilation effectiveness & FDD)
6. **Next-gen 'thermostats':** IAQ+Temp+Occupancy as controllers
7. **In-room filtration** – HEPA units and UVGI units

Central OA Investments for IAQ

8. **New damper/sensor/actuator and economizer** BAS algorithms expanding OA% and hours
9. **Filter improvements** – types, PD sensors, maintenance schedules, location/fit.
10. **DOAS** (separate ventilation and thermal) retrofits with electrification

Collect KPIs to Drive Improved IAQ

Priority #1

Collect <u>Annual Health KPI's</u> for each building and even mechanical zone to accelerate O&M in buildings for IAQ and Health

Collect responses to Wellness Surveys
(e.g. updated Sick Building Survey)

×

Table 3. Summary in prevalence of participants characteristics and sick building syndrome symptoms among office employees (n =417).

Individual Characteristics	%	Symptoms	%
Female	77.9	**Eye, any**	22.5
Age (≥40 years)	30.0	Eye dryness	18.7
Current smoker	11.3	Eye irritation	5.5
Working time >5 days/week	11.8		
Working time >9 h/day	20.9	**Upper respiratory, any**	15.3
Working stress	14.6	Nose itching	2.4
Lacking of family support	40.3	Runny nose	2.4
Asthma	3.4	Stuffy nose	6.2
Nasosinusitis	7.0	Sneezing	2.4
Atopic rhinitis	29.0	Dry throat	6.7
Migraine	17.0		
Dust allergy	24.5	**Lower respiratory, any**	6.5
Animal allergy	8.6	Difficulties in breathing	6.5
Sensitivity to tobacco smoke	68.3		
Sensitivity to chemicals in air	64.5	**Skin, any**	1.9
Exposure to ETS	15.6	Skin dryness	1.9
Using Sanitizing chemical	29.7		
Carpet in workspace	61.4	**Non-specific, any**	25.4
New furniture	4.6	Tiredness	20.9
New decoration	9.4	Difficulties in concentrating	14.6
Painting recently	5.5	Irritability	12.7
Leaking	10.1	Dizziness	7.2
Speck of molds	7.7		

×

Table 4. Crude and adjusted odds ratio and 95% confidence intervals (in parentheses) for sick building syndrome symptom associated with per 100 ppm increase in difference between indoor and outdoor carbon dioxide concentrations (dCO_2) obtained from generalized estimating equations logistic regression models (n = 417).

Sick-Building Syndrome Symptom	dCO_2 (per 100 ppm)		
	Crude	Adjusted [a]	Adjusted [b]
Eye, any	0.99 (0.97–1.01)	1.00 (0.96–1.04)	1.00 (0.96–1.04)
Eye dryness	1.01 (0.99–1.04)	1.02 (0.99–1.06)	1.02 (0.98–1.06)
Eye irritation	**0.85 (0.73–0.99)**	**0.81 (0.67–0.98)**	**0.74 (0.59–0.93)**
Upper respiratory, any	1.02 (0.91–1.14)	1.04 (0.93–1.17)	0.97 (0.89–1.06)
Nose itching	1.02 (0.86–1.21)	1.03 (0.80–1.32)	1.03 (0.80–1.32)
Runny nose	0.97 (0.79–1.20)	0.92 (0.71–1.18)	0.92 (0.72–1.19)
Stuffy nose	1.03 (0.94–1.13)	1.11 (0.96–1.28)	1.07 (0.92–1.25)
Sneezing	1.04 (0.94–1.15)	0.93 (0.69–1.25)	0.52 (0.12–2.31)
Dry throat	1.03 (0.89–1.18)	**1.10 (1.00–1.22)**	1.03 (0.91–1.15)
Lower respiratory, any	0.99 (0.94–1.18)	1.07 (0.96–1.20)	1.05 (0.94–1.18)
Difficulties in breathing	0.99 (0.94–1.18)	1.07 (0.96–1.20)	1.05 (0.94–1.18)
Skin, any	1.03 (0.87–1.22)	1.04 (0.85–1.28)	1.05 (0.82–1.34)
Dryness	1.03 (0.87–1.22)	1.04 (0.85–1.28)	1.05 (0.82–1.34)
Non-specific, any	1.04 (0.97–1.11)	**1.16 (1.04–1.29)**	**1.13 (1.02–1.26)**
Tiredness	1.03 (0.97–1.10)	**1.16 (1.07–1.26)**	**1.14 (1.06–1.23)**
Difficulties in concentrating	1.01 (0.93–1.09)	1.09 (0.99–1.20)	1.08 (0.98–1.19)
Irritability	0.97 (0.89–1.05)	1.13 (0.95–1.35)	1.09 (0.92–1.29)
Dizziness	1.10 (0.97–1.26)	**1.22 (1.08–1.37)**	**1.20 (1.07–1.34)**

In a 2015 field study in Taiwan, Lu et al identified that **SBS responses from 417 employees in 87 office spaces in 8 high-rise buildings correlated dry throats** (OR= 1.10), **tiredness** (OR=1.16), and **dizziness** (OR= 1.22) **with 100 ppm increase in CO2**, with 95% confidence intervals.

Building-Related Symptoms among Office Employees Associated with Indoor Carbon Dioxide and Total Volatile Organic Compounds, Chung-Yen Lu, Int. J. Environ. Res. Public Health 2015

Classic Wellness questions related to frequency of health conditions

Q1. How frequently do you experience the following conditions at work (daily, weekly, monthly, rarely)?
Q2. Do they go away when you leave work?

Eye/Dermal Symptoms
- Eye dryness
- Eye irritation
- Dry Skin

Respiratory Symptoms
- Runny Nose
- Stuffy Nose
- Dry Throat
- Coughing
- Colds
- Difficulty Breathing

General Symptoms
- Headaches
- Irritability
- Fatigue
- Difficulty Concentrating
- Dizziness/ Nausea

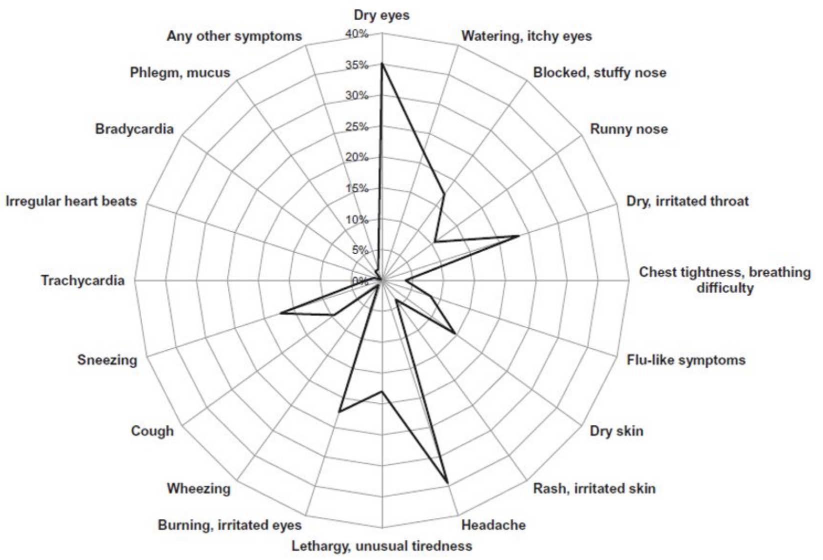


Fig. 4 Prevalence of building-related health symptoms in the OFFICAIR study

Barrero, Josefa (2020): OFFICAIR - Indoor air pollution in modern office buildings. European Commission, Joint Research Centre (JRC) [Dataset] PID: http://data.europa.eu/89h/eaf0191d-456c-4c2c-8b30-1ecae9b2f999

Compare AHU delivery of Outdoor Air with wellness surveys

fig. 6.3 Aggregating the 24-60 AHU's in each building studied reveals the 37% that do not meet ASHRAE minimums for the assumed area and occupant density served.

Deploy "Classic Wellness" survey for comparison of OA delivery in zones or before and after balancing

Collect annual health records from HR aggregated by building

(or perhaps mechanical zone)

(in-situ measurements that may be available in red).

Objective Health metrics vs baseline and change over time

1. **Absenteeism, records of Sick days**
2. **Asthma, Allergy, Covid and other Health records for building occupancy, short and long term, costs.**
3. **Health Insurance claims, Litigation related to health**
4. **Attraction-retention rates, turnover**

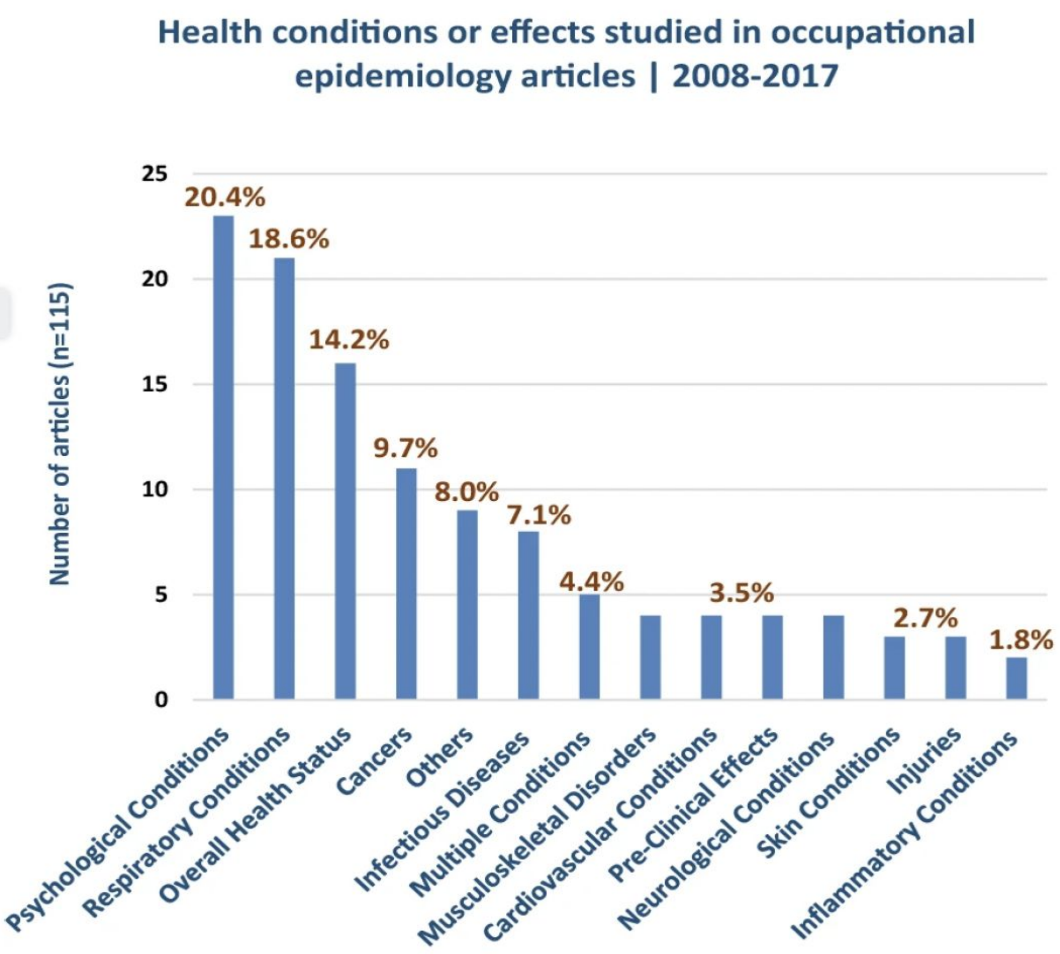
5. Sweat biomarkers of stress and immune response
6. Blood pressure (as an indicator of PM2.5 impacts on building occupants)
7. Resting Heart Rate and Heart Rate Variability (stress and relaxation response)
8. Physical activity, posture, and sleep quality - wearable health monitors
9. Combinations of the above

Other metrics

10. **Complaint numbers – thermal, air quality, other? manpower and material,**
11. **Fault detection frequency and speed of response relative to air quality**
12. **Energy cost/benefits**

13. Cognitive performance, next day cognition (relative to CO_2/PM 2.5)
14. Mood records
15. Inequity measures, Ethical/moral issues for human health

Compare IAQ performance between buildings that share health data with building manager and those that do not



Healthy worker, healthy citizen_ the place of occupational health within public health research in Switzerland _ SpringerLink 2019

JOEM • Volume 45, Number 7, July 2003

Workplace Threats to Health and Job Turnover Among Women Workers, Patricia W. Gucer, Marc Oliver and Melissa McDiarmid; Journal of Occupational and Environmental Medicine, Vol. 45, No. 7 (July 2003),pp. 683-690

TABLE 6

Changed Job as a Result of Concern for Workplace Health Threat (n = 890)

	Odds Ratio	95% CI
Demographics		
Age in years	1.01	0.98–1.03
Minority	1.51	0.73–3.11
Married/living with someone	1.56	0.81–2.98
Education	0.87	0.71–1.07
Work experiences		
Current union membership?	0.25	0.06–1.83
Ever worked while pregnant?	1.17	0.64–2.15
Ever exposed to chemicals at work?	1.14	0.56–2.31
Ever had work related illness, had ongoing health problems, or injured at work?	**4.50**	**2.40–8.43**
☆ Ever received information on health risks at work from employers?	**0.49**	**0.26–0.92**
☆ Ever talked with co-workers about health risks at work?	**2.76**	**1.39–5.47**
Serious concern ever - air quality/sick building syndrome?	**3.87**	**1.95–7.67**
Serious concern ever - hazardous materials?	**2.50**	**1.24–5.07**

Bolded odds ratios and confidence intervals indicate probability of chance occurrence of less than 0.05.

Chi-square 119.66 (df = 12) $P < 0.001$.

Likeliness of changing jobs goes up with symptoms, goes down with communication from employers

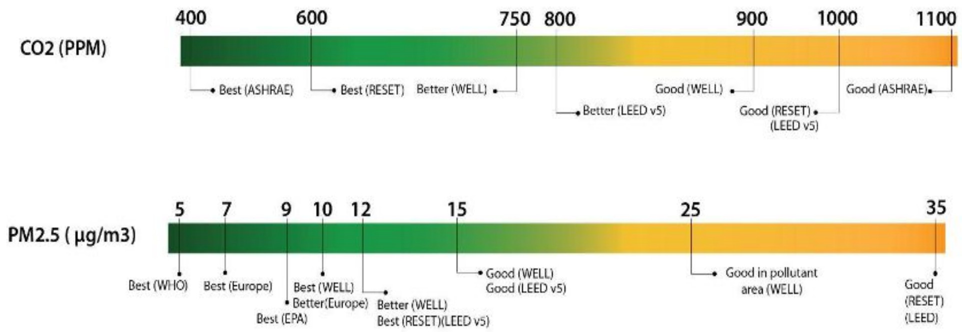
Collect KPIs to Drive Improved IAQ

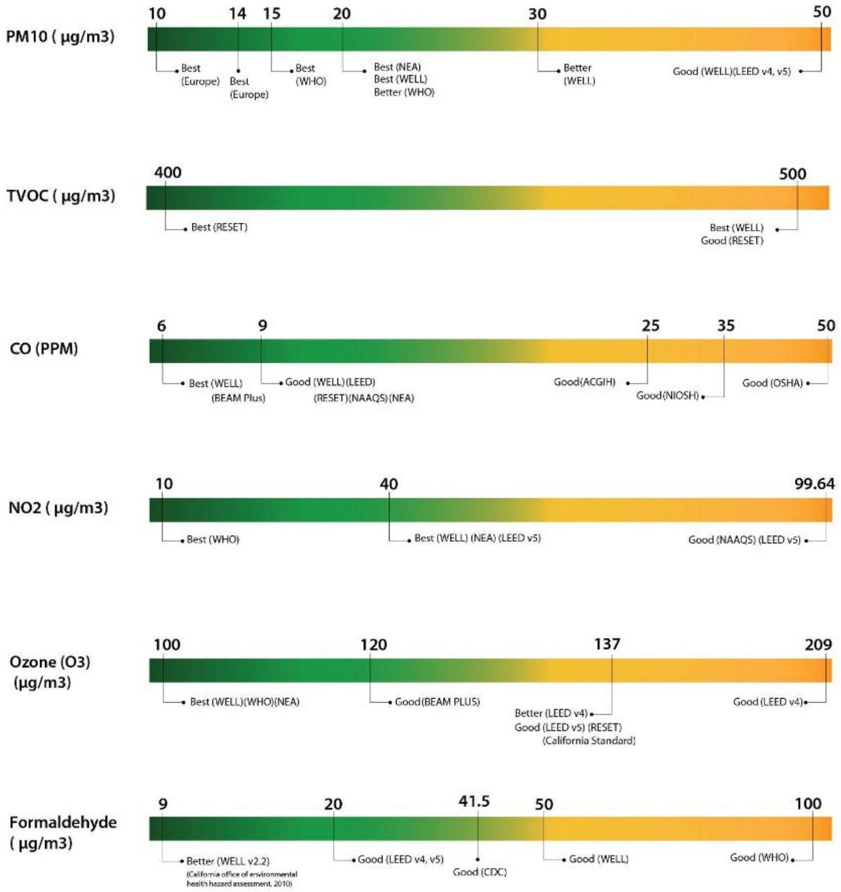
Priority #2

Collect IAQ KPI’s for each building and mechanical zone to emphasize O&M in buildings for IAQ and Health.

Baseline and Evaluate Outdoor Air cfm, CO2, IAQ measures as KPIs

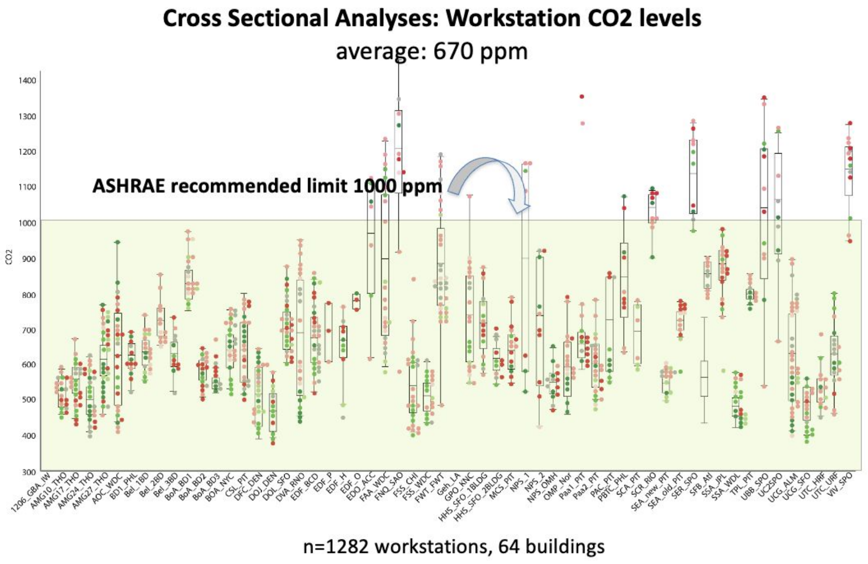
Prioritizing Contaminants of Concern and Identifying Thresholds for Action



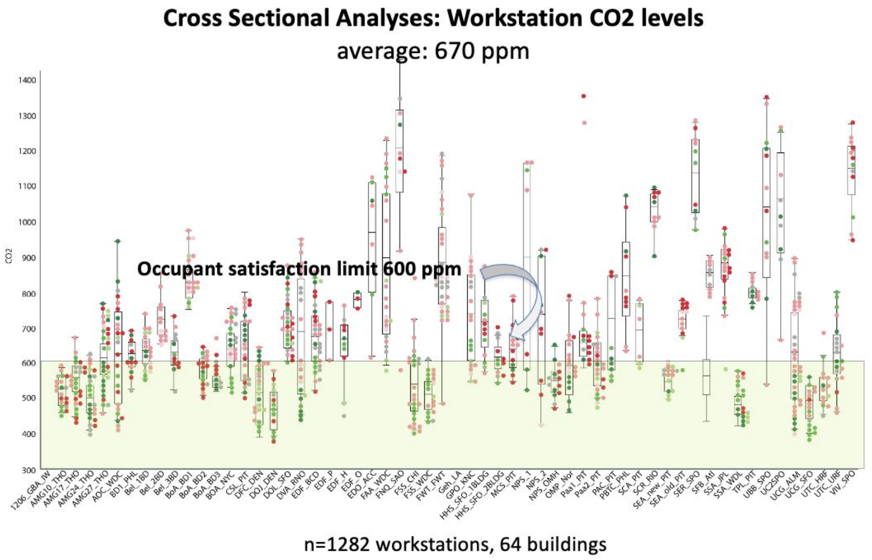


Compare IAQ performance between buildings that share IAQ data with building manager or occupants and those that do not

GSA/CMU NEAT Study - 15 years of Field Measurements

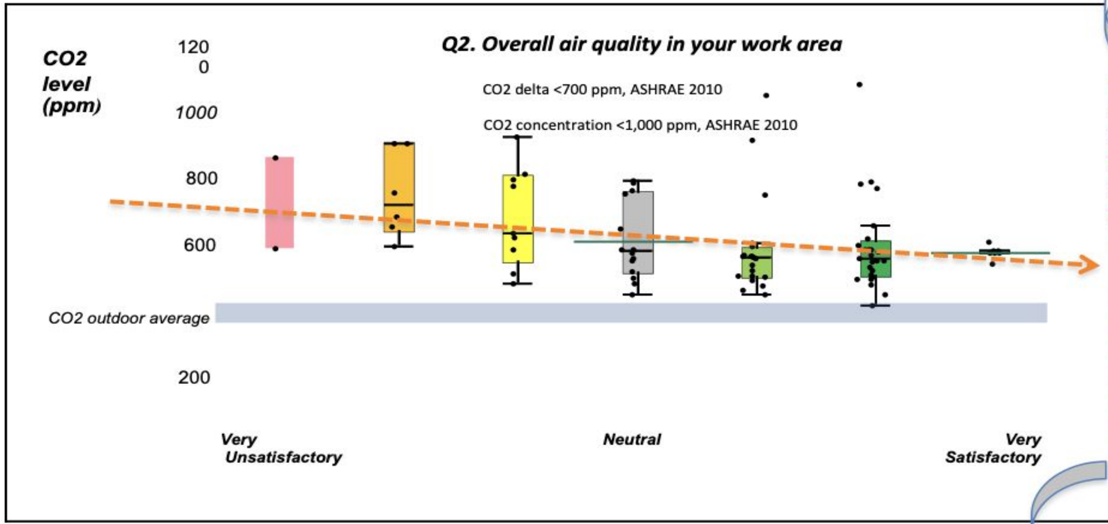


Summary of CMU/GSA NEAT Field Studies 1995-2020 Carnegie Mellon CBPD



Given measured CO2 levels and user satisfaction surveys in over 1200 workstations in 64 buildings, CMU CBPD identified **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, $p < 0.05$).

Satisfaction with air quality aligned with CO2 level



CO2: > 675 ppm (678 - 743 ppm)

Occupant satisfaction Survey	Measured CO2 concentration
Very Unsatisfactory	718.0 ppm
Unsatisfactory	743.7 ppm
Somewhat Unsatisfactory	677.2 ppm
Neutral	605.2 ppm
Somewhat Satisfactory	582.2 ppm
Satisfactory	587.1 ppm
Very Satisfactory	571.2 ppm
Overall Average	**611. 9 ppm**

CO2: < 600 ppm (571-587 ppm)

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).

Collect KPIs to Drive Improved IAQ

Priority #3

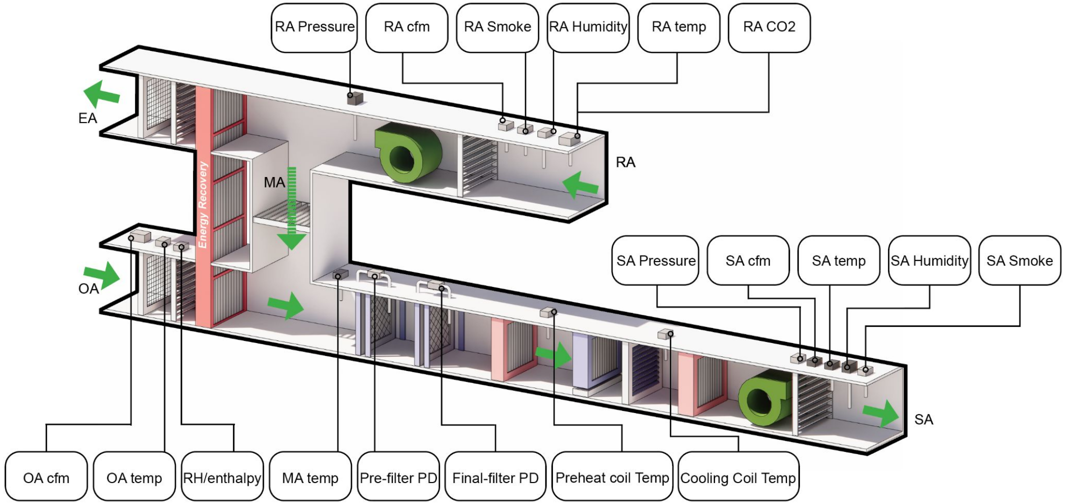
Collect <u>Annual Maintenance KPI's</u> for each building and mechanical zone to accelerate O&M in buildings for IAQ and Health.

Annual or one-time condition assessments

(e.g. GSA Ventilation Verification Program)

Table 2. Results of contractor survey on the prevalence of various economizer faults

Economizer is disabled and dampers are closed	30-40%
Actuator/linkage broken, misaligned, or loose, due to normal wear and tear or lack of lubrication	20-30%
High/low limit setpoints incorrect, set by installing contractor	
Range/action setup incorrectly	
Min Outside Air is not set correctly: too low	
Actuator/linkage broken, misaligned, or loose, due to occupant/operation staff action	10-20%
Min Outside Air is not set correctly: too high	
High/low limit setpoints incorrect, set by factory	
Dampers mechanically forced open	
OA Sensor (db, enthalpy) malfunction	
OA Sensor (db, enthalpy) drift	
High/low limit setpoints incorrect, set by occupants/operating staff	5-10%
OA sensor (db, enthalpy) miscalibration	



Heinemeier, K. (2014). Free cooling: At what cost?. ACEEE Summer Study Energy Efficiency Build.

