Shaping Tomorrow's Built Environment Today

MINUTES (DRAFT)

Environmental Health Committee (EHC)
January 31, 2022
Winter Meeting – Las Vegas

These minutes have not been approved and are not the official, approved record until approved by this committee.

MEMBERS PRESENT:
Luke Leung, *Chair*
Nick Clements, *Vice-Chair*
Brendon Burley
John Cohen
Mark Ereth
Rick Hermans, *BOD Ex-O*
Linda Lee
Claressa Lucas
Corey Metzger
Stephanie Taylor
Don Weekes
Junjing Yang
Marwa Zaatari

MEMBERS NOT PRESENT:
Bill Bahnfleth
Karel Kabele
Tim McGinn, *Coord. Officer*

ASHRAE STAFF:
Steve Hammerling, *MOTS*

GUESTS:
Hoy Bohanon
Darryl DeAngelis
Jeremy Fauber
Michelle Hall
Elliott Horner
Rick Karg
Kishor Khankari
Josephine Lau
Frederick Marks
Meghan McNulty
Matt Middlebrooks
LanChi Nguyen-Weekes
Andy Persily
Larry Schoen
Chandra Sekhar
Max Sherman
Dennis Stanke
Walt Vernon
John Weems

Table of Contents

MOTIONS

No.	Motion	STATUS
1	to appoint Luca Fortana to the Infectious Aerosols position document (PD) committee:	PASSED
2	that EHC withdraw the *Ventilation, Humidity Control & Health Effects in Buildings using Split Systems AC Equipment* EIB.	PASSED
3	that EHC withdraw the Vector Borne Disease, Climate Change and the Challenges to ASHRAE EIB	PASSED

LIST OF ATTACHMENTS

No.	Attachment
A	2021-2022 MBO's
B	Top 10 Environmental Health Trends prioritization
C	Filtration in Residential Elder Care Facilities
D	Dynamic Thermal Comfort EIB
E	Field Studies of ETF Guidance in Office Buildings
F	WS 1928
G	MTG on Health and Wellness final report

LIST OF ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
ACH	Air Changes per Hour
AI	Action Item
AiCARR	Italian Association of Air Conditioning, Ventilation and Refrigeration
AIHA	American Industrial Hygiene Association
AIVC	Air Infiltration and Ventilation Centre
ASA	Acoustical Society of America
ASHRAE	American Society of Heating, Refrigerating and Air-conditioning Engineers
A&WMA	Air & Waste Management Association
BOD	Board of Directors
CNV	Chair Not Voting
DRSC	Document Review Subcommittee
EH	Environmental Health
EHC	Environmental Health Committee
EIB	Emerging Issue Brief
ETF	Epidemic Task Force
ExO	Ex-Officio
GAC	Government Affairs Committee
HWBE	Health & Wellness in the Built Environment
IAQ	Indoor Air Quality
IAQA	Indoor Air Quality Association

IEQ-GA	Indoor Environmental Quality Global Alliance
ISHRAE	Indian Society of Heating, Refrigerating and Air Conditioning Engineers
ISIAQ	International Society of Indoor Air Quality and Climate
MBO	Management by Objectives
MERV	Minimum Efficiency Reporting Value
MOP	Manual of Procedures
MTG	Multi-disciplinary Task Group
OPS	Operations Subcommittee
PC	Project Committee
PD	Position Document
REHVA	Representatives of European Heating and Ventilation Associations
ROB	Rules of the Board
ROS	Reactive Oxidation Species
RP	Research Project
SIE	Society for Indoor Environment
SSPC	Standing Standard Project Committee
TC	Technical Committee
TPS	Title, Purpose Scope
VIC	Ventilation for Infection Controls
WHO	World Health Organization
WS	Work Statement

ACTION ITEMS FROM 2022 WINTER MEETING

No.	Responsibility	Action Item	Status
1	Staff	Staff to make changes and upload revised Reference Manual to website	
2	Staff	Remove *Ventilation, Humidity Control & Health Effects in Buildings using Split Systems AC Equipment & Vector Borne Disease, Climate Change and the Challenges to ASHRAE* from EHC webpage	
3	Burley	Reach out to outside health experts for ideas on next EHC seminar	
4	EHC	Review WS 1928, *Improving test methods to measure air cleaner performance against airborne pathogen* before February meeting.	
5	Bohanon	Send draft proposal to request SSPC 62.1 to change to MERV 13 filter minimums for EHC for co-sponsorship.	