Compare condition assessments in buildings with different O&M spend, staffing, qualifications

Linking Fault Detection and Diagnostics (FDD) and IAQ

Prioritize BAS FDD (GSALink Sparks) related to Inadequate, Compromised Fresh Air

1. **AHU Discharge pressure unreachable =** compromised filters or duct path
2. **AHU Discharge fan failure** = no air delivery, poor thermal comfort
3. **Terminal unit airflow setpoint unreachable** = poor air delivery
4. **AHU OA air damper stuck closed** = no fresh air delivery, especially in hot and cold periods.
5. **AHU Excessive Return Fan Speed** = negative pressure and pollution intake?
6. **AHU Damper Unstable** = poor air delivery, poor thermal comfort
7. **AHU Zone Pressure Setpoint Unreachable**
8. **AHU Discharge Pressure Unstable** = poor air delivery, poor thermal comfort
9. **AHU Outside Airflow Too Low** = poor air delivery
10. **AHU Discharge Fan Unstable** = poor air delivery, poor thermal comfort
11. **AHU Outside Airflow Unstable**

*In a 2020 data-driven study based on field data from a school building, **Taal & Itard identified 19 faults, including CO2 sensor fault, AHU damper, filter and fan faults, and proposed new FDD priorities to reduce high CO2 concentration in mechanical zones by 6.7%.***

Taal, A., & Itard, L. (2020). Fault detection and diagnosis for indoor air quality in DCV systems: Application of 4S3F method and effects of DBN probabilities. Building and environment, 174, 106632.

Compare fault detection data in buildings with different O&M spend, staffing, qualifications

Data Analytics to assign Total Estimated Energy Cost Impacts (GSALink TECI) of FDD

LGBM Model to Predict the Electricity Penalty of 60 Spark Types

Changing the Spark Value from 1 to 0 (Keeping Other Attributes Same)

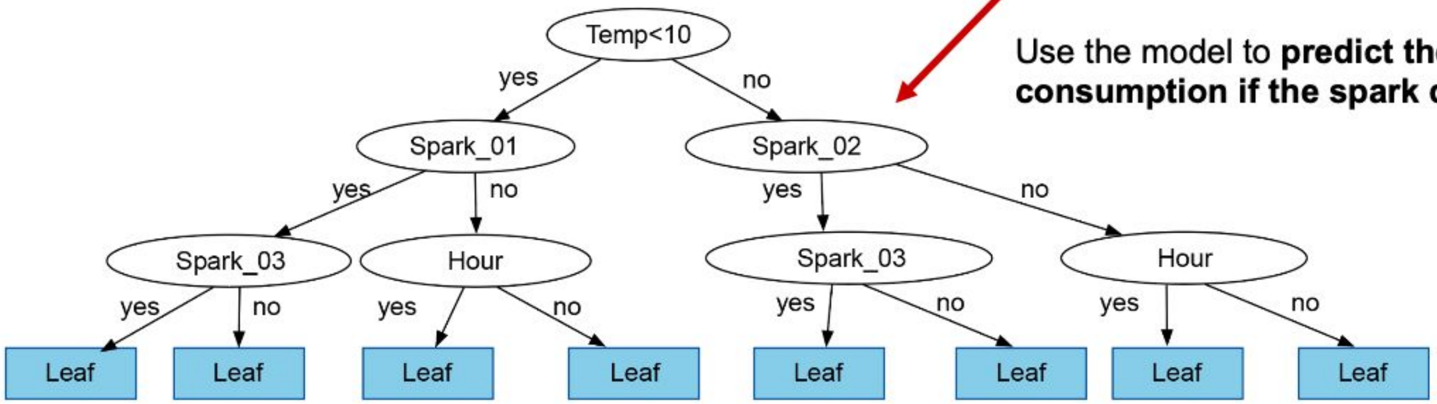
Temp OA	Spark1	Spark2	Spark3	Hour
25	1	1	1	6

Original Data

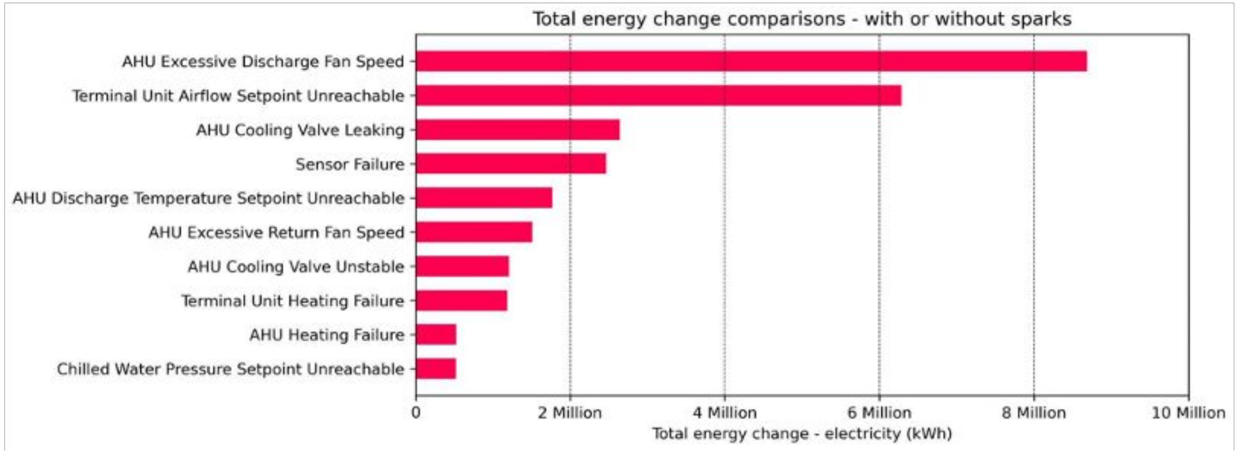
Temp	Spark1	Spark2	Spark3	Hour
25	1	0	1	6

Change the value of ‘Spark2’ from 1 to 0

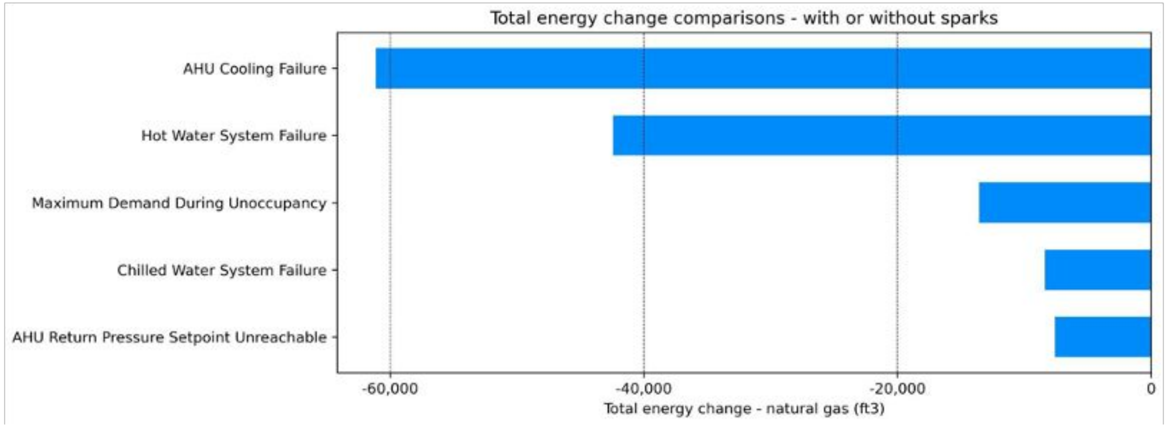
Use the model to **predict the energy consumption if the spark doesn’t happen**



Electric Penalty (Total) for Top 10 Sparks over 2 Years 47 Buildings (LGBM)



Natural Gas Savings (Total) for Overlapped 5 Sparks over 2 Years 21 Buildings (LGBM)



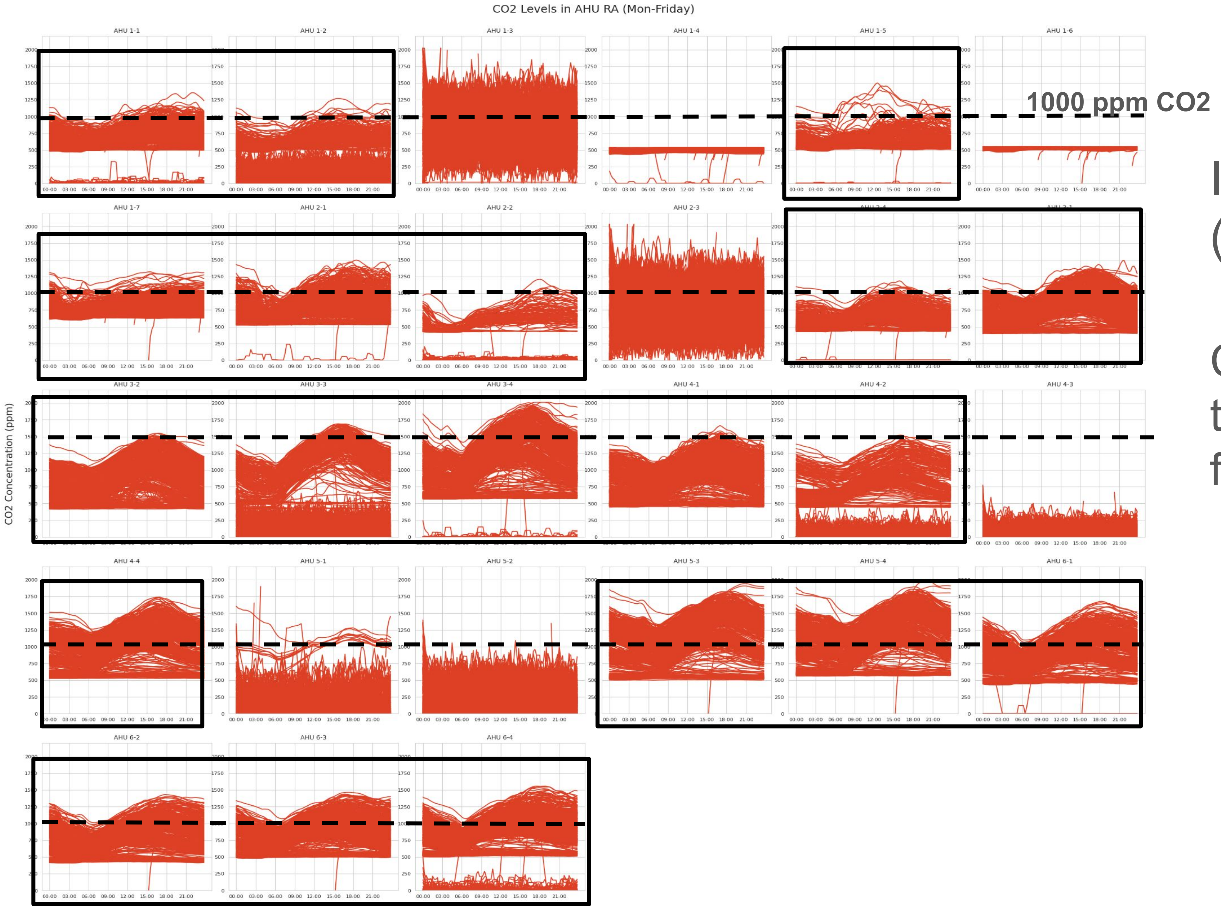
Two Existing CO_2 Data Sets Research Hypotheses

GSA 03/06

Specific FDD/Sparks or BAS records will have significant correlations with increases in CO_2 in the zone or AHU return air, suggesting prioritization for improving indoor air quality in federal buildings.

Choices in Economizer operational setpoints with have significant correlations with increases in CO_2 in the zone or AHU return air, suggesting increased commitment to economizer utilization for improving indoor air quality in federal buildings.

Monday-Friday AHU RA CO2 Data - One Georgia building 2018+2019



Identify viable CO2 sensor data (black frames = 20 of 27 AHU)

Clean viable CO2 sensor data based on the low and high limit of the CO2 sensor from the GSAlink:

CO2 Sensors (ppm)

- Outside co2: 300 - 700
- Inside co2: 300 - 2500

	A	B	C	D
1	Spark		Description	Possible Issue
2	AHU Faults			
3	AHU Outdoor Damper Stuck Closed		Find periods when discharge fan is on, outside damper is greater than a threshold and the calculated outside air percentage is lower by more than a percentage. The outside air percentage will be calculated using the return air temperature, mixed air temperature, and outside air temperature sensor. If the mixed air temperature sensor is not available then the discharge air temperature sensor will be used when cooling and heating are both off. If the return air temperature sensor is not available then the zone air temperature sensor will be used. Will not find these periods when the outside air temperature sensor is within a threshold of the return air temperature sensor.(1.5h)	● Outside air damper not operating properly ● Return air damper not operating properly ● Sensors may need calibration ● Mixed air plenum pressure issues; return fan not operating properly, plenum restrictions (intake screens, fire dampers, etc…)
4	AHU Damper Unstable	OA Damper	Find periods when any damper position jumps by more than a threshold (40%), more than a given amount of times, within a detection period of 2h	● Improper setpoints or deadband ● Incorrect sequence of operation ● Improperly tuned loop
5		RA Damper		
6		MA Damper		
7		Exhaust Damper		
8		Bypass Damper		
9	AHU Outside Airflow Too Low		Find periods when the discharge fan is on and the outside airflow is below the outside airflow setpoint for over a duration (1h) during occupancy.	● Equipment not programmed properly to maintain minimum outside airflow ● Airflow setpoint not properly set ● Sensors out of calibration ● Outside air damper not operating properly ● Minimum outdoor air damper not operating properly ● Mixed air plenum pressure issues; return fan not operating properly, plenum restrictions (intake screens, fire dampers, etc…)
10	AHU Outside Airflow Unstable		Find periods when the discharge fan is on and the outside airflow bounces above and below the outside airflow setpoint by a deadband (300cfm). Periods are only found when the airflow crosses (above and below) the setpoint by the deadband more than the given amount of crosses in any 2h detection period.	● Improper setpoints or deadband ● Incorrect sequence of operation
11	AHU Discharge Fan Failure		Find periods when discharge fan is on and duct static pressure is below a threshold (0.2inH2O) for over a duration (0.5h)	● AHU Fan is not working correctly ● Loose belts on fan
12	AHU Discharge Fan Unstable		Find periods when the discharge fan speed jumps by more than a threshold (40%), more than a given amount of times, within a period of 2h	● Improper setpoints or deadband ● Incorrect sequence of operation

Collect KPIs to Drive Improved IAQ

Priority #4

Collect Annual Facility Investment KPI's for each building to accelerate O&M in buildings for IAQ and Health.

Compare O&M resource levels per occupant and square foot

(e.g. Budgets, Staffing, Training/Promotion)

According to a 2011 study of the National Academy of Sciences FFC, U.S. federal buildings have long records of underfunding, with annual investments less than 1.5% of current plant value (CPV) when it should be between 2-4% depending on complexity and criticality.

A 2022 NAS FFC report on Renewing Federal Facilities identified the need for a 2.5% - 9% investment in O&M, with an average 5% of present replacement value (PRV) recommended based on a facility condition index (FCI) - FCI is the sum of maintenance requirements for a facility divided by present replacement value (PRV) of that facility.

Compare condition assessments in buildings with different O&M spend, staffing, qualifications

Compare O&M resource levels per occupant and square foot

(e.g. Budgets, Staffing, Training/Promotion)

A preliminary list of data that could be requested for each federal facility includes:

1. Per Square foot and per desk budgets for capital and for operations and maintenance
2. Record of full time vs part time staffers, in-house vs off-site, federal vs contract.
3. calculated sqft served per full-time on-site staffer (and full-time + part-time mix)
4. Years in the building of full-time staffers
5. Annual Turnover of full-time and part-time staffers
6. Annual Absenteeism of full-time and part-time staffers
7. Records of Promotion, Compensation, Training, of FM Staff

Compare condition assessments in buildings with different O&M spend, staffing, qualifications

10 Field Research Efforts to Improve IAQ and Health

KPIs for Improving O&M for IAQ

1. **KPI for health** in existing buildings (SBS surveys and health records metrics)
2. **KPI for HVAC condition** assessments (**Fault Detection Diagnostics, Ventilation Verification**)
3. **KPI for IAQ** in existing buildings (zone or room-level monitoring)
4. **KPI for FM investments** in existing buildings (2-4% Current Plant Value)

Room/Zone Investments for IAQ

5. **State of the Room** (Measuring ventilation effectiveness & FDD)
6. **Next-gen 'thermostats':** IAQ+Temp+Occupancy as controllers
7. **In-room filtration** – HEPA units and UVGI units

Central OA Investments for IAQ

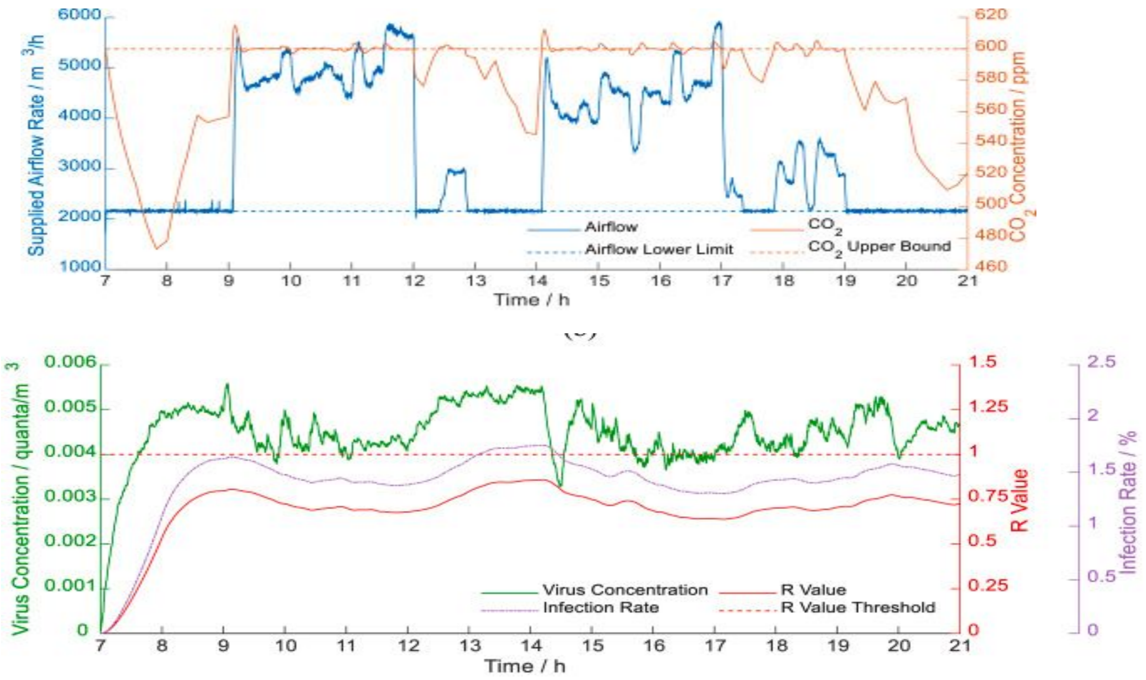
8. **New damper/sensor/actuator and economizer** BAS algorithms expanding OA% and hours
9. **Filter improvements** – types, PD sensors, maintenance schedules, location/fit.
10. **DOAS** (separate ventilation and thermal) retrofits with electrification

Room / Zone Investments to improve IAQ

Priority #6

Test Next Generation ‘Thermostat + IAQ’ Control

Test next generation ‘Thermostat + IAQ’ control



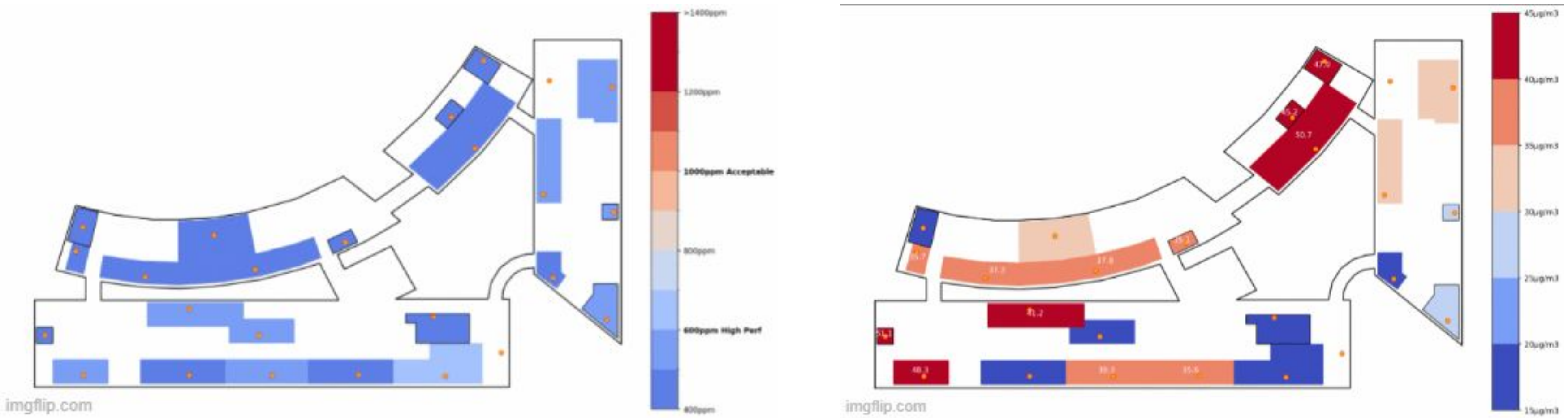
Bingxu Li, Wenjian Cai, A novel CO2-based demand-controlled ventilation strategy to limit the spread of COVID-19 in the indoor environment, Building and Environment, Volume 219, 2022

Examples of Integrated IAQ Sensors Currently on the Market (Top Left: Ecobee Thermostat Premium; Top Right: Awair Omni; Bottom Left: Kaiterra Sensedge; Bottom Right: Airthings Space Pro)

Add Next Gen Thermostat and compare IAQ, human health, maintenance, and energy outcomes in discrete before / after tests

Evidence in Washington DC Building
CO2 vs. Particulate Matter

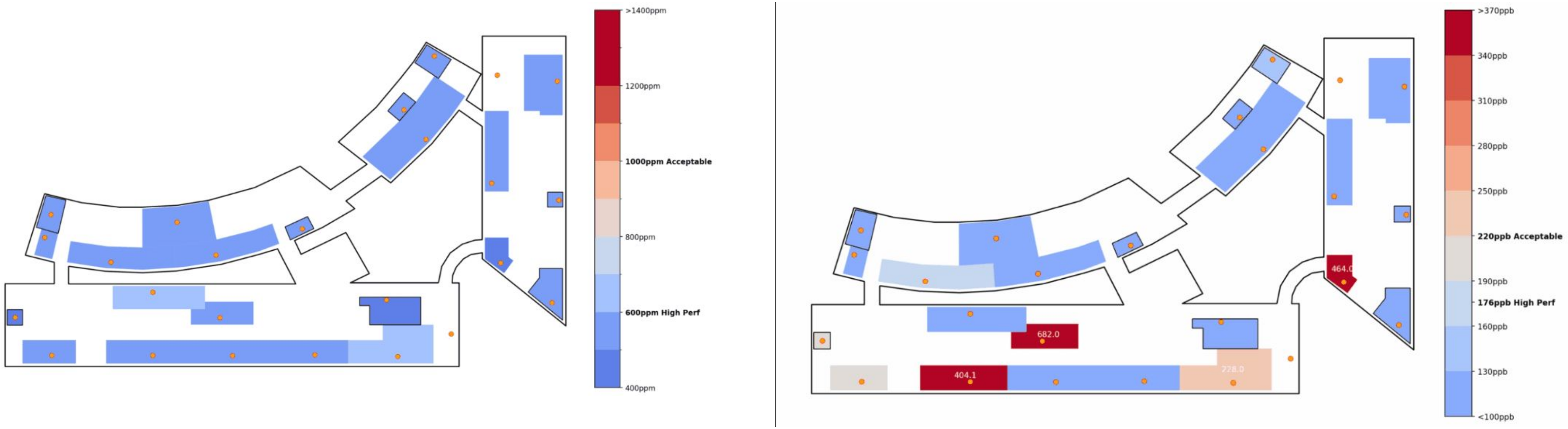
While CO2 remained low, indoor PM levels soared in certain spaces with high outdoor PM during the wildfire.



Two 1-hour snapshots of CO2 (left) and PM (right) level in ATC building, June 6-8, 2023.

Evidence in Washington DC Building
CO2 vs. TVOC

Good CO_2 levels can coincide with poor TVOC levels.



Four 1-hour snapshots of CO2 (left) and TVOC (right) level in ATC building, Aug 23~28, 2023.

Room / Zone Investments to improve IAQ

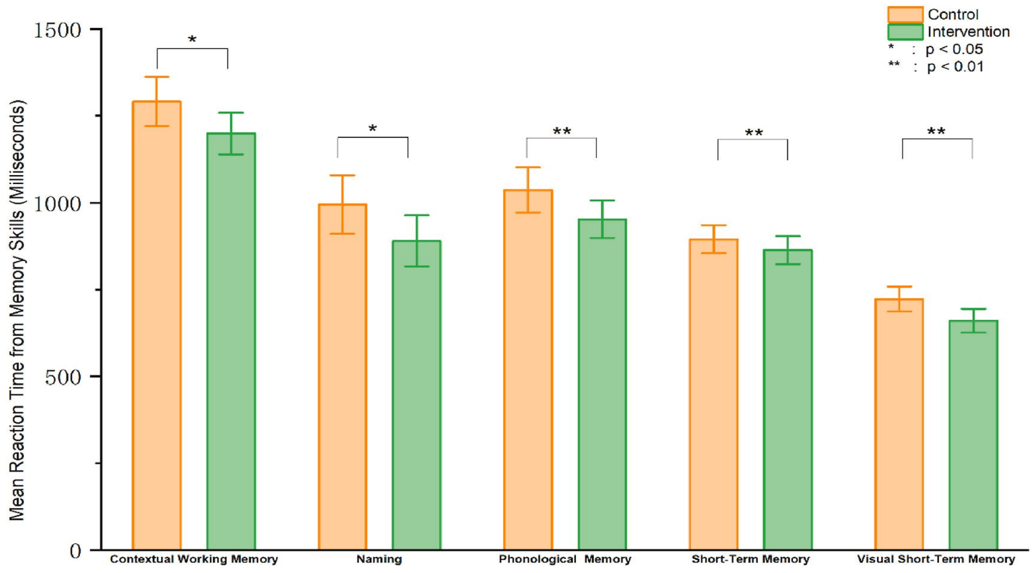
Priority #7

Test Benefits of Equivalent Outdoor Air

with Local Filtration and Air Cleaning

In-room HEPA and UVGI Filters

- Atem Desk Air Purifier, IQAir®, Switzerland
- clean air delivery rates from 4 to 66 m3/h. (30 m3/h for this study)
- Sound level: 35dB   Price: 399$



Zhou, J., Wang, H., Huebner, G., Zeng, Y., Pei, Z., & Ucci, M. (2023). Short-term exposure to indoor PM2.5 in office buildings and cognitive performance in adults: An intervention study. Building and Environment, 233, 110078. https://doi.org/10.1016/j.buildenv.2023.110078

*In a 2023 intervention study of a office in Beijing, Zhou et al. identified that **in-room HEPA filters** at each desk resulted in a **79.4% decrease in PM2.5 concentration associated with SARS**-Covid risk (from 18 to 3.7 µg/m3, p<0.05), as well as a **7.3% increase in employees' cognitive performance on memory tasks** and **a 8.2% increase in employee's perception of cognitive performance** (n=55, p<0.05)*

Test Equivalent Clean Air approaches and compare IAQ, Wellness, and energy outcomes

Central Plant Investments to Improve IAQ

Priority #8

Invest in Central AHU Delivery of OA
to improve IAQ and Health as well as saving Energy.

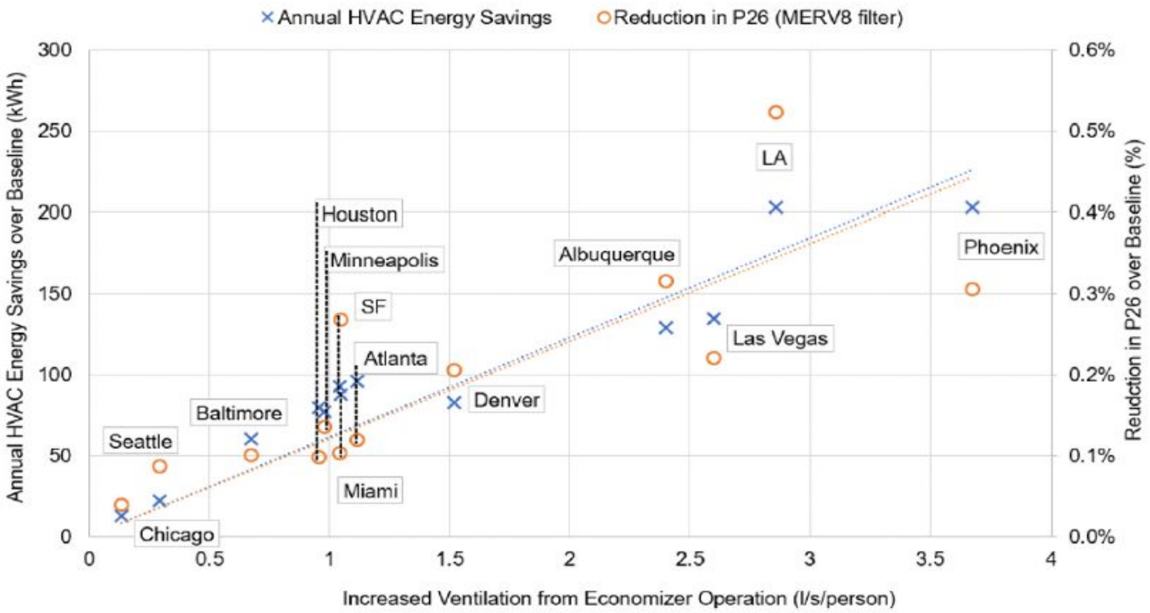
Update Damper/Sensor/Actuator and Building Automation Controls

fig. 6.3 Aggregating the 24-60 AHU's in each building studied reveals the 37% that do not meet ASHRAE minimums for the assumed area and occupant density served.

NOVA Concerns - 62 buildings
OA damper flaws in 48% of AHUs
OA damper manually closed in 9% of AHUs
OA sensor/actuator flaws in 13% of AHUs
OA damper BAS control flaws in 17% of AHUs
No Economizer operation in 38% of AHUs

Install next generation dampers with integrated sensors and BAS algorithms and compare IAQ and energy outcomes pre/post

Enhanced Economizer and Energy Recovery



In a comprehensive simulation study for 13 US cities, Pistochini et al identified that the ***10-50% increased ventilation from Economizer Operation (by climate) reduced disease transmission by .1-.5% and provided up to 12% HVAC energy savings.***

Pistochini, Mande, Chakraborty (2022), Modeling impacts of ventilation and filtration methods on energy use and airborne disease transmission in classrooms. Journal of Building Engineering 57, 2022.

Enhanced Economizer and Energy Recovery Extended Operation

In a multi-climate simulation study, Risbeck et al identified that ***increasing summer supply air temperature from 55F to 60F in humid climates and 65F in dry climates*** *would support longer economizer operation, and in combination with MERV 13 filters,* ***would provide 1 ACH increase in effective outdoor air (EOA) at the lowest energy cost*** *compared to doubling ventilation rates or installing in-room filtration given ASHRAE baselines between 2-2.5 ACH.*

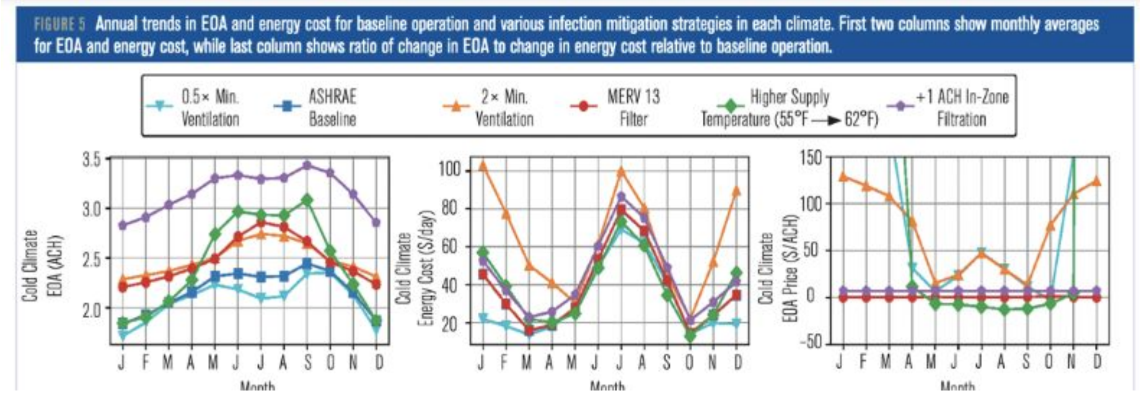
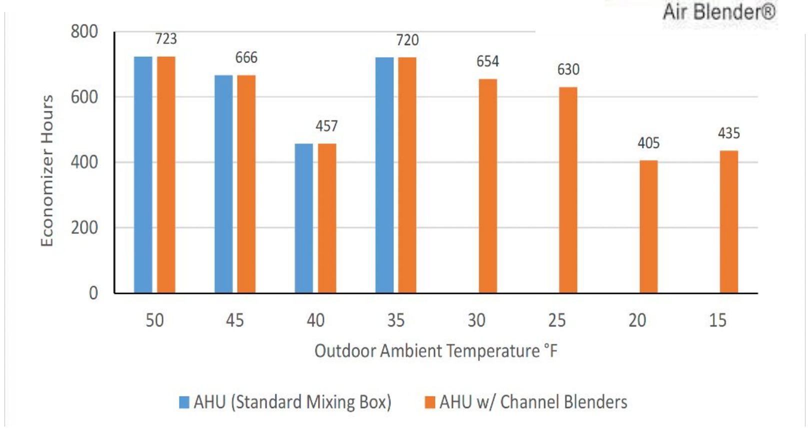


FIGURE 5 Annual trends in EOA and energy cost for baseline operation and various infection mitigation strategies in each climate. First two columns show monthly averages for EOA and energy cost, while last column shows ratio of change in EOA to change in energy cost relative to baseline operation.

Risbeck, M. J., Bazant, M. Z., Jiang, Z., Lee, Y. M., Drees, K. H., & Douglas, J. D. (2021). Assessment of Airborne Disease Transmission Risk and Energy Impact of HVAC Mitigation Strategies. medRxiv, 2021-11.



In a field intervention at St. Peter's Hospital in Albany NY, Starns et al identified that the introduction of ***channel air blenders in the AHU mixing box would eliminate freeze stat trips, reduce air stratification, and maintain 30% minimum OA air flow*** *(above the 20% typical minimum) even during cold weather, by* ***extending economizer operations to OA temperatures between 15°F-30°F*** *with a 1.9 year payback.*

Starns, Dorset, Pavol (2021), Extend Economizer Operations for AHUs and Improve Ventilation with Effective Mixing, February 16, 2021.

Central Plant Investments to Improve IAQ

Priority #10

Invest in Air Handling Unit Filter Improvements

Dedicated OA Ventilation with Separate Thermal Conditioning

(Improves both Zone and Central OA delivery; excellent companion to electrification)

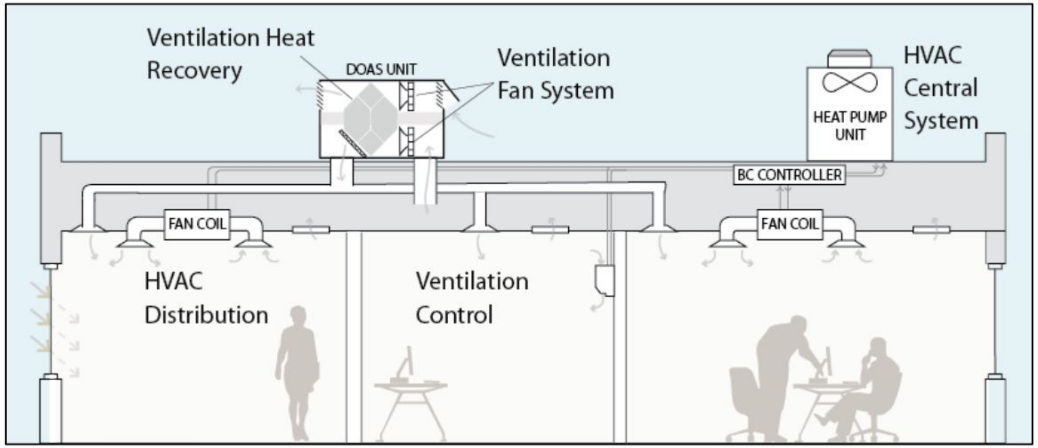


FIGURE 1: DIAGRAM OF DECOUPLED DOAS CONFIGURATION EXAMPLE

https://www.etcc-ca.com/reports/code-readiness-dedicated-outdoor-air-system-field-assessment-results

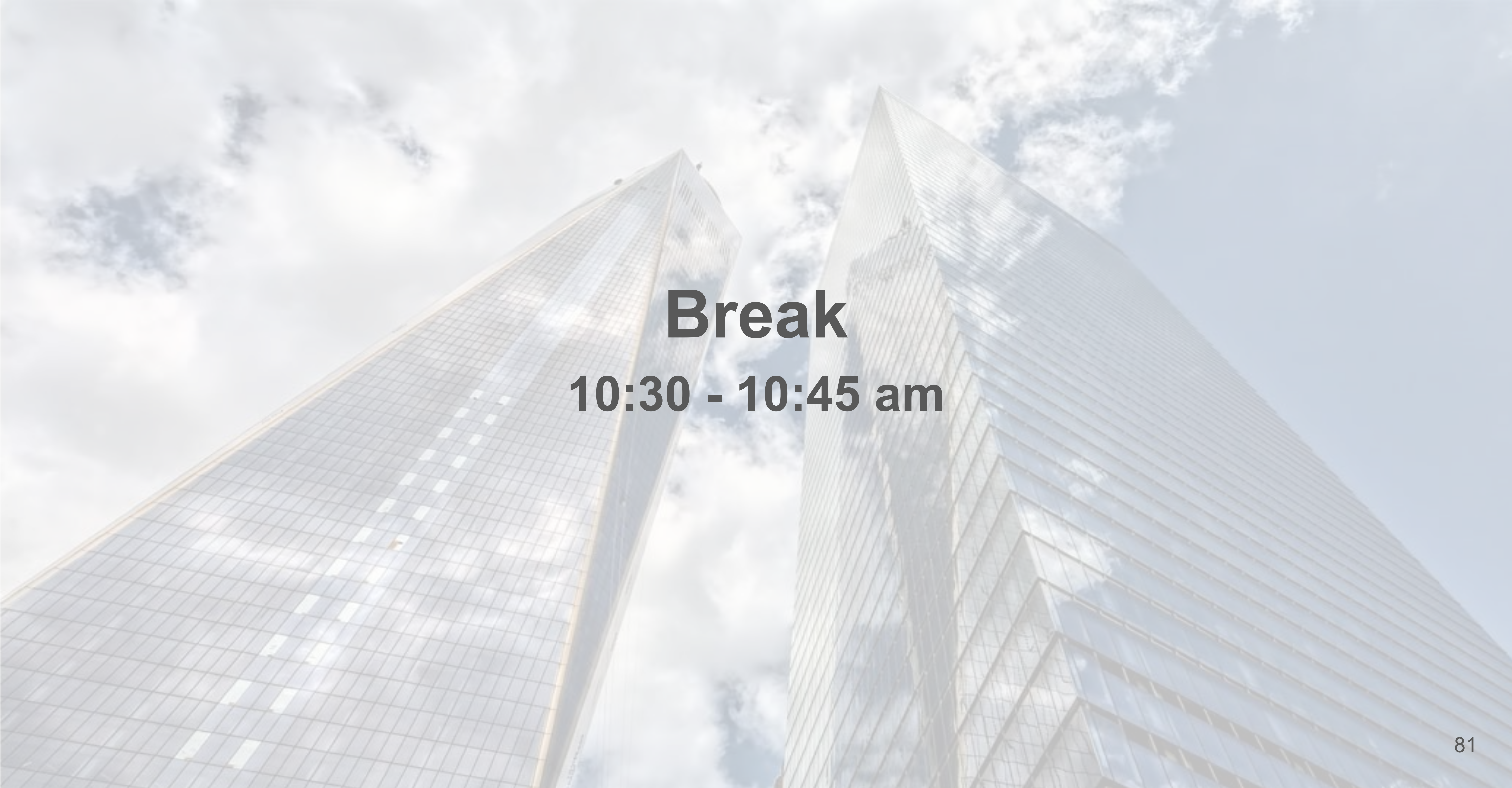
Dedicated Outdoor Air System
Field Assessment Results

ET18PGE1902

PGE identified DOAS saves 41-66% energy with ventilation rates at 100-140% of Title 24 *(using 20% new and 5% retrofit bldgs in CA).*

Compare IAQ performance and energy costs for DOAS and VRF replacements in small and mid size buildings (validate PGE and NYSERDA findings)

Questions?



Break

10:30 - 10:45 am

How might we use KPIs to improve IAQ, ventilation, and energy performance?

10:45 - 12:00 pm

Session Speakers

Bill Bahnfleth, PhD, PE
Pennsylvania State University
Professor of
Architectural Engineering
Chair, ASHRAE Std 241 Committee

Seema Bhangar, PhD
US Green Building Council
Board member of the
Indoor Air Institute

Vivian Loftness, FAIA
Carnegie Mellon University
Professor of Architecture
Center for Building
Performance & Diagnostics

Marwa Zataari, PhD
DZine Partners
Vice-chair of USGBC
Board of Directors

Audience Polls

Does your organization have KPI’s for Building Energy Use?

Does your organization have KPI’s for Indoor Air Quality?

The use of IAQ sensor data to improve design and operations – a story from commercial real estate.

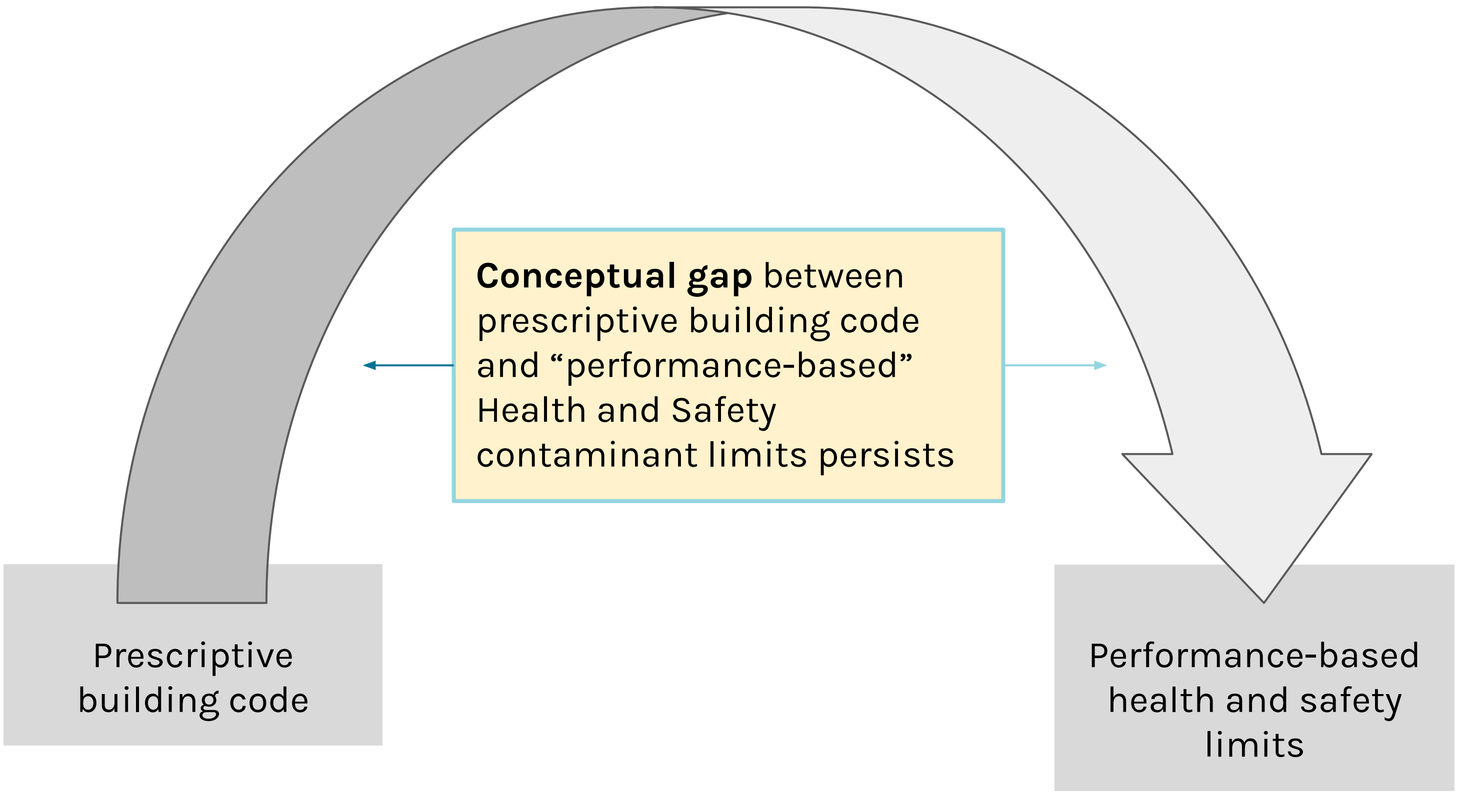
Seema Bhangar
U.S. Green Building Council
May 21, 2024

In the last few years, expectations on indoor air quality have increased, driven by new risks brought on by climate change and public health emergencies, newly available sensors and data management technology, and increasing public awareness and media attention.

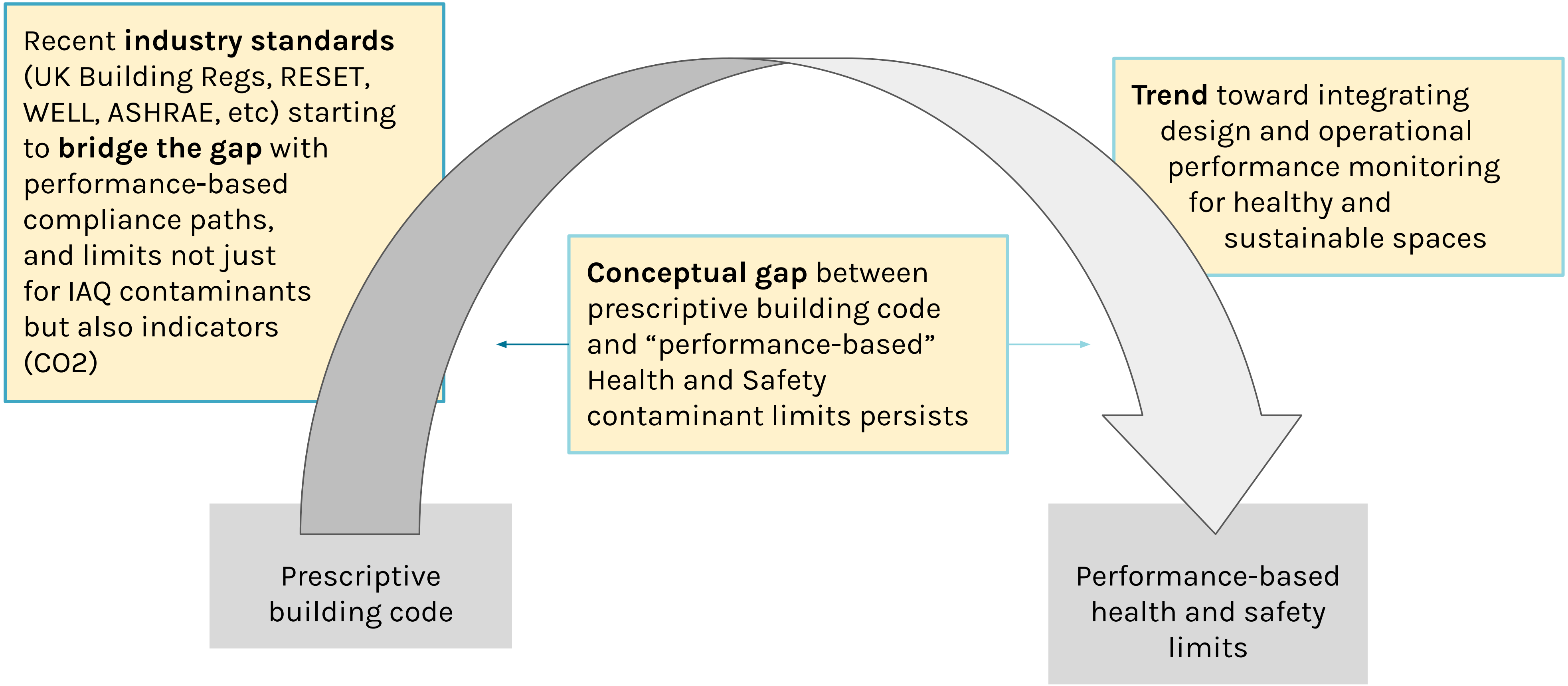
This Presentation

What I learned about this new world of **performance-based indoor air quality management** through my experience as an IAQ manager for a global, commercial real estate portfolio.

From Prescriptive to Performance-based Management



From Prescriptive to Performance-based Management



A story in five parts… Part 1 – Plan

Plan programmatically and strategically:

- What are the most pressing needs - pick indicators to match, considering **place and people** across scales.
- What can you do now to build up the sensor program over time, with **proof points** along the way?
- How will you use data to improve design and operations **now**?
- What do you need to do to ensure you learn for iterative **improvement**?

Image credit: Larkin Johnson

Part 2 - Deploy

- **Network design**
  - 4000 sensors
  - 100 buildings
  - 8 cities
  - 2 continents
  - Stratified by space type
  - RESET spatial layout as a guide

- **Parameters:**
  - CO_2, T, RH at full scale
  - +PM at pilot scale, single market

Part 3 - Data

- **Aggregate metric:** Spatial extent, temporal extent, and severity. Evaluated on a granular, per day or per hour basis at specific floors or rooms; and on a whole year, whole market grid to see monthly scores per building or city.
- Custom **dashboard** for technical users. Topline scores integrated into central facilities and environmental safety reporting.
- **Action thresholds** (rather than health or compliance levels) – indicator rather than contaminant mindset.
- **Portfolio** lens: Where do we need to invest resources first.