1. "ASHRAE COMMITMENT TO CARE"

The health and safety of all ASHRAE conference attendees is a top priority. Out of respect for our fellow attendees, we commit to wear masks indoors, monitor our health, seek medical attention if symptoms development and adhere to all ASHRAE Commitment to Care protocols. We are committed to the well-being of one another."

2. CALL TO ORDER & INTRODUCTIONS

Chair Leung called the meeting to order at approximately 2:30 PM PST. Members and guests introduced themselves. Quorum was confirmed.

Those in meeting room were asked to clearly address microphone in the room for all virtual attendees to be able to hear and participate.

3. ASHRAE CODE OF ETHICS COMMITMENT

'In this and all other ASHRAE meetings, we will act with honesty, fairness, courtesy, competence, integrity and respect for others, and we shall avoid all real or perceived conflicts of interests.' (See full Code of Ethics: www.ashrae.org/about-ashrae/ashrae-code-of-ethics.)

4. REVIEW OF AGENDA

Guest Hoy Bohanon asked to add discussion on EHC co-sponsoring a change proposal to SSPC 62.1 for minimum MERV 13 filter levels. Leung added to 11. New Business.

5. MINUTES

Notes from fall meeting were approved at November meeting (sent in Nov 19 email)

6. CHAIR'S REPORT (Leung)

A. Past EHC meetings since 2021 Annual meeting:
- July 8, 2021 (Kickoff)
- September 23, 2021
- October 28, 2021 (Fall Meeting)
- November 29, 2021
- December 16, 2021

B. Motions from Past Meetings Requiring Higher Body Approval
1. Motion to make ROB changes approved at December Meeting were sent to OPS for their consideration *[OPS to consider at Tuesday Feb. 1 meeting].*
2. Motion to make Reference Manual changes approved at October Meeting were implemented into Reference Manual. *(06B) [Staff to make changes and upload revised document to website (**Action Item** 1)]*

C. 2021-2022 MBO's
A status update on MBOs (**Attachment A**) will be reported to OPS.

D. Other
Leung listed a number of topics that have come up since the last mee
1. LEED –Passive Survivability thermal envelope in a building when there is no utility
2. WHO Air Quality Action
3. Antimicrobial Surface Product Use
4. Top 10 Trends prioritizing **(Attachment B)**
5. UK ventilation standard

E. Filtration in Residential Elder Care Facilities
SSPC 170 member Jeremy Fauber gave EHC a 15-minute presentation (Attachment C) on Filtration in

Residential Elder Care Facilities. These facilities are varied and include independent living facilities, assisted living facilities and skilled nursing facilities. Code requirements for within dwelling units are limited with no minimum efficiency. ASHRAE Standards 170 and 62.1 include some requirements but are not referenced in the codes.

EHC discussed what can be done or said in ASHRAE position documents or emerging issue briefs to help address issue. A comment on best practice could be made on helping to assure ventilation, mixing/distribution and filtration in these spaces.

7. VICE-CHAIR'S REPORT (Clements)

A. ROB/MOP/Reference Manual changes
No new changes were proposed to EHC ROB, MOP or Reference Manual

B. EH Award
Letter ballot to consider two nominees is closed. Winner sent to Honors & Awards committee for their consideration.

8. BOARD OF DIRECTORS (BOD) EX-OFFICO (EXO) & COORDINATING OFFICER REPORT

A. BOD EX-Officio
Hermans noted he would give his Ex-O presentation when more time was available.

9. SUBCOMMITTEE REPORTS

A. Policy Subcommittee (Hermans)
1. Position Documents
a. *Infectious Aerosols*
Hermans noted the Infectious Aerosols PD committee wishes to add Luca Fortana, WHO, to the committee.

(1) It was moved (Leung) and seconded (Clements) that EHC recommends that DRSC recommend to Tech Council that they appoint Luca Fortana to the Infectious Aerosols position document (PD) committee.

BACKGROUND: The Infectious Aerosols PD committee was appointed earlier with the understanding that someone from the WHO would be identified and appointed. Mr. Fortana was identified and has been working with the PD committee and contributing for some time already.