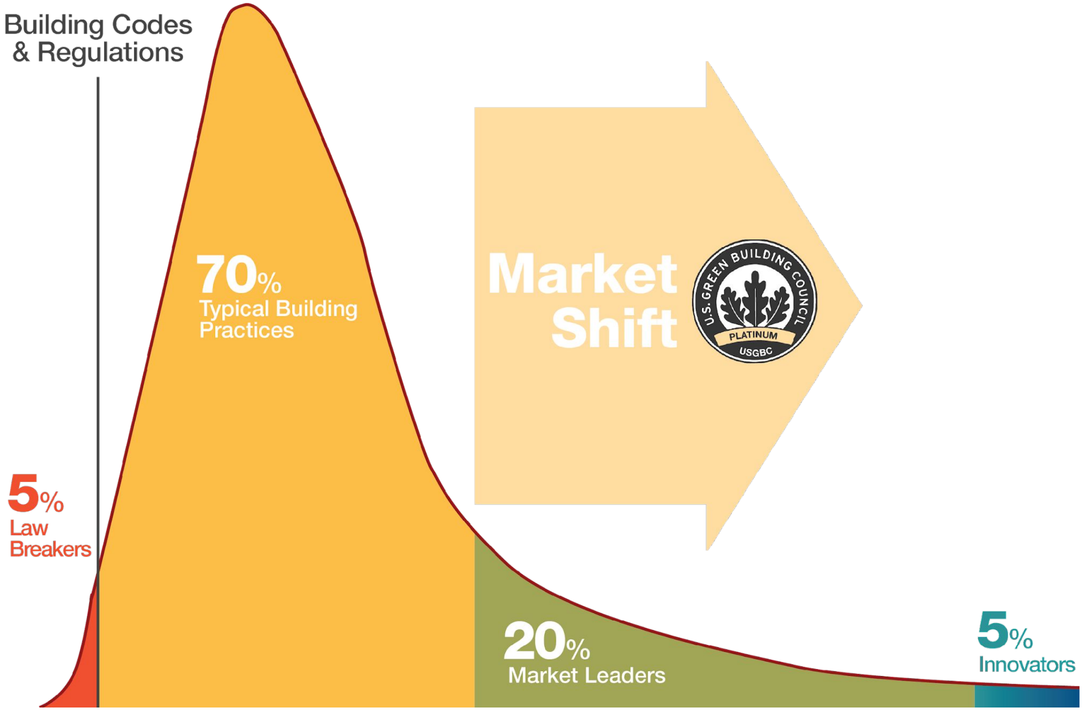


Image credit: Chris Pyke

Part 4 - Action

Manual fault detection and response

Description
On site Facility management visibility for IAQ data to be actionable, e.g. this buildings IAQ reading is X and needs to be reduced to Y.

Value Proposition
Better occupant experience by anticipating and solving faults before they result in complaints; opportunity for operational efficiency via remote monitoring of IAQ performance.

Data Product description
Automated alerts linked to manual response protocols, queryable dashboard

External reporting

Description
Report data to ESG, Green building certifications

Value Proposition
Marketing, brand

Data Product description
External reporting of KPIs

Curated access to real-time data for occupants

Description
Display indoor air quality of spaces to occupants

Value Proposition
Sales and marketing; attraction and retention

Data Product description
Real-time sharing of IAQ performance via a dashboard or app

Automatic fault detection and response

Description
Link sensors data to BMS systems for an automatic fault detection and response

Value Proposition
Cost saving and operational efficiency; better occupant experience

Data Product description
Automated alerts linked to BMS controls; closed loop, periodic reports

Responding to occupant’s complaints

Description
Answer IAQ/Ventilation complaints from occupants with current and historical data

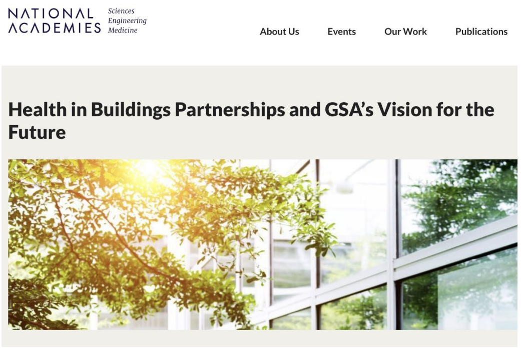
Value Proposition
Better occupant experience through quicker issue resolution; cost savings via fewer third-party consultant tests needed

Data Product description
Internal, granular "pull" data access

Slide credit: Sylvain Blanchard

Part 5 – Review, Reflect, Improve

- **Biggest challenge:** Staff turnover, and ongoing maintenance of the system to drive sustained impact.
- For **program longevity**, all parts of the sensor program must be integrated into normal workflows, and supported with ongoing tools, training, and budget.
- A consortium effort like the Health in Buildings Roundtable mitigates **uncertainty risk** and risk of reinventing the wheel (over and over again).
- For long term success, need **policy** (along with guidance from central, trustworthy agencies, and integration into building code).



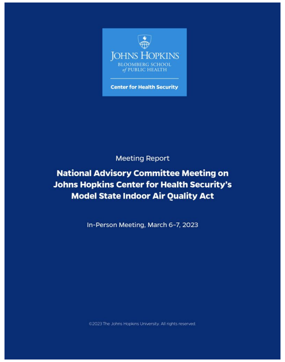


Image credits: Individual organization websites

Key Performance Indicators for Airborne Infection Control

William Bahnfleth, PhD, PE
Penn State/ASHRAE

What is a Key Performance Indicator?

Key Performance Indicators (KPIs) are the critical (key) quantifiable indicators of progress toward an intended result. (source: kpi.org)

- Intended results for control of airborne infection risk
  - Level 1 – prevented infections
  - Level 2 – pathogen exposure is controlled to desired levels
  - Level 3 – control measures are operating as designed intended
  - Level 4 – intended controls are present
- Progression from Level 1 to Level 4 corresponds to:
  - Increasing uncertainty and feasibility
  - Increasingly prescriptive indicators

Level 1 – Prevented Infections

- KPI is change in rate of infections
- What we really want to know
- Low current feasibility, retrospective
- Issues
  - What is baseline risk without intervention?
  - Multiple pathogens/diseases
  - How does risk partition among different causes
    - Infection transmission modes
    - Possible exposure sites
  - Must collect a lot of data not routinely collected today
  - Not feasible for all building types
- Limited applicability today, but must be the long-range objective

Level 2 - Pathogen Exposure Controlled to Desired Levels

- KPI is concentration of pathogens
- Low to moderate current feasibility
- Issues
  - Uncertainty in risk assessment (a topic in ARPA-H BREATHE)
  - Availability of affordable, reliable, maintainable sensors (also addressed by ARPA-H Breathe)
  - Infectious aerosols are very dilute – possible role for other indicators like wastewater testing
  - What are desired levels???

Level 3 - Control Measures Operating as Designed

- KPI could be multiple assessments or a measure like equivalent clean airflow
- Feasible, addressed by some existing standards
- Issues
  - Not generally required, so not done in a comprehensive way
  - CO_2 differential can be used to estimate outdoor airflow but not impact of pathogen removal or inactivation
  - Real-time methodologies for testing of inactivation technologies are emerging

Level 4 - Intended Controls are Present

- KPI is presence of operable controls
- Feasible – partially required by code
- Issues
  - Generally only applies at time of occupancy
  - Does not account for degradation over time
  - Weak quantitative link to risk

ASHRAE Standard 241 – Control of Infectious Aerosols

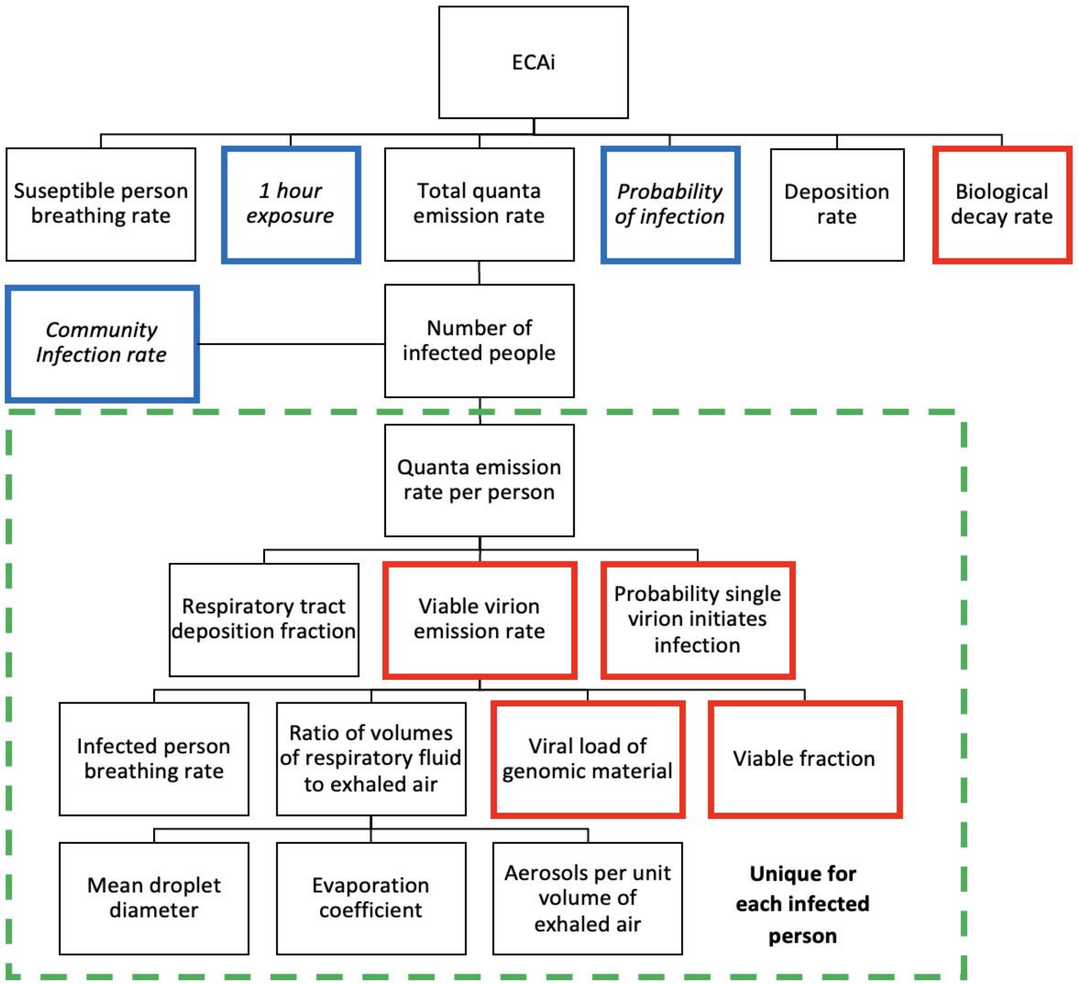
- Based on risk assessment, so effectively a level 2 control
- Application of the standard is at level 3 unless sensors for pathogen concentration is used
- Equivalent clean air approach used in ASHRAE Standard 241-2023 is a useful way to quantify engineering controls and their effects

  Equivalent Clean Airflow*: 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 airflow can be generalized to other contaminant classes…but must narrow list of contaminants of concern to be practical

Risk assumptions in Standard 241

- Wells-Riley model
  - Some variables are **deterministic**. Other variables are probabilistic using distributed variables.
  - Some variables are **based on SARS-COV-2**.
  - Variables inside the **green box** represent variables that are **unique for each infected person**.
- Low individual risk per hour
- Equal risk for all space types



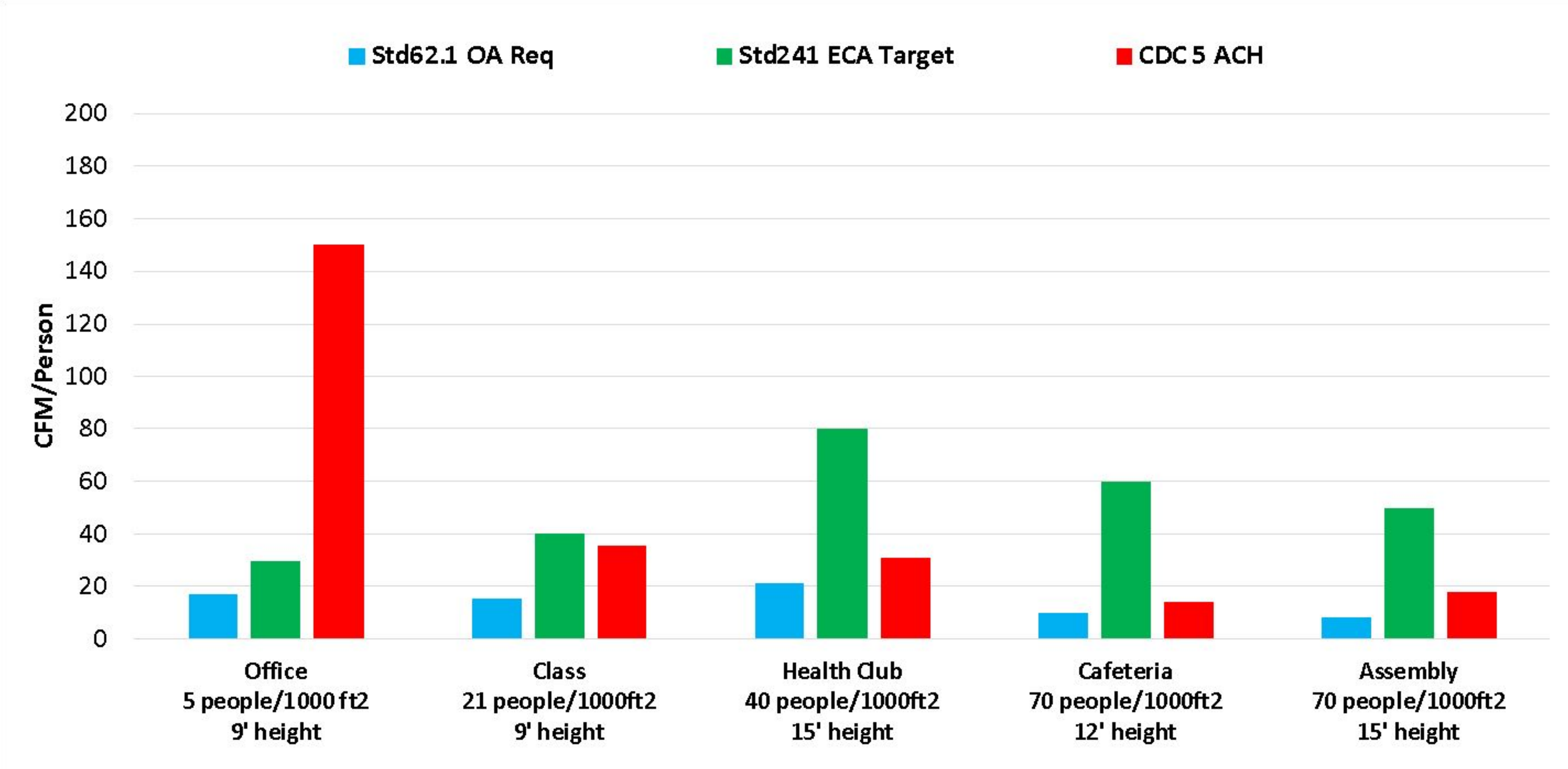
Current Status

- Level 1 KPI – not implemented, aspirational
- Level 2 KPI – limited feasibility now, but may be possible soon
- Level 3 KPI – current best practice
- Level 4 KPI – current minimum standard

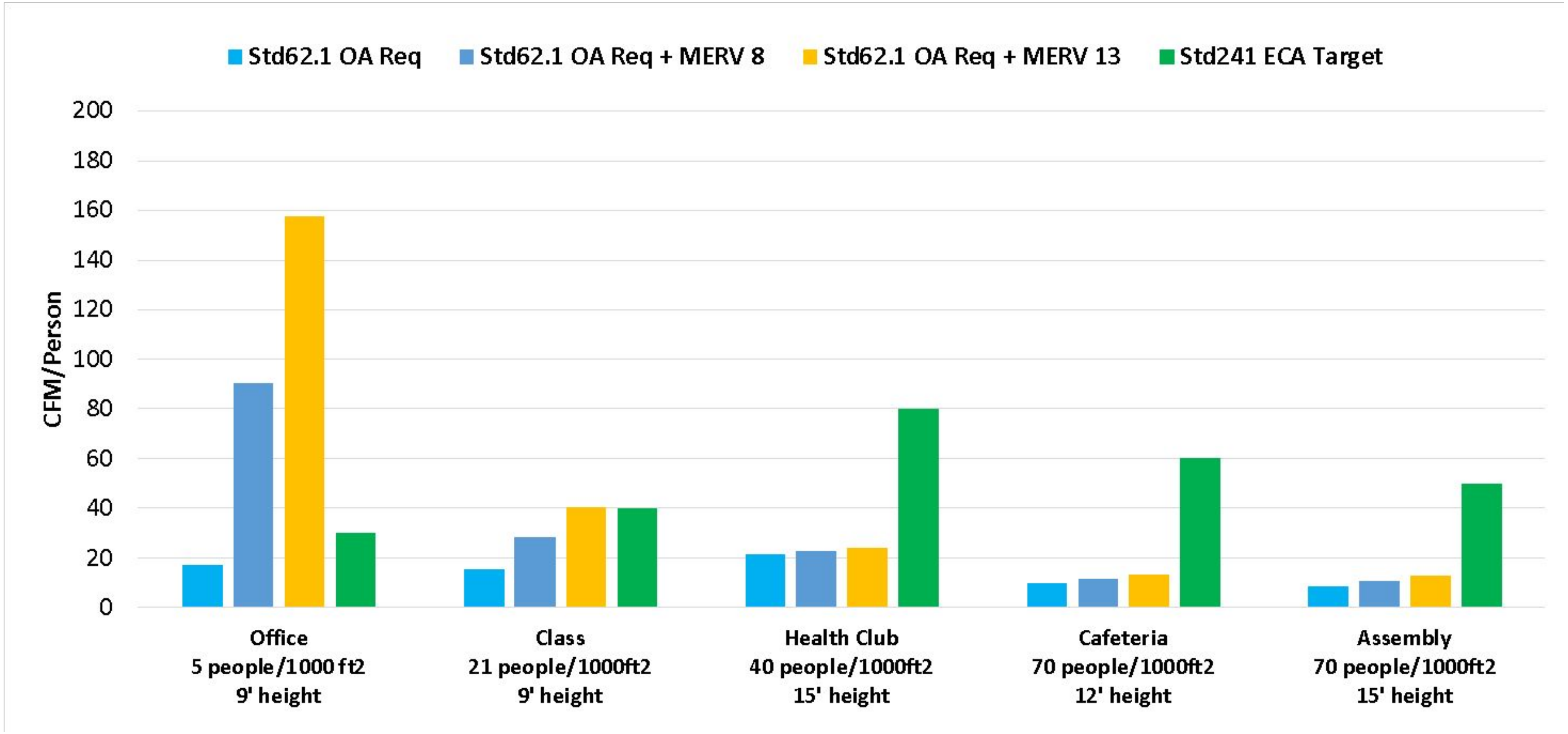
ASHRAE
Equivalent Clean Air Flow

Marwa Zaatari, PhD
DZine Partners Inc

ASHRAE Standard 241: Equivalent Clean Airflow

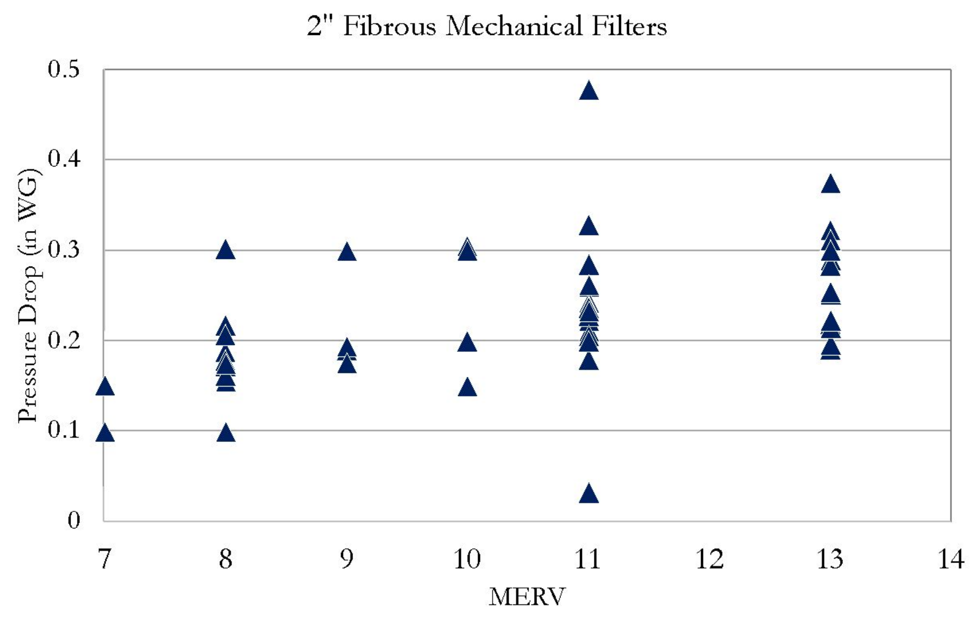


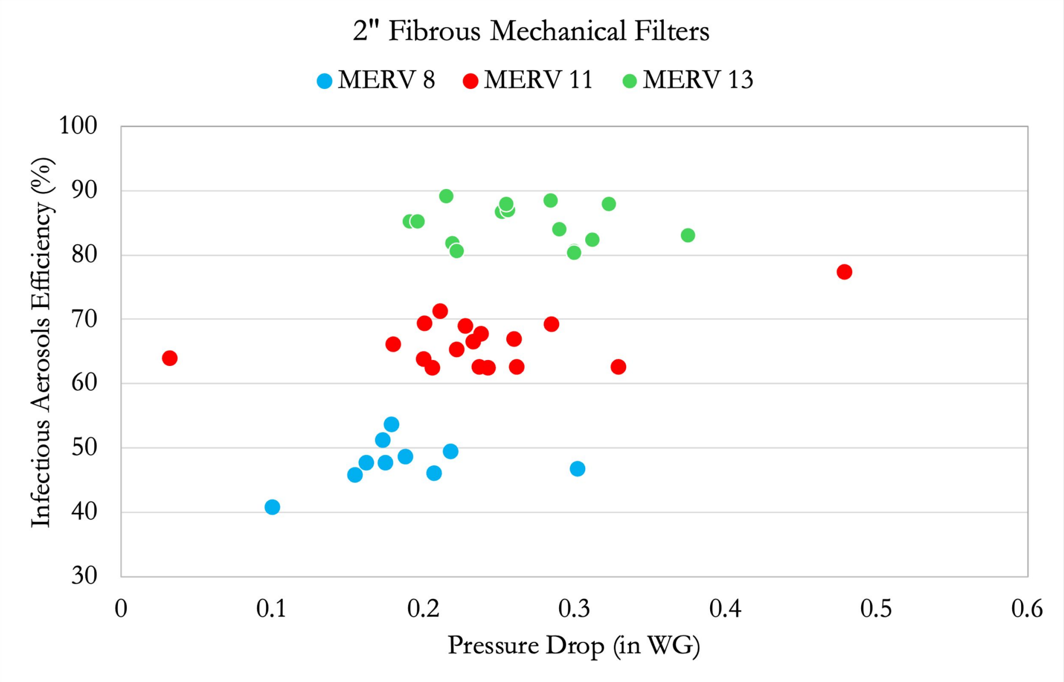
Using mechanical fibrous filtration can help achieve compliance to 241 in spaces with low to medium density such as offices.



1) MERV 8 calculations: Per ASHRAE Standard 241 Table 7-1, ECA credit for MERV 8 is zero. To get credit for MERV 8, filtration ECA must be tested per Appendix C: In-Place Test Method For Determining The Equivalent Clean Airflow For Infection Risk Mitigation (ECAi) Of A Single Occupied Space By Means Of Tracer Aerosol Decay. For this example, it is assumed that tested ECA for MERV 8 is 40%.
2) We assumed supply air to be 1 cfm per 1 ft^2.

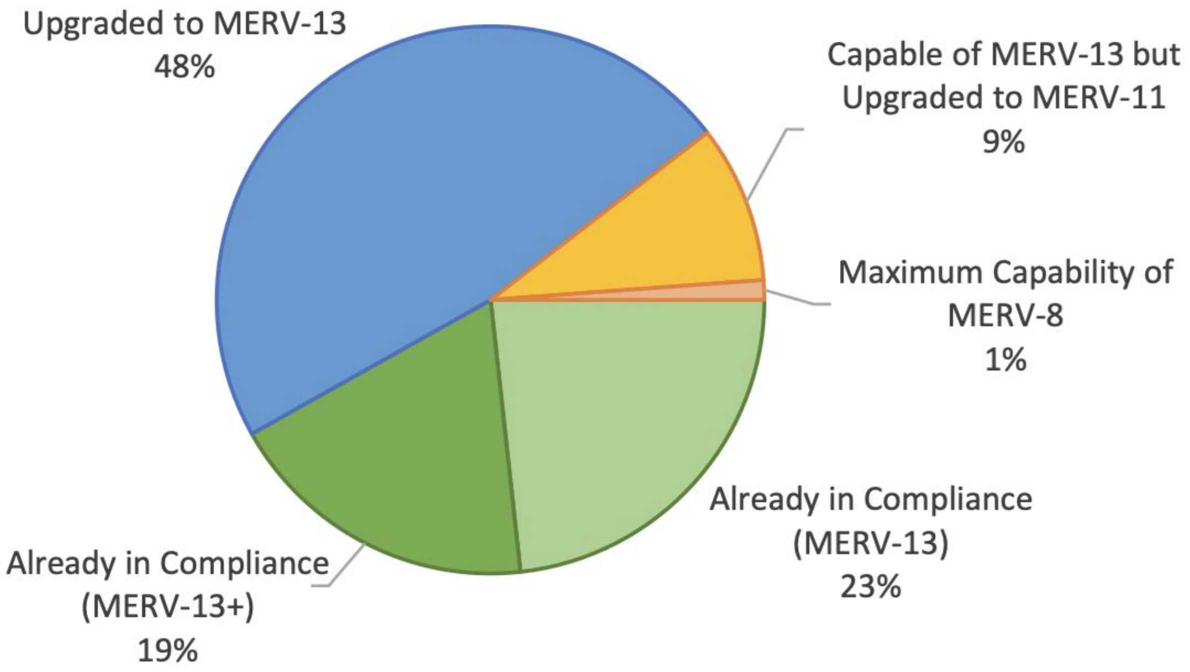
A higher MERV does not necessarily mean a higher pressure drop, and filtration efficiency can vary between products with the same MERV.