MOTION 1 PASSED: 11-0-0 CNV

Work to revise the Infectious Aerosols PD is ongoing. A draft has been completed but the PD committee is working to finalize it before submission in mid-February.

b. *Indoor Carbon Dioxide*
The *Indoor Carbon Dioxide* PD committee developed a draft PD. EHC reviewed and commented in November with comments addressed by the PD committee. The draft was distributed to DRSC, Tech Council and the BOD in late December. A revised draft was sent again January 24 with changes to address Tech Council and BOD comments. A motion to approve the PD in on the DRSC agenda.

c. *Filtration and Air Cleaning*
The PD committee revising the Filtration and Air Cleaning PD has met twice and is starting their work. No timeline was provided at this time.

d. *Combustion of Solid Fuels and Indoor Air Quality in Primarily Developing Countries* PD
This PD is set to expire June 26, 2022 so a recommendation to reaffirm, revise or withdraw is expected this spring. EHC will consider at next meeting.

2. Emerging issue briefs
   a. *Biological agents and airborne transmission*
   Hermans is bringing this EIB to the MTG.VIC for review to see if they are interested in updating.

   b. *Ventilation, Humidity Control & Health Effects in Buildings using Split Systems AC Equipment*
   Sekhar noted this is an old paper but the issue still is prevalent. The recent pandemic has only highlighted problems and issues here. Suggest review and revision and that some content be in one of the PDs.

      (2) It was moved (Leung) and seconded (Burley) that EHC withdraw the *Ventilation, Humidity Control & Health Effects in Buildings using Split Systems AC Equipment* EIB.

      MOTION 2 PASSED: 11-0-0 CNV

   c. *Vector Borne Disease, Climate Change and the Challenges to ASHRAE*

      (3) It was moved (Leung) and seconded (Clements) that EHC withdraw the Vector Borne Disease, Climate Change and the Challenges to ASHRAE EIB.

      BACKGROUND: This PD was initially approved in June 2010. Much of this topic is covered in more recent EIBs and guidance from ETF, or is no longer considered emerging.

      MOTION 3 PASSED: 11-0-0 CNV

   Staff would have these two EIB removed from website (**Action Item 2**).

   d. *Ozone and Indoor Chemistry*
   Taylor reviewed and suggested revising keeping content until Filtration and Air Cleaning PD is revised and published.

   e. New EIBs
      - Dynamic Thermal Comfort (Leung)
      Leung summarized the effort to draft a new EIB (**Attachment D**). More buildings utilizing outdoor environments (such as operable windows) so some are researching how this impacts building occupant health. Gail Brager and others on EHC are working on a draft for completion by March.

      - Reactive Oxidation Species (ROS) (Clements)
      Clements is leading an effort to summarize the latest state of knowledge in ROS and byproducts. Five people have volunteered and developed an outline. TC 2.4 & 2.3 will be reached out to for help and volunteers. Clements is seeking someone with indoor chemistry research expertise. The group aims to have a draft this summer.

B. Education Subcommittee (Burley)
Burley noted his subcommittee met earlier in January with Policy subcommittee.

1. EHC programs for Winter Meeting:
   - No proposals were made for Winter Meeting.

2. EHC proposals for Annual Meeting:
   - Seminar/Forum proposals for Toronto are due Feb 17th.

   - EHC brainstormed some ideas for future program proposals:
     - Human health standard indoors (Taylor)
     - MERV 13 filters in PTAC, etc. (Panel discussion at Winter Meeting with Fauber, manufacturers on their technologies).
     - New EIBs (Dynamic thermal environment, ROS)
     - Seminar on emerging issues that would include three topics above for TOR, panel in ATL. (Cohen to chair with Bohanon, Taylor, Clements, Leung)

3. ASHRAE Journal IEQ Applications Column
   - Taylor is drafting an article for April. Persily is drafting a column on the Indoor CO2 PD for May. Burley is seeking articles for July and later this year and asked anyone with ideas to reach out.

4. Handbook Chapter
   - Next revision due in 2024 for 2025 publication
     A small group of volunteers agreed to review the chapter, meet Feb 25th to discuss what needs update/change.

5. Online short presentations/seminars to EHC and beyond
   - Three EHC sponsored seminars in 2021. Should EHC consider another for 2022?
     - Burley agreed to reach out to outside health experts for ideas on next seminar (**Action Item 3**). What are these outside health experts interested in that may be off the ASHRAE radar.