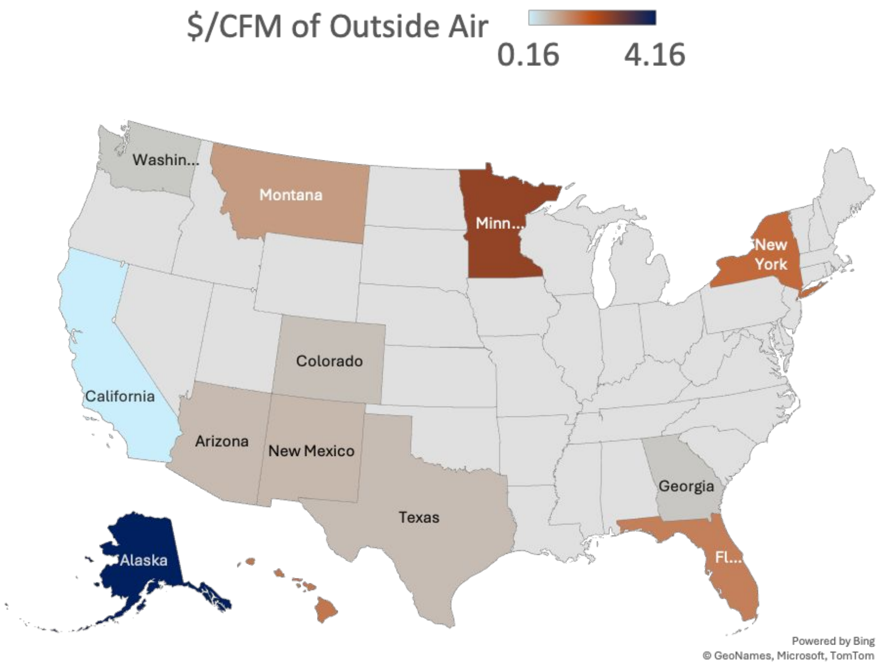
Ref: M. Zaatari presentation "HVAC Strategies in the Age of COVID". Data from M Zaatari, A Novoselac, J Siegel. The relationship between filter pressure drop, indoor air quality, and energy consumption in rooftop HVAC units. Building and Environment 73, 151-161.
Note: Infectious Aerosols Efficiency is based on ASHRAE Standard 241 with distribution of 30% for E1, 30% for E2, and 40% for E3:

Assessment of central filtration in 95 US commercial office buildings show that 99% of buildings could use MERV-13 filtration without any adverse performance issues.



Ref: Mcnulty, M. K.; Kono, J.; Abramson, B. From Guidance to Implementation: Applying ASHRAE Epidemic Task Force Building Readiness Strategies in 95 Commercial Office Buildings. ASHRAE Transactions, [s. l.], v. 128, n. 1, p. 393–401, 2022.

Increased outdoor air is more energy intensive than upgrading particulate filtration from lower efficiency (MERV 7) to higher efficiency (MERV 13).



Climate Zone	$/CFM of Outside Air	$/CFM Filtered Air MERV 13*	Blended Utility Rate $/kWh
1A	1.66	0.14	0.15
2A	1.55	0.16	0.14
2B	0.81	0.16	0.15
3A	0.65	0.16	0.14
3B	0.79	0.16	0.14
3C	0.16	0.32	0.28
4A	1.82	0.29	0.24
4B	0.84	0.18	0.15
4C	0.63	0.14	0.12
5A	3.25	0.34	0.28
5B	0.74	0.16	0.14
6A	2.63	0.21	0.16
6B	1.21	0.12	0.1
7A	2.98	0.21	0.16
8A	4.16	0.21	0.16

Zaatari, M, A. Goel, and J. Maser. 2023. ASHRAE J. 65(9):18-24.
*Modified to account for 77% MERV 13 efficiency.

Case Study - Office Building: Comply with ASHRAE Standard 62.1, 241, and Guideline 44P.

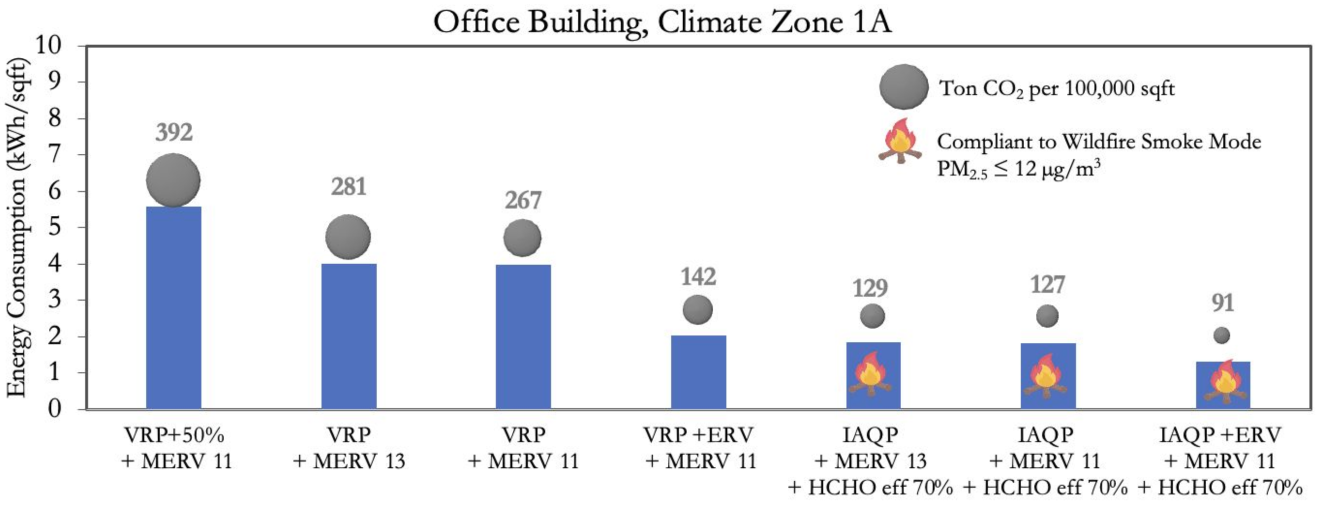
- We considered different ventilation design approaches that comply with ASHRAE 241 targets as well as the prerequisite ASHRAE Standards 62.1 in 5 space types.
- These design approaches include multiple "hybrid ventilation" strategies that combine filtration and air cleaning of recirculated indoor air with outside air.

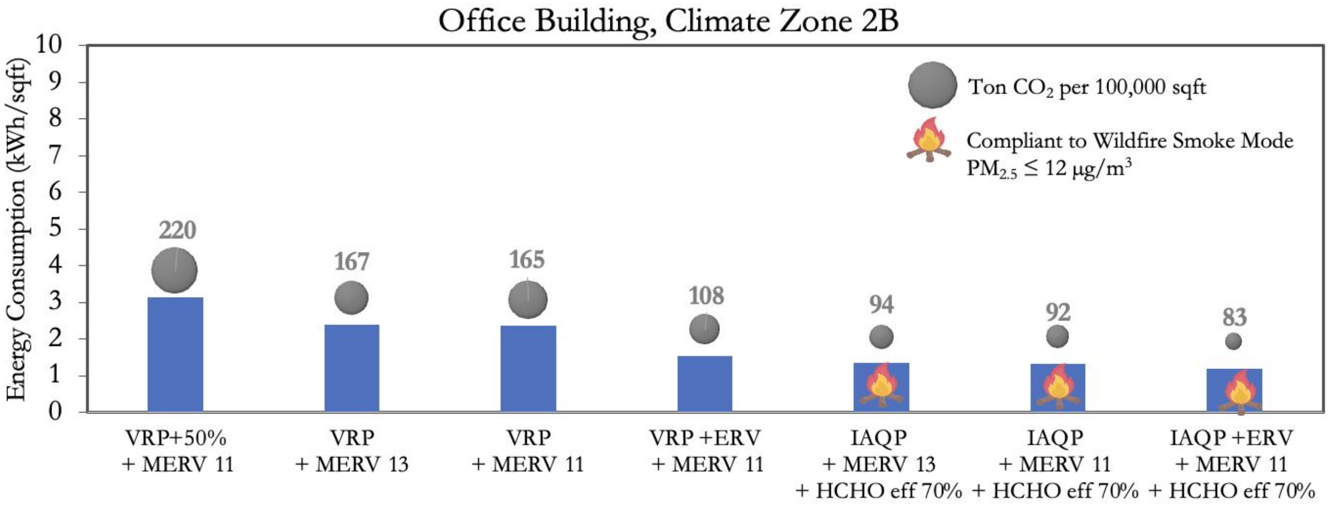
Prototype Building Type	Floor Area (ft^2)	Height (ft)	# Occupants	Annual Fan Hours
Office	10,764	11	50	3,120

Ventilation Strategies	• VRP • IAQP + gaseous air cleaning
Energy Savings Measure	• ERV
Filtration and Air Cleaning	• MERV 7,11,13 • HEPA • GUV

- To calculate energy impact of each scenario, we used a large-scale simulation of prototypical building energy models using the SCOUT software tool. The simulation consisted of 50 custom SCOUT Energy Conservation Measures (ECMs) and 210 unique OpenStudio/EnergyPlus "Commercial Prototype" models in 15 climate zones.

For office buildings, using IAQP + MERV 11/13 + formaldehyde air cleaning ensures compliance to ASHRAE Standards 62.1, 241, and Guideline 44P and saves operational energy.





Note:
- Outdoor concentration during wildfire = 150 ug/m3.
-All scenarios presented are compliant to Standard 241

Ref: Zaatari, M. Maser, J. ASHRAE Standard 241: Energy Implications of Different Strategies to Meet Equivalent Clean Air Requirements for Commercial and Educational Spaces. 2024 ASHRAE Winter Conference – Chicago.

Questions?

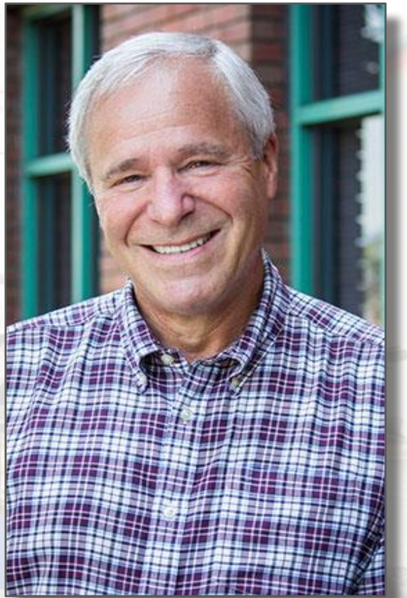
Lunch

12:00 - 1:00 pm

How do existing standards and guidelines help improve indoor air quality?

1:00 - 2:00 pm

Session Speakers



Bill Bahnfleth, PhD, PE
Pennsylvania State University
Professor of Architectural Engineering
Chair, ASHRAE Std 241 Committee

Seema Bhangar, PhD
US Green Building Council
Board member of the Indoor Air Institute

Whitney Austin Gray
PhD, LEED AP, WELL AP, Hon FASID
Well Building Institute

Steve Taylor, PE
Taylor Engineering
Principal

Marwa Zataari, PhD
DZine Partners
Vice-chair of USGBC Board of Directors

Audience Poll

Which of the following standards or guidelines address air quality (select all that apply)?

CATALYZING GLOBAL ADOPTION

WELL is the world's largest certification and ratings platform for healthy buildings

5.16B+
square feet

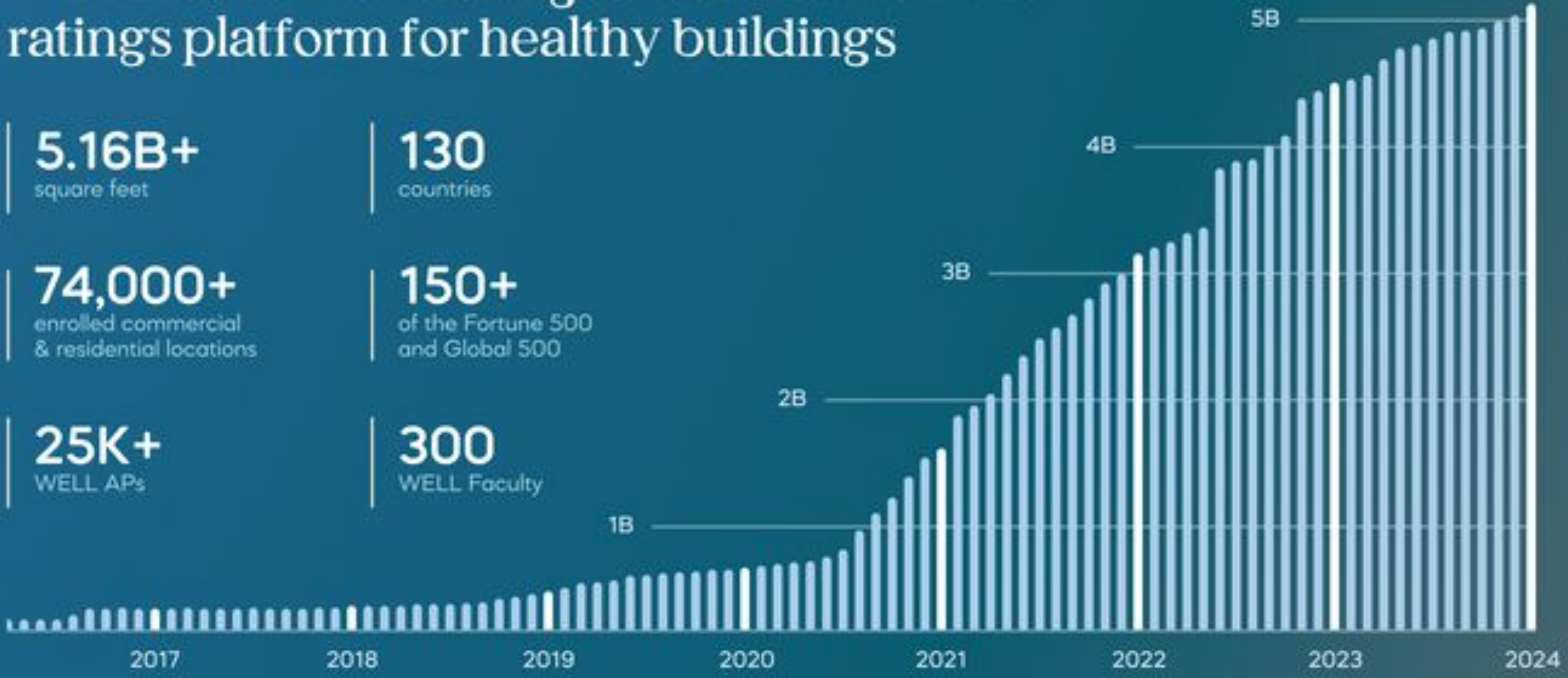
130
countries

74,000+
enrolled commercial & residential locations

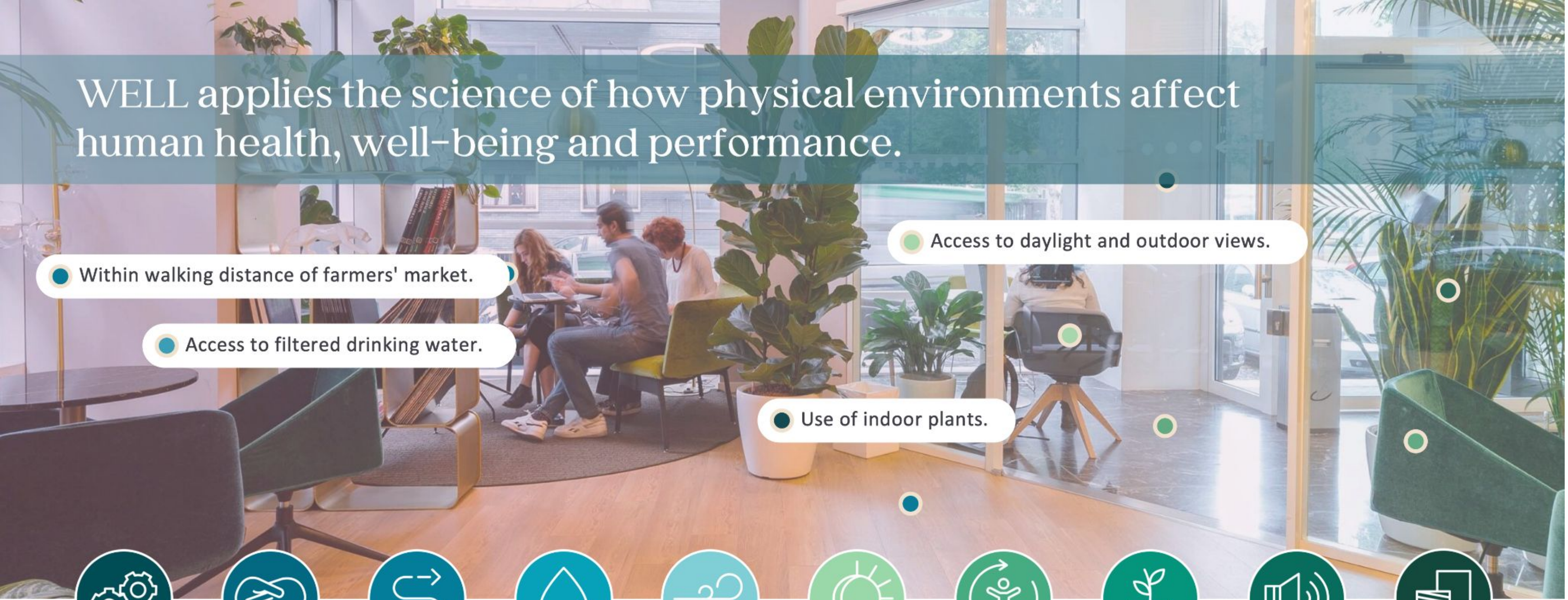
150+
of the Fortune 500 and Global 500

25K+
WELL APs

300
WELL Faculty



WELL applies the science of how physical environments affect human health, well-being and performance.



MIND | COMMUNITY | MOVEMENT | WATER | AIR | LIGHT | THERMAL COMFORT | NOURISHMENT | SOUND | MATERIALS

7,000+
peer-reviewed studies and citations

20,000+
industry leaders and practitioners

30,000+
locations enrolled

500+
evidence-based interventions

AIR

The WELL Air concept aims to achieve high levels of indoor air quality across a building's lifetime through diverse strategies that include **performance monitoring**, **source elimination or reduction**, **active and passive building design** and **operation strategies** and **human behavior interventions**.

- A01 Fundamental Air Quality*
- A02 Smoke-Free Environment*
- A03 Ventilation Effectiveness*
- A04 Construction Pollution Management*
- A07 Operable Windows
- A08 Air Quality Monitoring and Awareness

Table A.3
WELL performance verification results for required WELL features (preconditions) by company.

Parameter	WELL Feature	Measurement (unit)	Threshold	Company					
				A	B	C	D	E	F
Indoor Air Quality	01 Air Quality Standards	Formaldehyde (ppb)	<27	5.2–5.7	25	6–7	15.97–21.4	12–23	10.4–11
		TVOC ($\mu g/m^3$)	<500	190–260	340–460	240–330	450–460	130–370	23–38
		Carbon monoxide (ppm)	<9	0	0	0	0	0.1–0.8	0.4–0.6
		PM2.5 (ug/m3)	<15	1.5–2	0.2–0.23	1	0.2–0.6	3.68–5.49	4.7–5.4
		PM10 (ug/m3)	<50	2	5.64–7.87	1	7.4–14.6	12.49–37.04	18–30.7
		Ozone (ppb)	<51	0	0	2–3	0	0–7	<10
		Radon (pCi/L)	<4	N/A	N/A	N/A	N/A	<0.6 ± 0.2	N/A
Thermal Comfort	76 Thermal Comfort	Dry Bulb Temperature	ASHRAE 55-2013	70.2–72.9	73.7–75.2	72.5–76.3	–	72.1–73.5	–
		Mean Radiant Temperature	ASHRAE 55-2013	71.2–73.4	N/A	N/A	N/A	N/A	N/A
		Relative Humidity	ASHRAE 55-2013	61–62.4	37.4–39.5	17.3–22	–	49.8–59.1	–
Lighting	53 Visual Lighting Design	Average ambient light intensity (lux)	≥215	567	419	514	628	292	376
Acoustics	75 Internally Generated Noise[†'>†]	Open office spaces and lobbies noise criteria (NC)	≤40	35–48	38	40	37	36	35
		Enclosed offices noise criteria (NC)	≤35	N/A	29	30	17–36	23–36	35
		Conference and breakout rooms noise criteria (NC)	≤30	33–36	30–39	28	19–32	23–28	35–40

The impact of WELL

A new study published in *Building and Environment* found that occupants in WELL Certified spaces report **improved workplace satisfaction**, **increased levels of productivity** and **gains in perceived health and well-being**.

Research Spotlight

The WELL Factor: Understanding the Impact of WELL Certification

A new study in the *Journal of Building and Environment* finds WELL Certification boosts occupant perceived satisfaction, health, well-being and productivity

Brief Synopsis

In the largest and most comprehensive research of its kind, a newly published peer-reviewed study in the *Journal of Building and Environment* found that occupants in WELL Certified spaces report improved workplace satisfaction, increased levels of productivity and gains in their health and well-being. The study analyzed the impact of WELL Certification using more than 1,300 pre- and post-occupancy survey responses from six companies in North America with analyses conducted at both the aggregate and company level. Specifically, the study showed WELL Certification improved overall occupant satisfaction by nearly 30%, as well as occupant perceived well-being scores by 26%, reported mental health scores by 10% and productivity gains by 10 median points.

In the *Journal of Building and Environment*, September 2022

Title:

Impact of WELL Certification on Occupant Satisfaction and Perceived Health, Well-being, and Productivity: A Multi-Office Pre-Versus Post-Occupancy Evaluation

Authors:

Nasim Ildiri, University of Colorado Boulder
Heather Bazille, Cornell University
Yingli Lou, University of Colorado Boulder
Kathryn Hinkelman, Pennsylvania State University
Whitney A. Gray, International WELL Building Institute
Wangda Zuo, Pennsylvania State University and National Renewable Energy Laboratory

Key Findings

Using extensive pre- and post-occupancy survey data, the analysis was able to assess the impact of WELL Certification on the people inside a space when compared to their experiences before certification. The study comprehensively analyzed the impacts of WELL Certification on

30% ↗
in overall workplace satisfaction

10-point ↗
in reported productivity scores

26% ↗
in reported well-being scores

10% ↗
in overall mental health

Additional Sources

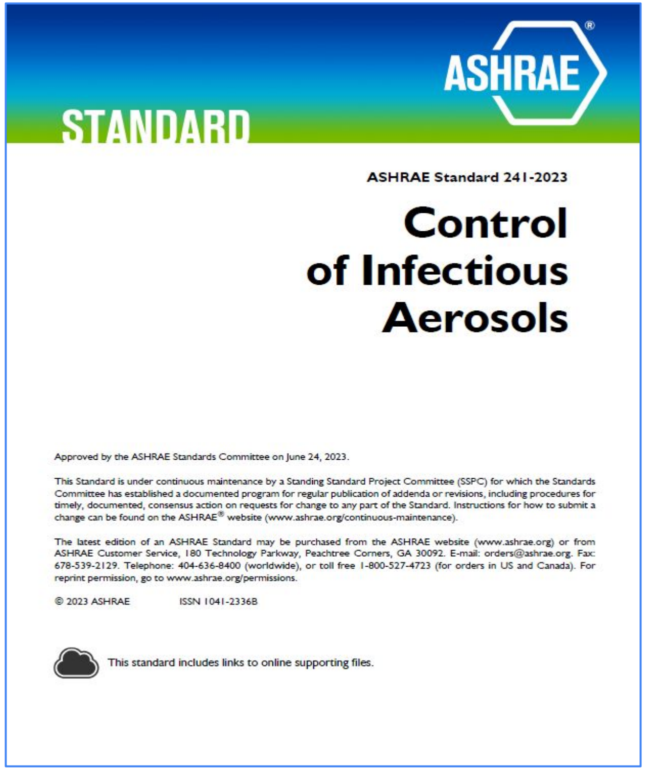
- WELL Forum
  - A digital forum that helps users convene with healthy building practitioners, earn CEUs, and accelerate WELL implementation
- Interface Case Study
  - A global leader in modular flooring
  - Headquartered in Atlanta, GA
  - Pre-occupancy utilization research was conducted by Perkins & Will’s Planning and Strategies practice to better understand how employees use the office
- Corvias WELL for Residential Pilot
  - Residential Pilot program launched with 25 global pilot participants
  - Transforms the way homes were designed
- Healthy Building Accord
  - This groundbreaking initiative seeks to redefine the future of our built environment, emphasizing the critical role of health in building design, construction and operations

How ASHRAE Standard 241 Supports Improved IAQ

William Bahnfleth, PhD, PE
Penn State/ASHRAE

ASHRAE Standard 241-2023 Control of Infectious Aerosols

- Prerequisite minimum IAQ compliance
- Equivalent clean air requirements for infection control
- Air cleaning system testing
- Retro-commissioning of systems
- Maintenance requirements
- Building Readiness Plan
- Potentially a model for improvement of other standards


STANDARD

ASHRAE

ASHRAE Standard 241-2023

Control of Infectious Aerosols

Approved by the ASHRAE Standards Committee on June 24, 2023.

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).

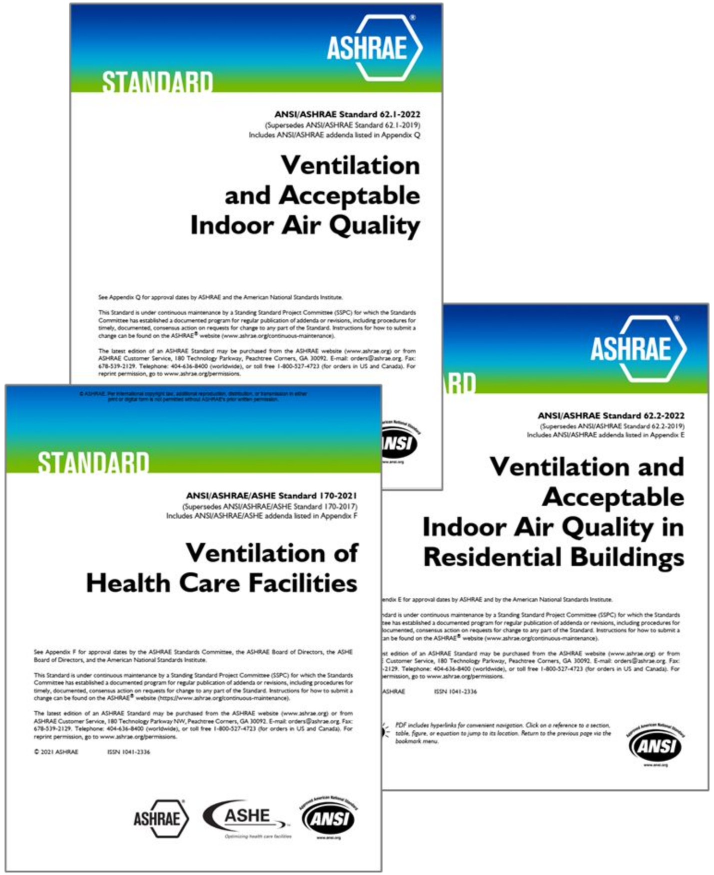
The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 180 Technology Parkway, Peachtree Corners, GA 30092. E-mail: orders@ashrae.org. Fax: 678-539-2129. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

 ISSN 1041-2336B

This standard includes links to online supporting files.

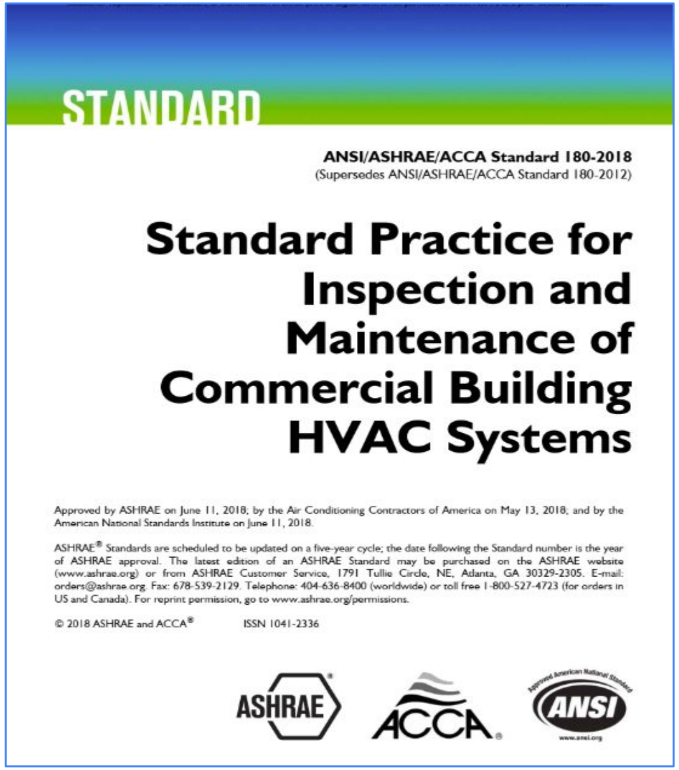
Prerequisites

- Standard 241 only addresses infection risk
- Must comply with version of ASHRAE 62.1, 62.2, 170 or other standard approved by the authority having jurisdiction based on occupancy and date of construction/major renovation
- Prerequisite standards set minimum requirements of outdoor air and filtration for normal operation
- IAQP may be the compliance path for 62.1



Maintenance

- Standard 241 references Standard 180
- Ventilation-specific requirements based on ASHRAE Standard 62.1, with increased minimum frequency
- New requirements
    - General
    - In-room air cleaners
    - Germicidal UV systems
    - Separation spaces


STANDARD

ANSI/ASHRAE/ACCA Standard 180-2018
(Supersedes ANSI/ASHRAE/ACCA Standard 180-2012)

Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems

Approved by ASHRAE on June 11, 2018; by the Air Conditioning Contractors of America on May 13, 2018; and by the American National Standards Institute on June 11, 2018.

ASHRAE® Standards are scheduled to be updated on a five-year cycle; the date following the Standard number is the year of ASHRAE approval. The latest edition of an ASHRAE Standard may be purchased on the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 678-539-2129. Telephone: 404-636-8400 (worldwide) or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

© 2018 ASHRAE and ACCA®   ISSN 1041-2336

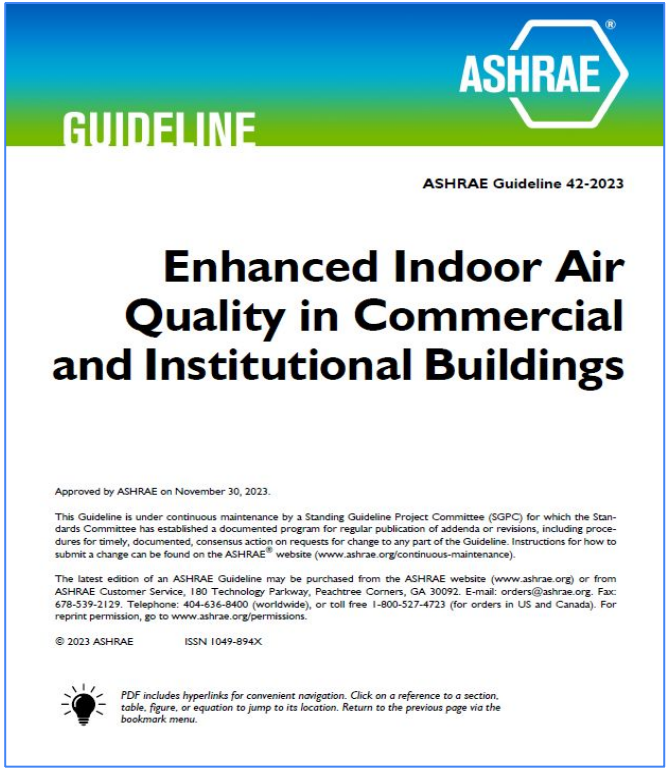
ASHRAE ACCA ANSI

ASHRAE Guideline 42

- Not referenced in Standard 241-2023

  (M)easures that exceed minimum requirements for improving indoor air quality (IAQ) in commercial and institutional buildings. These measures are intended to provide enhanced IAQ that is acceptable to human occupants and that minimizes adverse health effects.

- “Beyond 62.1”


GUIDELINE

ASHRAE

ASHRAE Guideline 42-2023

Enhanced Indoor Air Quality in Commercial and Institutional Buildings

Approved by ASHRAE on November 30, 2023.

This Guideline is under continuous maintenance by a Standing Guideline Project Committee (SGPC) 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 Guideline. Instructions for how to submit a change can be found on the ASHRAE® website (www.ashrae.org/continuous-maintenance).

The latest edition of an ASHRAE Guideline may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 180 Technology Parkway, Peachtree Corners, GA 30092. E-mail: orders@ashrae.org. Fax: 678-539-2129. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

© 2023 ASHRAE ISSN 1049-894X

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.

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

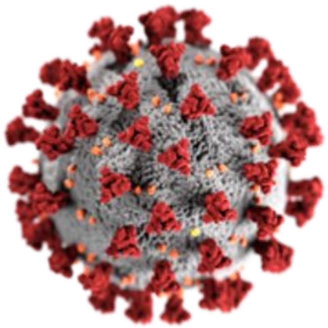
ASHRAE's Evolving Vision

Marwa Zaatari, PhD
DZine Partners Inc

The new IAQ paradigm shift is a holistic approach. It intertwines wellness with resilience and sustainability.

Health and Wellness

Resilience



Sustainability & Decarbonization

Ref: Slide is courtesy of Bill Bahnfleth

The new IAQ paradigm is a holistic approach. It intertwines wellness with resilience and sustainability. New and updated standards/guidelines will help us implement this vision.

- Minimum requirements for normal operation
  - ANSI/ASHRAE Standard 62.1-2022 *Ventilation and Indoor Air Quality – Indoor Air Quality Procedure*

High IAQ

- IAQ resilience – requirements during periods of elevated risk
  - ASHRAE Standard 241-2023 *Control of Infectious Aerosols*

IRMM

- IAQ resilience – smoke exposure mitigation during wildfires
  - ASHRAE Guideline 44P *Protecting Building Occupants from Smoke During Wildfire and Prescribed Burn Events*

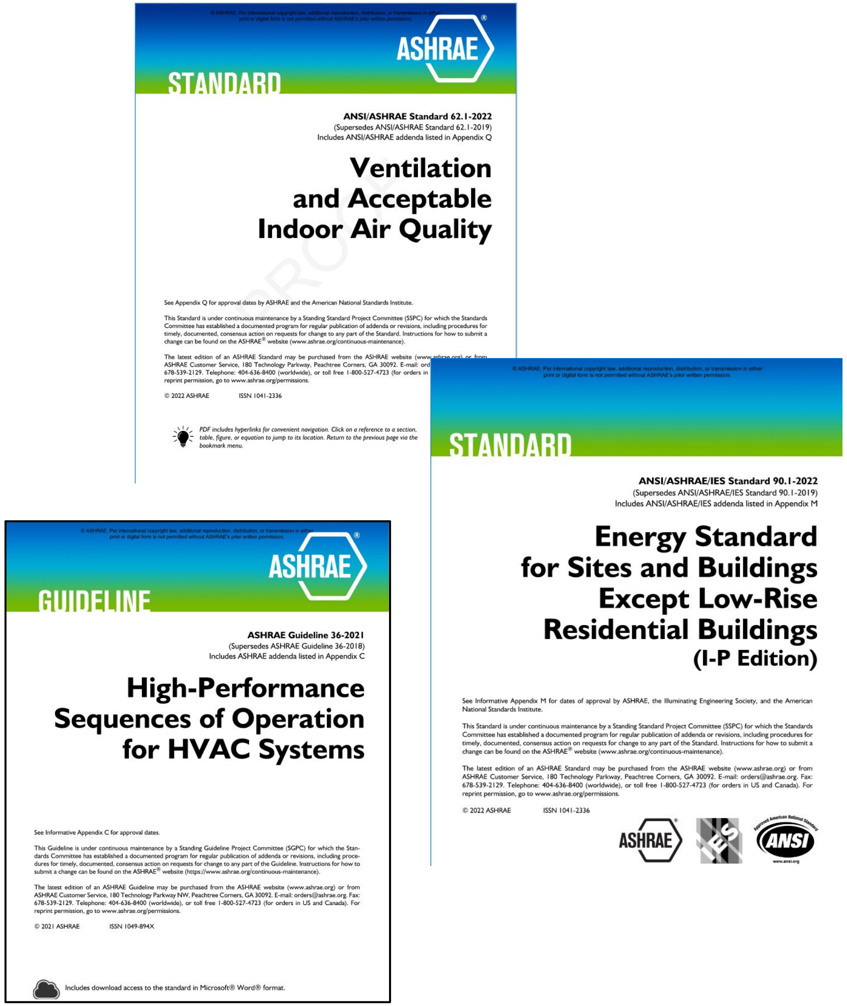
WFSM

Balancing Energy and IAQ

Steve Taylor, PE
Taylor Engineering

ASHRAE Standards & Guidelines and Commercial Building IAQ

- ASHRAE Standard 62.1 Ventilation and Acceptable Indoor Air Quality
- ASHRAE Standard 90.1 Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings
- Guideline 36 High Performance Sequences of Operation for HVAC Systems
- ASHRAE Standard 241 Control of Infectious Aerosols



Standard 62.1 Ventilation

- Rates for ~90 non-residential occupancy types
  - Intended to be “code minimum” for acceptable indoor air quality
  - Mitigate pollutant emissions from usually expected indoor sources
  - Rates do not address disease transmission
  - Rates do not consider productivity impact
- Allows demand-controlled ventilation (DCV)
  - CO_2 high limits range from 1000 ppm to 2500 ppm (assuming 400 ppm ambient)
- Allows occupied standby for most occupancy types
  - Ventilation may be shut off if occupancy sensor indicates space is unoccupied even if scheduled to be occupied
- Requires dynamic outdoor air control (e.g. AFMS and dampers) for VAV systems
  - Fixed damper positions do not work

Standard 90.1 Energy

- Only indirectly addresses indoor air quality to minimize energy impact
- Prescriptively limits outdoor air to no more than 30% above 62.1
  - Based on LEED credit for increased ventilation
    - Also WELL credit and ASHRAE Guideline 42 recommendation
  - Limit also specifically applies to Standard 170 and 241 compliance
    - Any added “equivalent” ventilation must be from cleaned recirculated air, UV etc.
- Limits VAV box deadband minimum to 30% above 62.1 Simplified Procedure minimum
- Requires DCV for densely occupied spaces
  - CO2 limits must be initially configured to 62.1 limits to maximize energy savings
- Requires occupied standby where an occupancy sensor is required for lighting
- Requires exhaust air energy recovery depending on outdoor air rate and climate zone

Guideline 36 Control Sequences

- Sequences fully comply with all 90.1 and 62.1 prescriptive requirements
  - When 62.1 and 90.1 addenda are published, G36 immediately develops a matching addendum
- Sequences dynamically determine ventilation rate using
  - Occupancy schedules
  - Occupancy sensors
  - CO2 sensors (DCV)
  - Diffuser supply air temperature (adjusts distribution effectiveness)
  - Window switches
- Used to reset both zone VAV box minimums and AHU outdoor air minimums
  - Ensures 62.1 compliance at lowest energy costs

Questions?

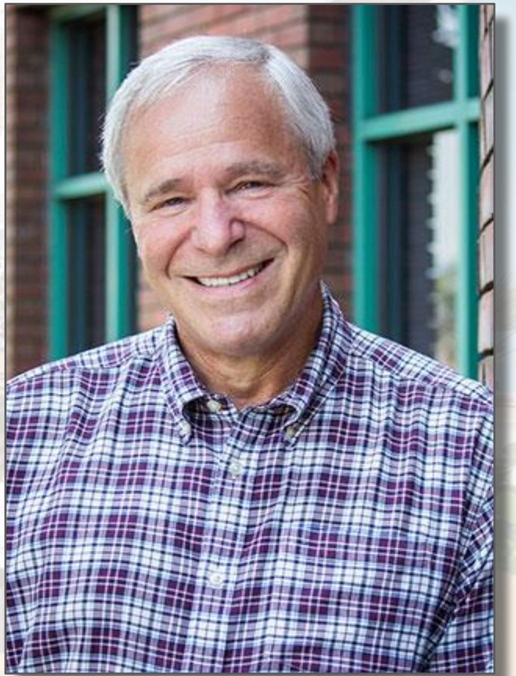
GSA’s efforts to enhance operations and maintenance

2:00 - 3:00 pm

Session Speakers

Brian Gilligan, PE
US General Services Administration
Acting Director,
Office of Federal High-Performance Green Buildings

Mark Kutchi, PE
U.S. General Services Administration
Mechanical Engineer
Office of Architecture and Engineering



Steve Taylor, PE
Principal
Taylor Engineering

Martin Weiland, PE
U.S. General Services Administration
Chief Engineer
Office of Facilities Management

Audience Poll

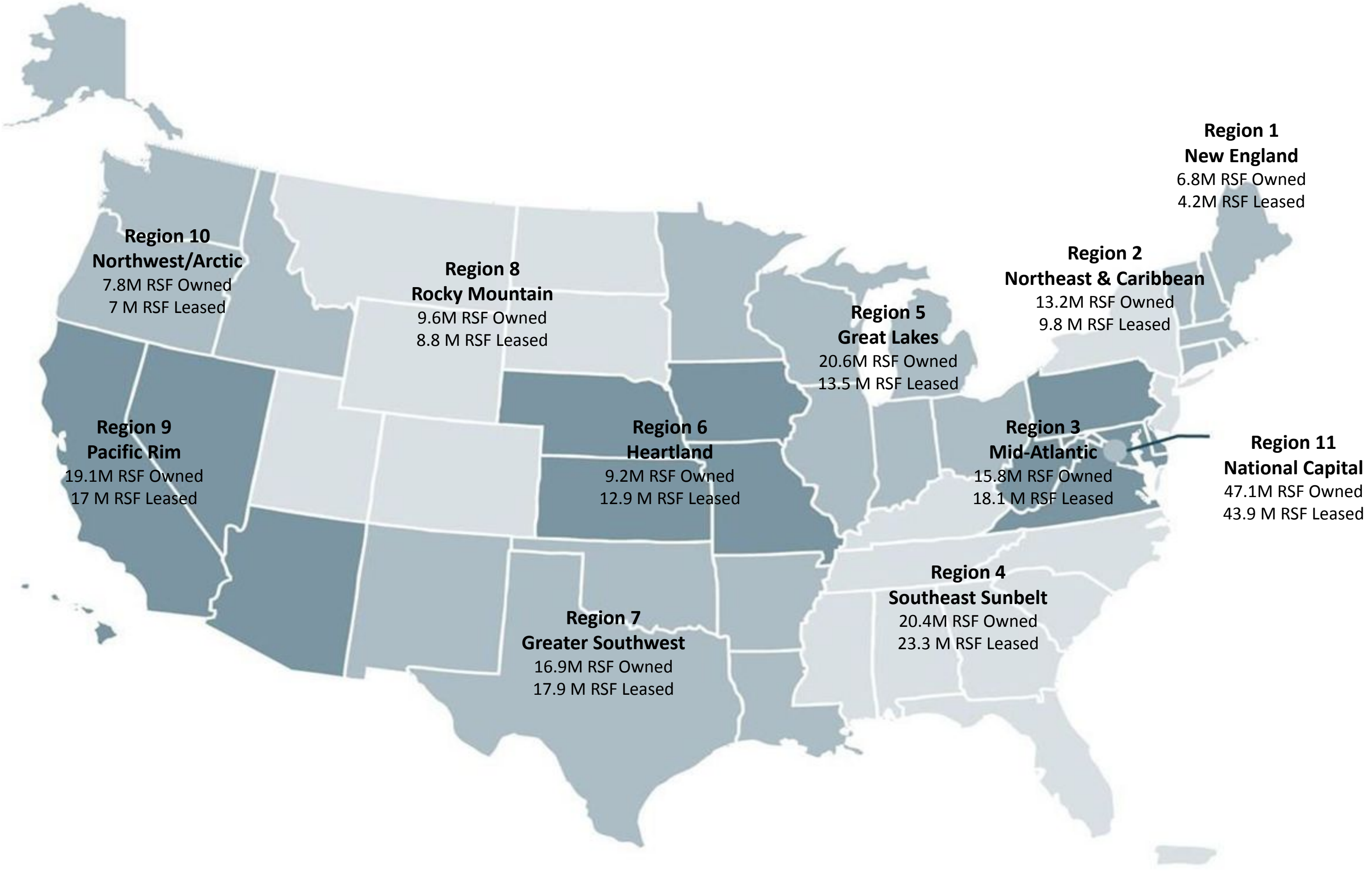
How often is testing and balancing of HVAC systems required in ASHRAE 62.1?

GSA's Portfolio - What do we manage?

- 370 Million rentable square feet
  - 190M in 1600+ federally-owned assets
  - 170M in 6500+ leased assets
- Housing 1.1 Million federal employees
- 168 Smart Buildings on GSALink
- Active Research Programs:
  - GSA's Green Proving Ground
  - Office of Federal High-Performance Green Buildings - Wellbuilt for Wellbeing

Facility Type	*Total SF (Millions)*
Office	103.6
Courthouse	64.3
Warehouse	7.1
Land Port of Entry	4.8
Laboratory	1.7
Public Facing Facility	0.9
Child Care Center*	0.2
Parking	0.2
Other	3.9

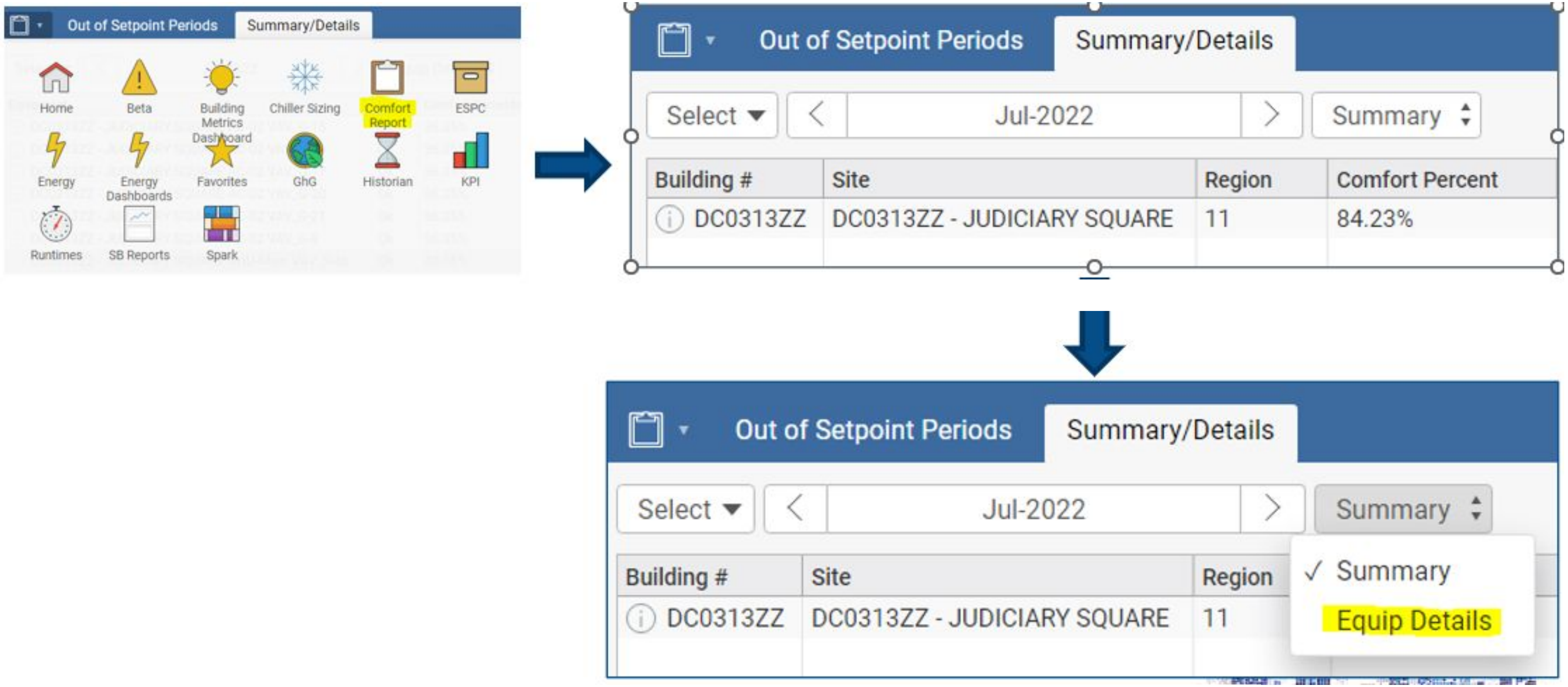
GSA's Portfolio - Where are we located?



Thermal Comfort KPI for Smart Buildings

- **Goal:**
  - Reduce the number of occupied hours in which building spaces deviate from the desired temperature set point
- **Measure:**
  - Amount of time within 2°F of cooling/heating setpoints (3°F of a tolerance limit) during normal, occupied hours
- **Criteria:**
  - Quarterly reporting

Thermal Comfort KPI - GSAlink allows drill down to zone level



Thermal Comfort KPI - GSAlink allows drill down to zone level

Out of Setpoint Periods | Summary/Details

Select | Jul-2022 | Equip Details

Equipment	Va...	Comfort Percentage	View Sparks	Zone Temp Average	Z...	Occupied Heat Sp Average	Occupied Cool Sp Average
DC0313ZZ - JUDICIARY SQUARE AC-02 VAV_G-15	Ok	36.35%	Link	81.18°F	0	72.0°F	74.0°F
JARE AC-02 VAV_G-16	Ok	36.35%	Link	78.72°F	0	72.0°F	74.0°F
JARE AC-02 VAV_G-17	Ok	36.35%	Link	80.35°F	0	72.0°F	74.0°F
JARE AC-02 VAV_G-20	Ok	36.35%	Link	85.52°F	0	72.0°F	74.0°F
JARE AC-02 VAV_G-21	Ok	36.35%	Link	81.65°F	0	72.0°F	74.0°F
JARE AC-02 VAV_G-8	Ok	36.35%	Link	80.94°F	0	72.0°F	74.0°F
JARE AHU-Main VAV_3-46	Ok	40.16%	Link	66.06°F	0	72.0°F	74.0°F
JARE AHU-Main VAV_8-40	Ok	40.16%	Link	65.8°F	0	72.0°F	74.0°F
JARE AHU-Main VAV_8-37	Ok	41.51%	Link	66.47°F	0	72.0°F	74.0°F
JARE AHU-Main VAV_7-40	Ok	44.01%	Link	67.52°F	0	72.0°F	74.0°F
JARE AHU-Main VAV_6-49	Ok	45.52%	Link	68.09°F	0	72.0°F	74.0°F
JARE AHU-Main VAV_7-10	Ok	46.35%	Link	68.73°F	0	72.0°F	74.0°F
JARE AHU-Main VAV_7-15	Ok	46.41%	Link	68.91°F	0	72.0°F	75.0°F

Possible KPI for Air Quality: CO2 and particulates

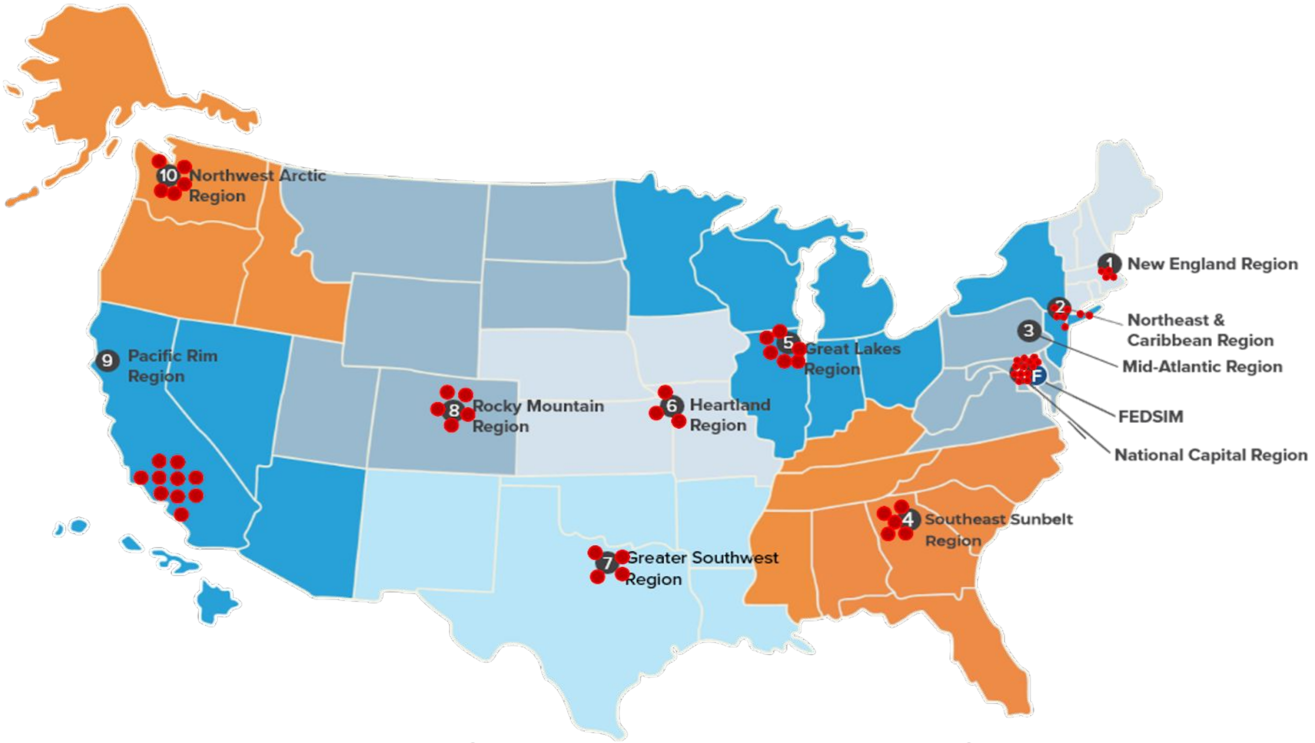
- **Goal (under consideration):**
  - Reduce the number of occupied hours key building spaces deviate from thresholds for CO2 (600 ppm) and Particulate Matter (12 mg/M3)
  - Manage average peak CO2 in small, highly occupied spaces (i.e. conference rooms, focus rooms, etc.) below targets in ASHRAE 62.1
- **Measure:**
  - The amount of time a space is below optimal thresholds
  - Average peak values for CO2 conditions are below max thresholds
- **Criteria:**
  - Quarterly reporting

ASHRAE Guideline 36 Pilot

Piloting Guideline 36 (G36) as an ECM on Existing Buildings

- 17 buildings selected in 3 Regions - Pacific Rim, Heartland, Mid-Atlantic
- Developing methodology to select existing buildings likely to succeed using G36 as an ECM
- Teasing out only the direct savings from G36 apart from associated equipment improvements
- For IAQ, the hopes are for:
  - Better control of air flows, IAQ, monitoring of IAQ and air handling operations
  - Spend a little of the saved energy on more ventilation

Condition Assessments: Ventilation Verification Program



Phase 1: Evaluated 1756 air handling units in 62 buildings

Key data collected at each AHU

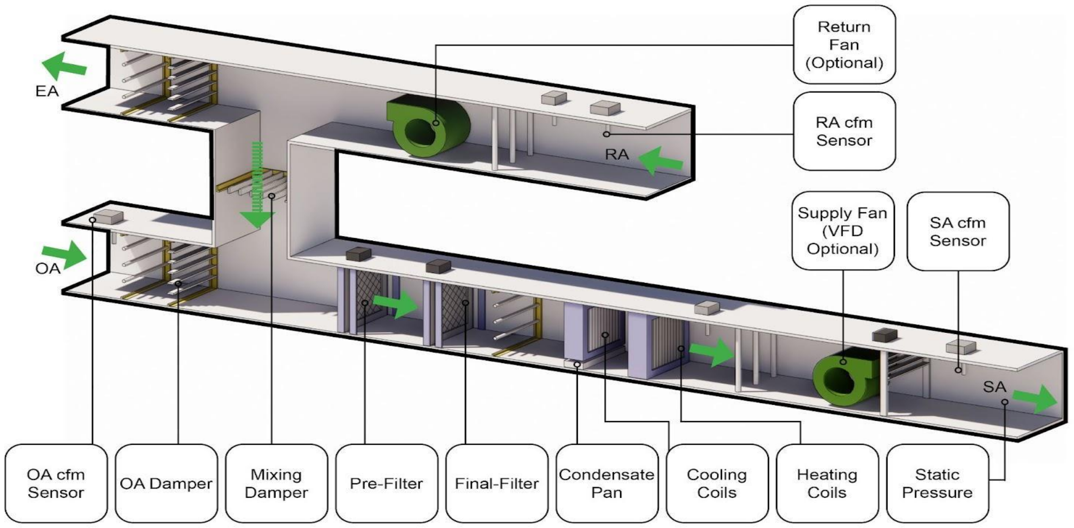
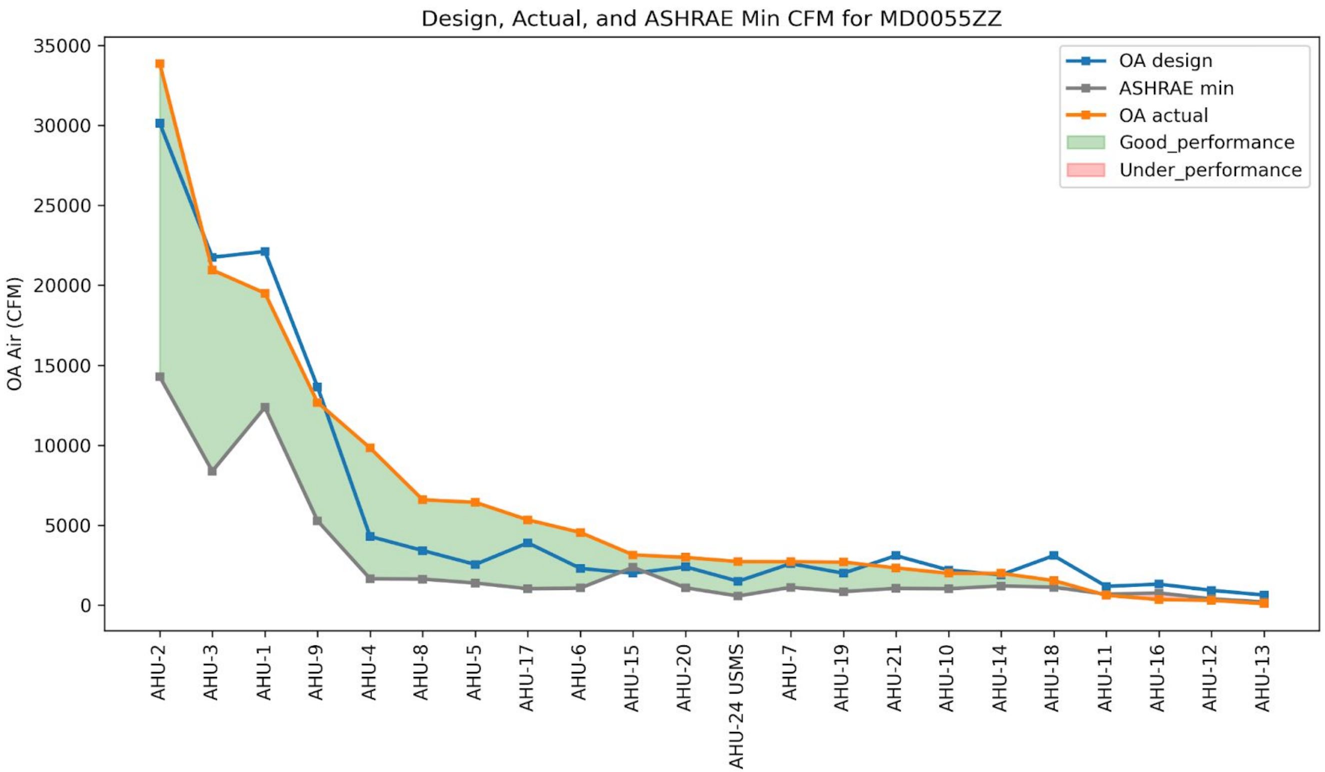


Figure 3.1 Field data records for 1756 AHU in 62 buildings

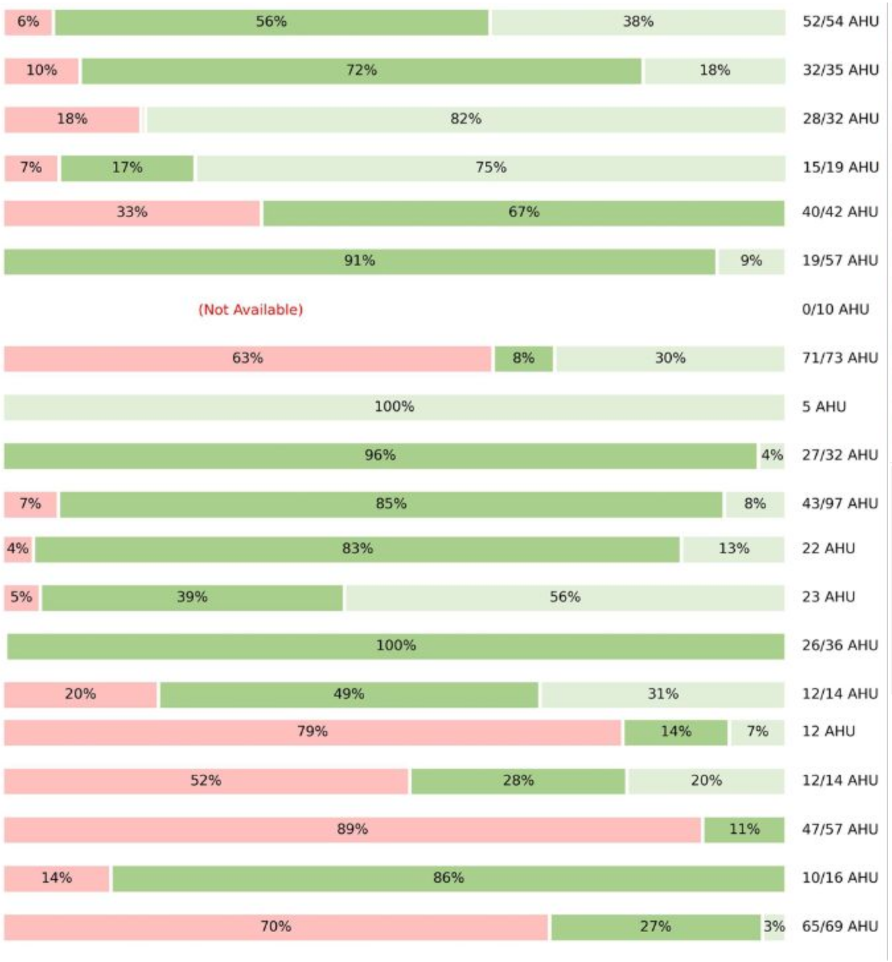
1. **Outdoor Air (OA) minimums**: Measured vs. Initial Design and Field-Calculated ASHRAE Default
2. **OA intensity**: calculated cfm/sqft served
3. **OA Damper** condition/position (min and max)
4. **Filter type/condition** (pre-filter and final filter)
5. **Coil and condensate pan** condition
6. **Supply 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

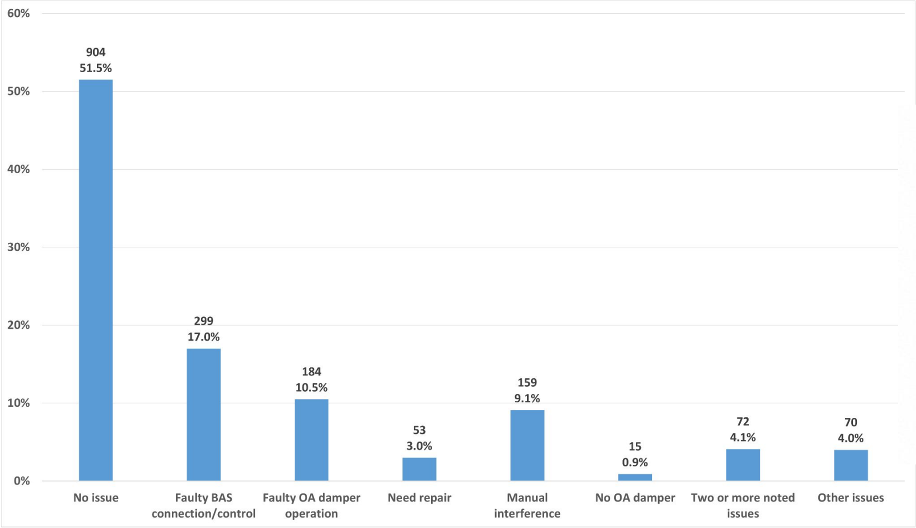
Measured Outdoor Air vs. thresholds: a new dashboard



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

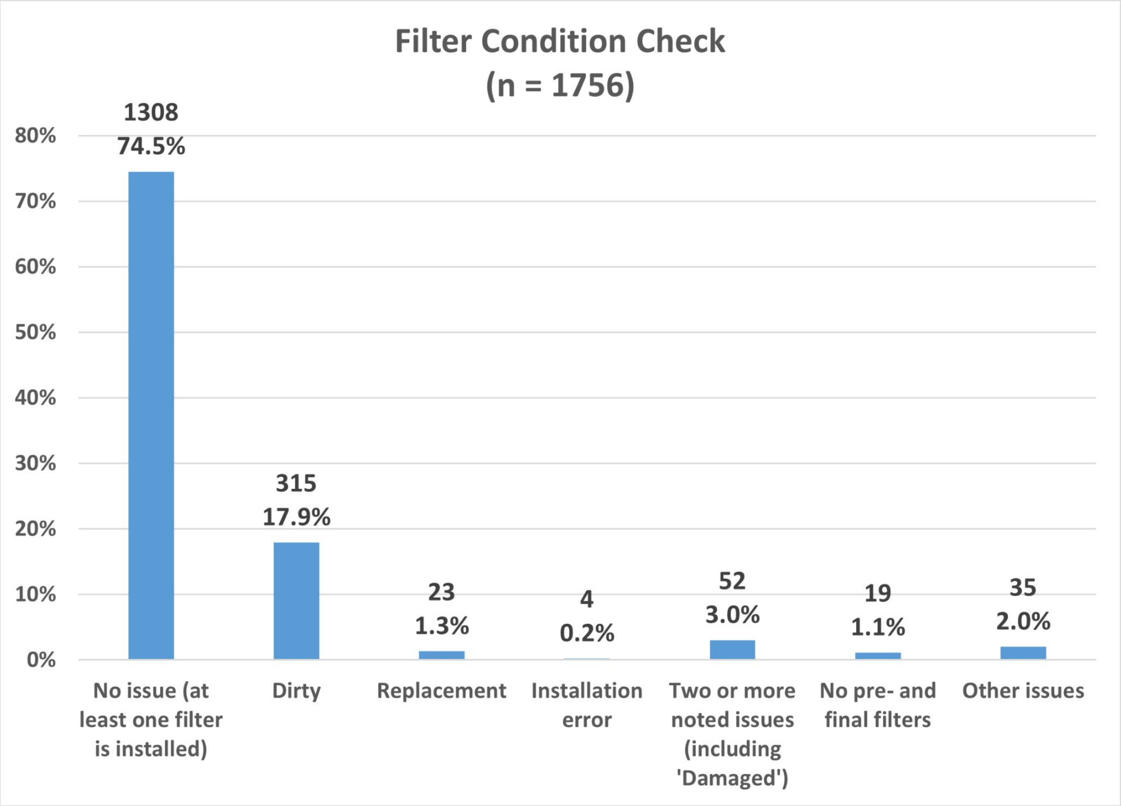
- **Below field-calculated ASHRAE min OA**
- **Above field-calculated ASHRAE min OA**

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

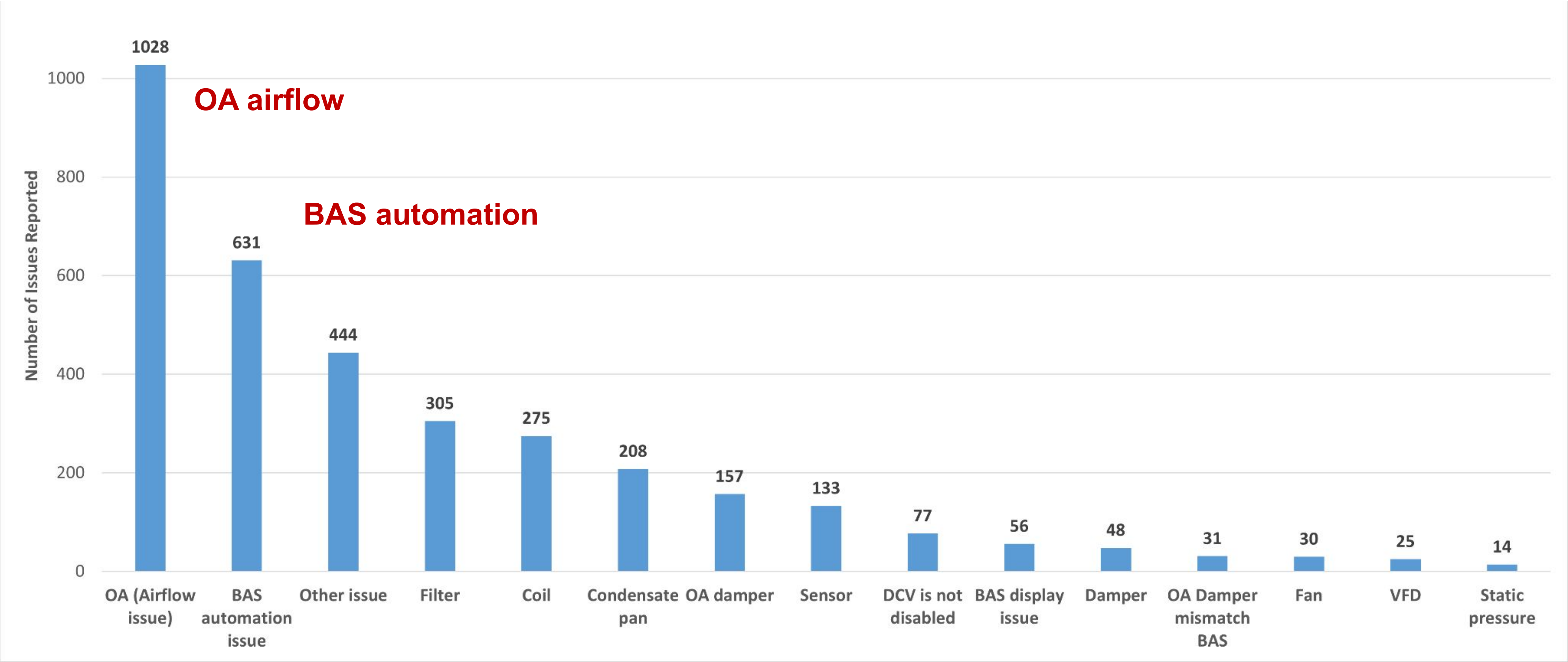
Pre/Final filter condition, MERV Rating



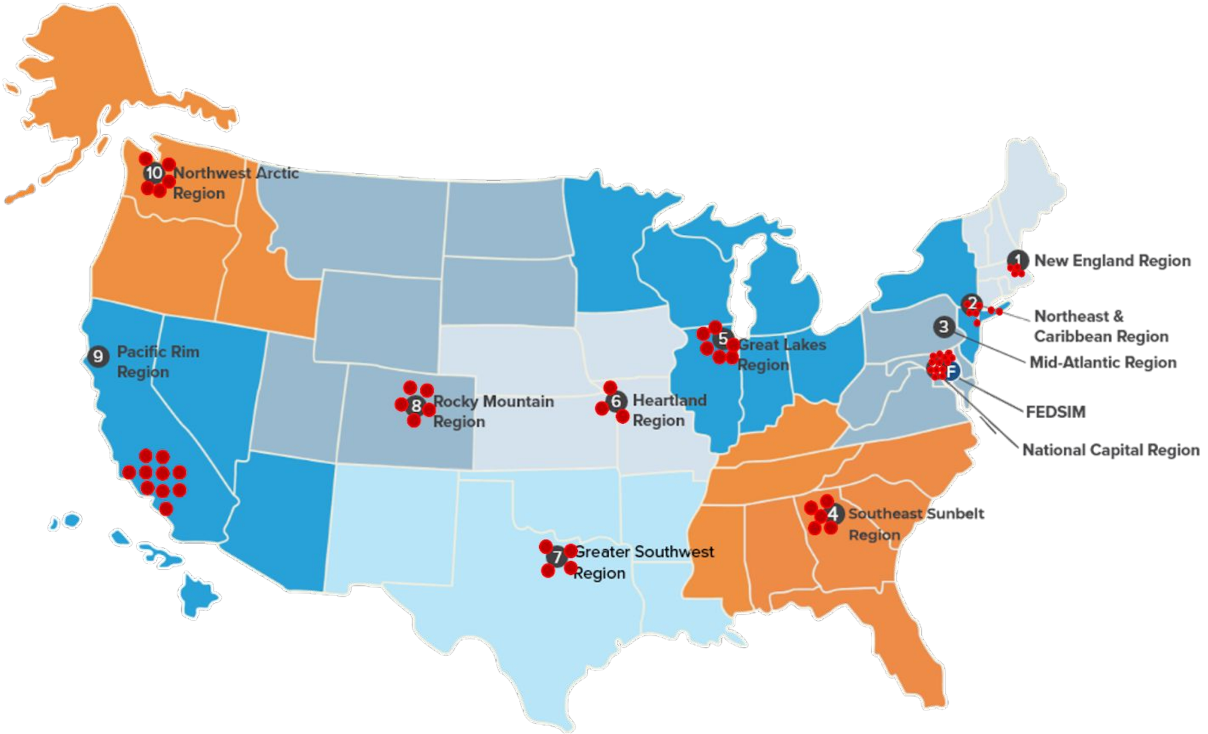
GSA has been a leader in moving to MERV 13 or higher, replacing over 65% of the filters.

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

Issues identified across all 62 buildings



Condition Assessment: Ventilation Verification Program



Phase 2: Test and Balance 78 buildings to Air Handling Unit (9 to the diffuser)

Ventilation Verification Program Phase 1

Objective

Assessment of the building's HVAC system to determine the air handling units quantity of outdoor air ventilation

Scope of Work

Ventilation Verification contractor:

- Download and review existing building documentation
- HVAC system assessment using ASHRAE 62.1-2019, section 8 Operation and Maintenance inspection tasks
- Measure air handling unit minimum outdoor air ventilation and provide a report
- Functional performance test of the AHU minimum outdoor air system (dampers, operators, controllers, etc.)
- No ASHRAE 62.1 ventilation calculations

Ventilation Verification Program Phase 2

Objective

Assessment of the building's HVAC system to determine whether the building's air handling units and the airflow distribution system meet the ASHRAE 62.1-2022 (or the version that was active when the system was designed/installed) Ventilation Rate Procedure (VRP) minimum outdoor air requirements.

Scope of Work

Ventilation Verification contractor:

- Download and review existing building documentation
- Provide an HVAC system assessment
    - HVAC Assessment Field Checklist
    - HVAC Assessment Data Forms
- Identify deficiencies that prevent measurement and balancing the HVAC system OA intake airflow and ventilation zone airflow to meet minimum OA requirements
- Provide testing, adjusting and balancing (TAB) of the HVAC system outdoor air intake and ventilation zone airflow to meet the ASHRAE 62.1 VRP minimum OA airflow requirements
- Provide a TAB report

Ventilation Verification Program Phase 2

Scope of Work

Ventilation Verification contractor:

- Registered professional mechanical engineer:
  - Provide ASHRAE 62.1 VRP ventilation calculations
  - Provide an engineering review of the HVAC system assessment report
  - Provide an engineering review of the testing, adjusting and balancing report

Ventilation Verification Program Phase 2

HVAC Assessment Tools

- HVAC Assessment Field Checklist, Link
  - Developed by CMU after review of the VVP Phase 1, HVAC Assessment Reports and TAB Reports

- HVAC Assessment Data Forms, Link
  - Developed by GSA using NEMI, National Energy Management Institute Ventilation Verification sample methods of procedure and data collection forms
    - https://www.nemionline.org/ventilation-verification/

ASHRAE Standard 241 Feasibility Study

Peter V. Domenici U.S. Federal Courthouse
Albuquerque, NM

ASHRAE Standard 241 Feasibility Study

Objective

Add ASHRAE Standard 241-2023 Control of Infectious Aerosols requirements and an evaluation of Standard 241 Equivalent Clean Airflow alternatives to the VVP Phase 2 SOW

Scope of Work additions

- Evaluation of Standard 241 Equivalent Clean Airflow alternatives including;
  - Cost estimates
  - Energy modeling
- Standard 241 requirements:
  - Equivalent Clean Airflow Rate calculations
  - Building Readiness Plan (BRP) report
  - Additional HVAC assessment requirements not included in the VVP Phase 2 SOW

ASHRAE 241 Compliance logic

- Calculate VECAi-target for each room and zone with design occupancy
- Calculate existing zone VECAi-actual based on
  - Existing AHU filter MERV
  - Fan-powered box supply air rate and its filter MERV
  - Minimum primary airflow at zone (after ventilation assessment)
  - Minimum outdoor air at AHU (after ventilation assessment)
- Determine VECAi-target at reduced occupancy
  - At least low enough people can be spaced more than 6 feet apart to handle shirt-range
  - Determine lowest density that would allow VECAi-actual to meet target. Is that acceptable to GSA?
- Estimate if IRMM will be
  - Short term (e.g. months): keep first costs low and don't worry about energy impact
  - or Long term (year+): find low energy impact options

If IRMM is expected to be short term

- First, improve filtration (since it’s inexpensive):
  - Increase AHU filter to MERV-13A
- If VECAi still not met:
  - Increase zone primary air minimum setpoints to max out capacity
  - Verify zone coil and plant capacity through calc’s
- If VECAi still not met:
  - Increase AHU outdoor air minimum to max out capacity
  - Verify zone coil and plant capacity through calc’s
- If VECAi still not met:
  - Add portable air cleaners to meet remainder of VECAi

If IRMM is expected to be long term

- First, improve filtration:
  - Increase AHU filter to MERV-13A if minimum 4” depth available
  - Then test AHU filter to MERV 15A if minimum 15” depth available
  - Then test increasing fan-powered box filter to MERV-10 or whatever they can handle
- If VECAi still not met:
  - Increase zone primary air minimum but no greater than 30% above 62.1 rate
    - Verify capacity through calc’s if above original design
    - May already be done as part of ventilation assessment
  - Then increase AHU outdoor air minimum but no greater than 30% above 62.1 rate
    - Verify capacity through calc’s if above original design
    - May already be done as part of ventilation assessment
- If VECAi still not met:
  - Add portable air cleaners to meet remainder of VECAi

Questions?

Break

3:00 - 3:15 pm

What opportunities are you considering to advance IAQ in buildings?

3:15 - 4:15 pm

Session Speakers

Seema Bhangar, PhD
US Green Buildings Council
Board member of the
Indoor Air Institute

Whitney Austin Gray, PhD
PhD, LEED AP, WELL AP, Hon FASID
The International WELL Building
Institute

Wyatt Merrill, PhD
US Department of Energy
Building Technologies Office

Vincent Rizzo, PE
US Veterans'
Administration

Liz York, FAIA
U.S. General Services
Administration

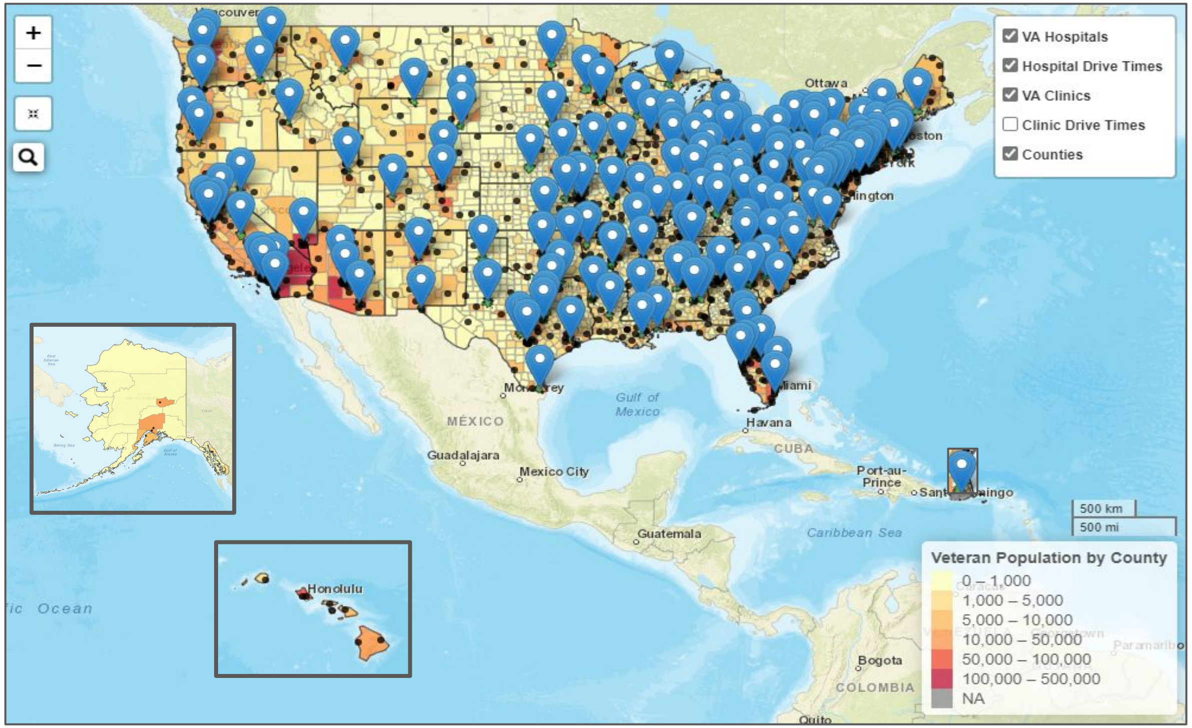
Some questions for discussion

- *Is improving the health of your building occupants high on your priorities?*
- *Are occupants asking for improved ventilation and infection risk protection?*
- *How will your organization address the next pandemic, wildfire?*
- *Is your organization considering piloting new initiatives or strategies?*
- *What would you want to get out of a HiBR partnership?*

Veterans Health Administration

Vincent Rizzo PE
Director
Office of Healthcare Engineering
Veterans Health Administration, Department of Veterans Affairs

- **VHA is within the U.S. Department of Veterans Affairs**
  - Provides health care to America's Veterans
  - Largest integrated healthcare system in the U.S. (over 9 million enrollees)
- **Over 1,200 sites of care, including:**
  - 171 VA medical facilities
  - 134 Community Living Centers (Long term care)
  - 48 Residential rehabilitation facilities
  - 1,113 Outpatient clinics and ambulatory surgical centers
  - 154 million square feet of VHA owned space.



https://www.aei.org/multimedia/va-mission-act-access-map/
Accessed June 2023

- All Healthcare facilities are required at a minimum to comply with industry standards for indoor air quality (e.g., ASHRAE 170 requirements).
    - VHA has established stringent indoor air quality requirements that meet or exceed industry standard.
    - Updated VA HVAC Design Manual (since 2020) incorporated enhanced air filtration and increased coverage for emergency epidemic operations, which has been included since 2008.
- Healthcare industry prioritizes occupant safety programs.
    - Infection Prevention and Control teams at every VHA Medical Center that prioritize patient safety, including coordination with multiple aspects of VHA facility operations.
    - Industrial Hygienist position at every VHA Medical Center that prioritizes occupational safety and health.

- In addition to facility staff, VA/VHA have centralized subject matter expertise to provide support to facilities and develop standards and guidance for indoor air quality.
    - VHA Office of Healthcare Engineering
    - VA Office of Construction and Facilities Management
    - VHA National Infectious Diseases Service
    - VHA Office of Occupational Safety and Health
- As part of VA standards development, industry standards and codes are reviewed for minimum requirements and improved upon for VA standards implementation.
    - As a current example, VHA is reviewing ASHRAE 241 for overlap/coordination/gap analysis with current VHA design requirements.

Department of Energy

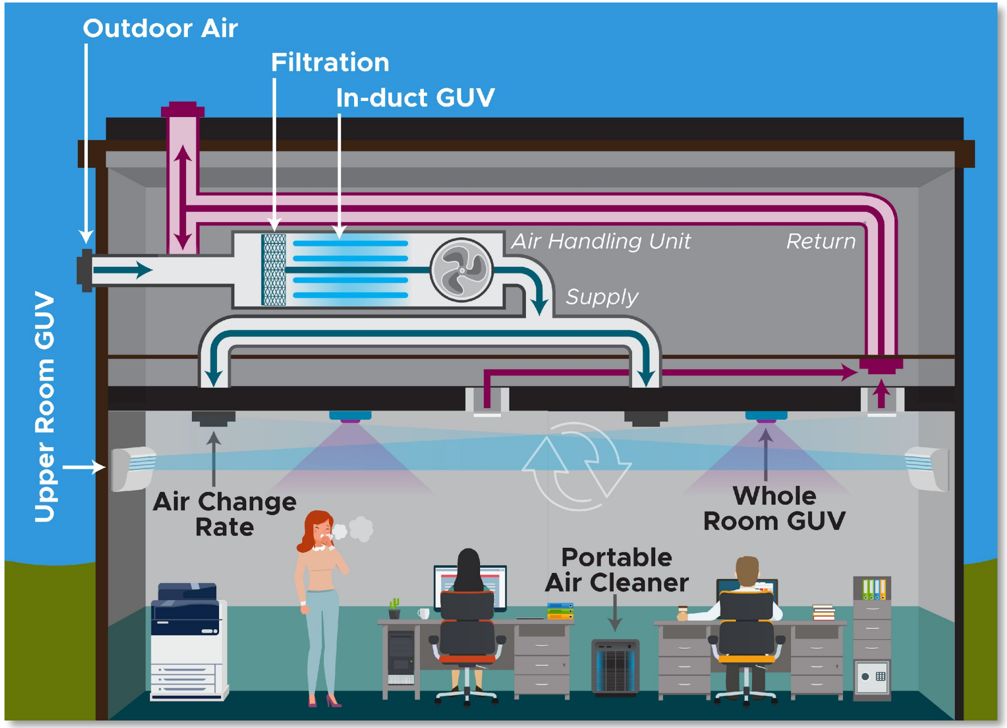
Wyatt Merrill, PhD
Building Technologies Office

Opportunity: reduce airborne disease transmission and achieve ASHRAE/CDC targets at lowest energy, carbon, cost

Pacific Northwest NATIONAL LABORATORY

BERKELEY LAB

PNNL simulation research finds supplementing HVAC ventilation with GUV can achieve ASHRAE/CDC targets using 80-90% lower energy use and carbon emissions than HVAC-only approaches



Tools in the toolbox:

- Increase outdoor air ventilation
- Improve ventilation filtration (e.g., MERV13, HEPA)
- Increase room air change rate (ACH)
- Install in-duct GUV
- Install upper-room GUV
- Install whole-room GUV
- Install portable air cleaner

PNNL/LBNL Current IAQ and GUV Activities

Pacific Northwest NATIONAL LABORATORY

BERKELEY LAB

Simulation Models

- Assess effectiveness, efficiency, life cycle costs of GUV and HVAC measures across building types and climate zones
- Consider multiple contaminants with airborne pathogens and wildfire smoke

Framework Development

- Propose metrics and considerations to improve comparability of mitigation measures
- Define standard reference scenarios

GUV Field Evaluations

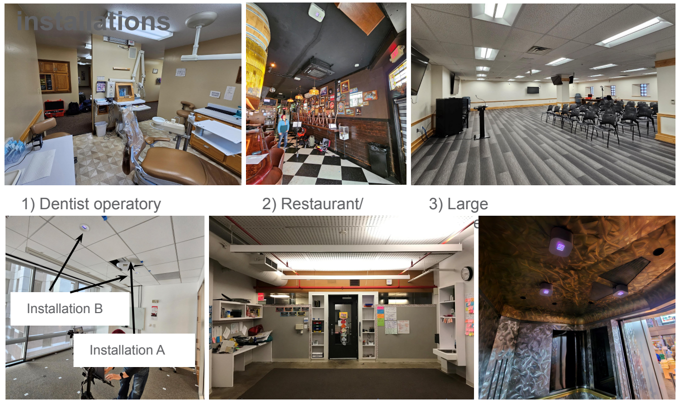
- Assess real-world performance (energy, effectiveness, safety, acceptance, etc.) of GUV across 10 installation sites
- Deep dive comparison of GUV and HVAC energy performance in GSA facilities

GUV Product Testing and Evaluations

- Independently test commercially available GUV products
- Assess current test methods; reduce inaccurate product claims; educate

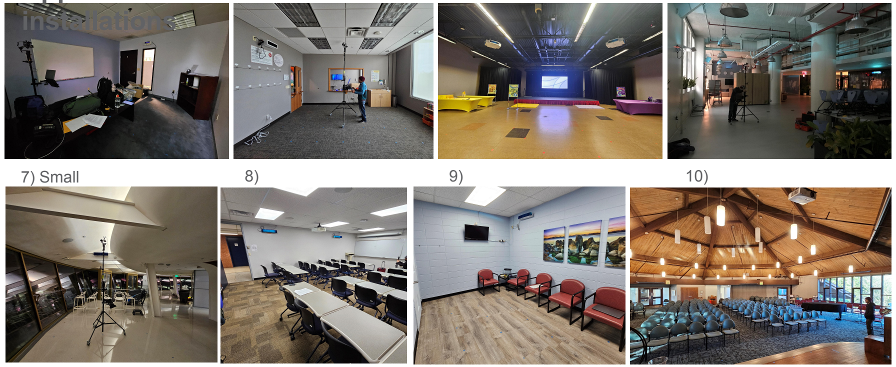
Preliminary findings from in-situ field evaluations of existing upper-room and whole-room installations

Whole-room installations

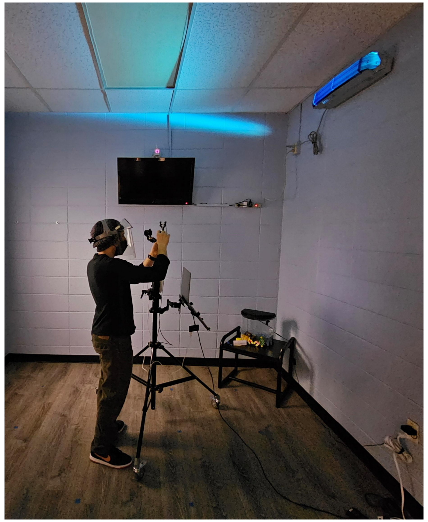


1) Dentist operatory
2) Restaurant/
3) Large
4) Small conference room
5) School classroom
6) Elevator

Upper-room installation



7) Small
8)
9)
10)
11) Public assembly
12) University classroom
13) Health center waiting room
14) Worship room



Average fluence rate

MS2 and human coronavirus HCoV-229E susceptibility constant

$$eACH_{GUV} = 3600 \times f_{avg} \times Z \times \left({h_{uv}}/{h_r} \right)$$

The fraction of the room that is irradiated

Field Evaluations Update

Existing Installation Evaluations

- Evaluate 10 pre-existing GUV installations to gather data on how technology is being deployed (energy use, effectiveness, safety, acceptance)

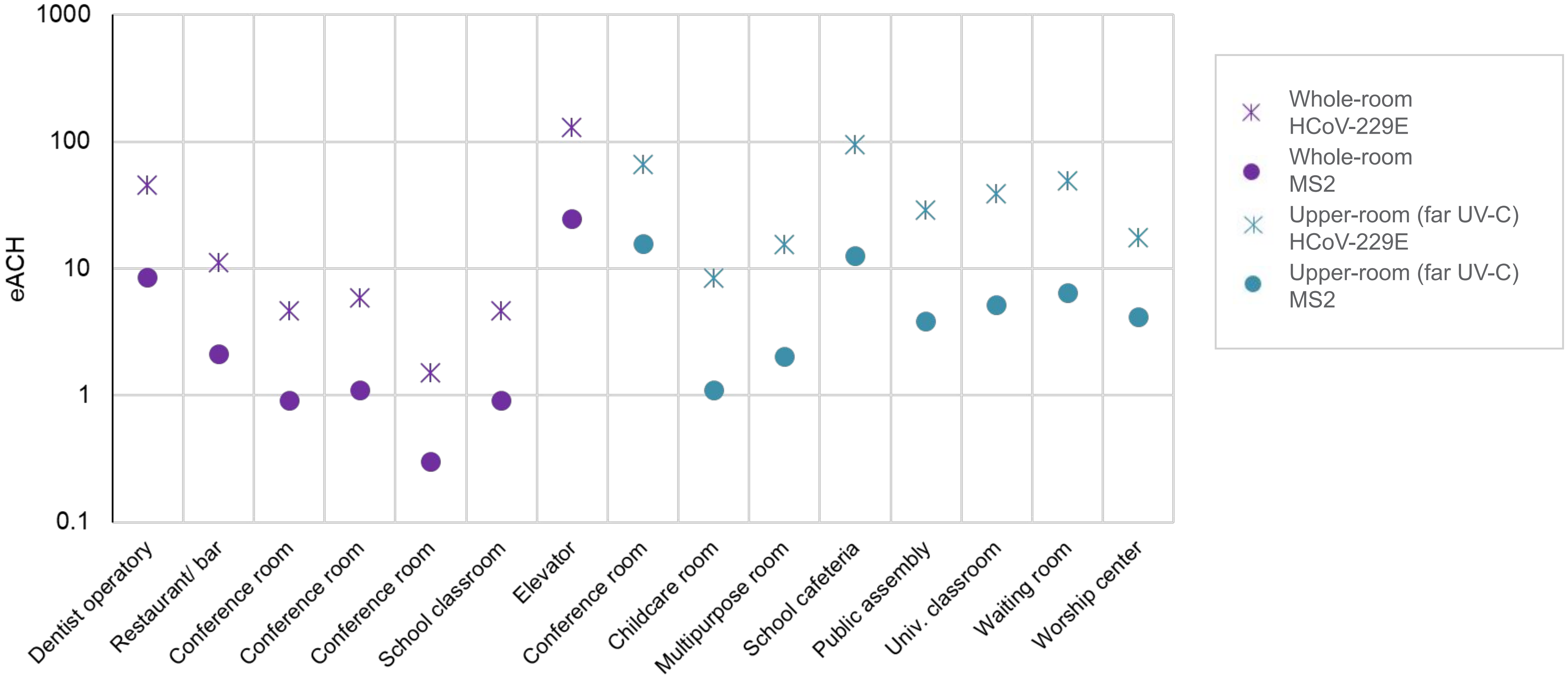
Evaluations complete; paper to be submitted to journal shortly

GSA Green Proving Ground Evaluations

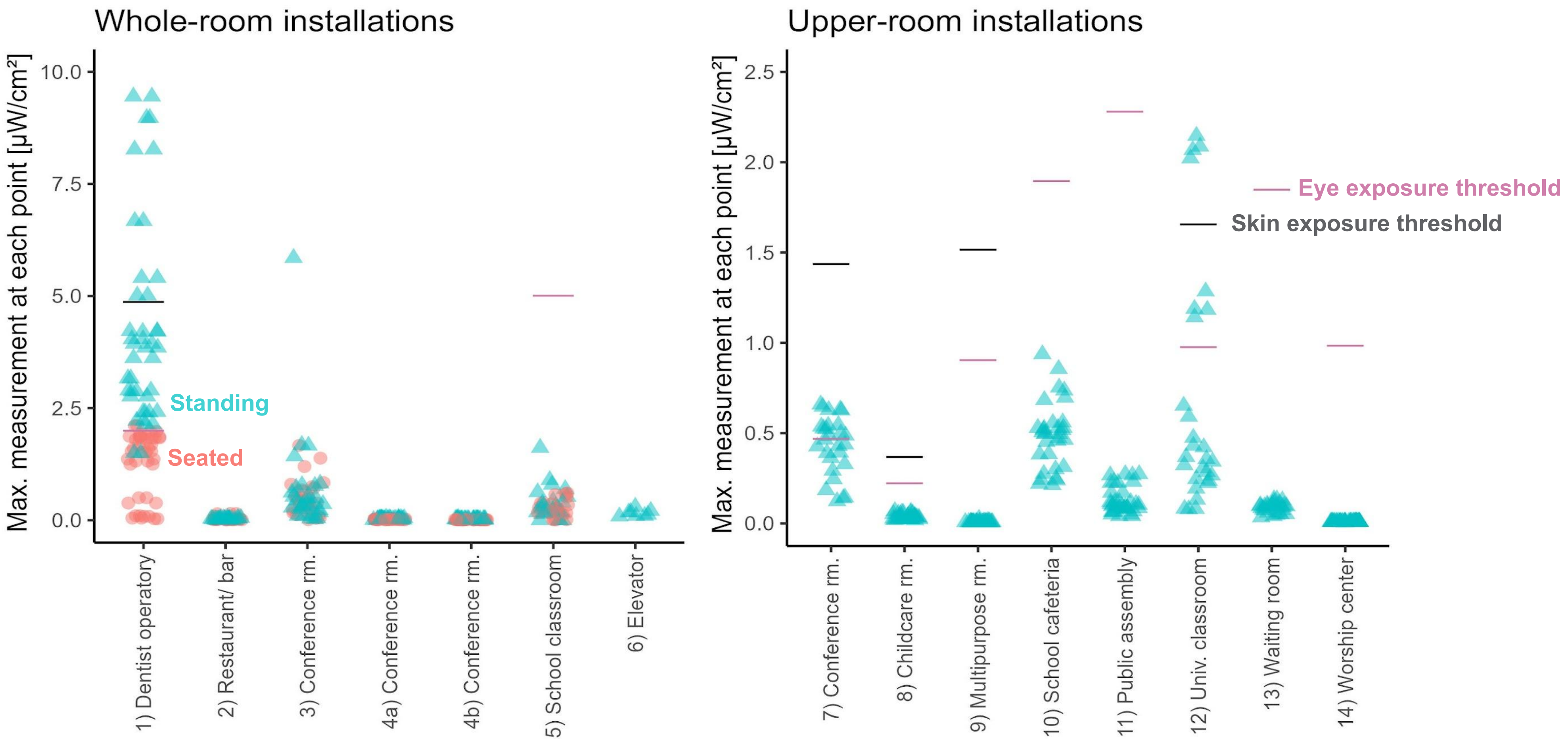
- Evaluate 3-4 GUV vendor solutions in GSA facilities to achieve ASHRAE Standard 241 (energy/carbon savings vs. HVAC, effectiveness, safety, cost-effectiveness, acceptance)

Currently vetting sites, report(s) expected ~18 months from now

Calculated $eACH_{GUV}$ based on radiometric measurements



Most installations did not exceed ACGIH time-weighted average limit for a typical occupancy duration



International Well Building Institute

Whitney Austin-Gray, PhD
Senior Vice President of Research

Residential Pilot

- The evidence-based, third-party verified certification program is poised to transform the way homes are designed, built and maintained to support human health and well-being
- The WELL for residential program, informed by the evidence-based principles of the WELL Building Standard (WELL) and its 10 WELL concepts, offers more than 100 strategies to create homes that prioritize resident health, comfort and well-being
- The development of the program drew upon two years of industry input, market insight and expert recommendations from IWBI’s WELL for residential Advisory, a working group of over 100 globally renowned subject matter experts, including leading builders and developers, architects and engineers, public health and building scientists, government officials and academics, as well as other real estate professionals

Some questions for discussion

- *Is improving the health of your building occupants high on your priorities?*
- *Are occupants asking for improved ventilation and infection risk protection?*
- *How will your organization address the next pandemic, wildfire?*
- *Is your organization considering piloting new initiatives or strategies?*
- *What would you want to get out of a HiBR partnership?*

How can federal agencies and other organizations get involved?

4:15 - 4:30pm

Audience Poll

What topics would you like to see the HiBR form working groups for 1-2 hour discussions?

Audience Poll

Which topics are in greatest need of research, tools, and guidance?

Audience Poll

Which areas are of greatest impact to study for employees working mostly or exclusively from home?

NATIONAL ACADEMIES Sciences Engineering Medicine

Health in Buildings Roundtable

Current Sponsors:

- *General Service Administration*
- *Veterans Health Administration*
- *Green Building Initiative*
- *IN2WIBE/NSF*

Other Prospective Sponsors:

EPA, CDC, Honeywell, Carrier, IWBI, ASHRAE,

Thoughts on technical topics and working groups?

- Physical Activity
- Indoor air quality and ventilation
- Lighting
- Energy, health and sustainable communities
- Climate adaptation collectively with health
- Water and indoor moisture
- Equity and social justice
- Emerging technology

If you (or your organization) are interested in:

- design, technology, management, and behavioral strategies employed in buildings to support and improve health and wellness
- identifying and fill gaps in knowledge to improve the performance of buildings and the health of occupants
- giving input into the roundtable focus areas and output.
- knowledge-sharing of emerging guidance and best practices with diverse group of engineering and health organizations and researchers.
- assisting in developing project requirements and research implementation plans
- recognition as committed to health and wellness through healthy buildings

Going Forward – How to Get Involved

To discuss sponsorship, nominate yourself for membership, or request to join our mailing list

Brittany Segundo
email: bsegundo@nas.edu

Cameron C. Oskvig
email: coskvig@nas.edu

Board on Infrastructure and the Constructed Environment

Audience Poll

What topics would you like to see the HiBR form working groups for 1-2 hour discussions?

Audience Poll

Which topics are in greatest need of research, tools, and guidance?

Audience Poll

Which areas are of greatest impact to study for employees working mostly or exclusively from home?

HiBR upcoming activities

- Future working groups: KPIs, Chilled Beams/DOAS, Standards pilots.
- Our next HiBR Workshop - Circadian Lighting, September 2024
- Thank you!

Thank you!