6. Other
   - Field Studies of ETF Guidance in Office Buildings
     Meghan McNulty gave a presentation (**Attachment E**) titled "*From Guidance to Implementation: Applying ASHRAE Epidemic Task Force Building Readiness Strategies in 95 Commercial Office Buildings".*
   - Evaluated 95 office buildings constructed over 60 years for alignment with ETF guidance, and recommended changes where additional risk reduction was needed.
   - Risk mitigation and improved health outcomes are achievable. We must start by assessing our existing buildings
   - Most buildings are highly adaptable to COVID risk reduction strategies, even if not designed for infection control.
   - Better ventilation, filtration, and Legionella risk management are possible without extreme cost or effort.
   - Assessments can be customized by building type (schools, multifamily, etc.) and applied at scale.

C. Coordination and Outreach Subcommittee (Weekes)

1. Interaction with ASHRAE committees
   Weekes noted the subcommittee has been focused most recently on 62.1 and GAC activities. ASHRAE position documents and ETF guidance is in heavy use with GAC and their outreach to legislators and chapter education. GAC is seeking volunteers for state/local/grassroots outreach.

2. Interaction with outside organization that impact EH or IAQ
   Weekes has been working on coordination with AIHA and ACGIH. ASHRAE and ACGIH are cooperating in an Industrial Ventilation Conference this summer.

3. IAQ 2020 Conference
   The IAQ 2020 Conference, *IEQ Performance Approaches, Transitioning from IAQ to IEQ*, will be take place May 4-6, 2022. The conference will take place in Athens, Greece as a hyrbid meeting. Chair's Bill Bahnfleth and Max Sherman are chairing the event which will be co-organized by ASHRAE, AIVC and the IEQ-GA. Details on the conference can be found at www.ashrae.org/iaq2020.

4. IEQ-GA (Weekes/Bahnfleth)
   ASHRAE continues to participate in the IEQ-GA with Bill Bahnfleth as the ASHRAE representative. The IEQ-GA is now finalized as a legal entity and operates with 11 full member organizations (ACGIH, AICARR, AIHA, AIVC, ASA, ASHRAE, FAIAR, FEDECAI, IICRC, ISHRAE, REHVA). There are two other affiliate associations (MAIQC, SIE). The IEQ-GA has held webinars, podcasts and ls planning a publication. All are invited to listen and participate.

   The IEQGA is meeting in Las Vegas with a focus on strategic planning. The BOD is meeting in February.

5. ASHRAE Epidemic Task Force.
   The ASHRAE Epidemic Task Force (ETF) held their 28th meeting and their 1st face to face meeting at the Winter Meeting in Las Vegas. Their current task is to write a final report and coordinate transitioning guidance with various ASHRAE TCs, PCs, etc.

6. Research
   Matt Middlebrooks addressed EHC and requested EHC co-sponsorship of WS 1928, *Improving test methods to measure air cleaner performance against airborne pathogen (***Attachment F***).* EHC members were asked to review before February meeting (**Action Item 4**). Authors have March 15 deadline for submission to RAC.

10. LIAISON ACTIVITIES

A. Standard 62.1 (*Burley)*
   SSPC met in Vegas and is working towards a 2022 version publication. They aim to finalize addenda in February and a reorganization of the standard is in the works. An addendum including mandatory elevation density corrections for ventilation rates is approved pending letter ballot for public review.

B. Standard 188 (*Lucas*)
   There is not much new since the last meeting. The committee is meeting Tuesday in Vegas to consider one change proposal.

C. Standard 62.2 *(Sherman)*
   The SSPC approved responses to comments on an addendum on unvented combustion, as well as changes to the TPS and definitions. Public reviews were approved on addenda related to ozone and filtration upgrades to MERV 11.

D. Guideline 10 (*Clements*)
   Various updates, including an update to references, are in preparation for this summer. The guideline committee is awaiting MTG.HBWE output and recommendations for consideration.

E. Standard 170 *(Burley)*
   The SSPC is meeting at the Winter Meeting. An addendum to help match and be consistent with 62.1

is on the agenda.

F. Guideline 42P committee *(Burley)*
Current efforts to help with usability are in the works. Changes are ready for publication public review.

G. MTG on Health and Wellness *(Weekes/Horner)*
The final report (**Attachment G**) from the MTG was sent to EHC for consideration and implementation of recommendations. EHC can review for second time. The final report document is intended to reside with EHC for implementation going forward. The MTG will disband shortly.

H. MTG.ACR Air Change Rate (*Khankari*)
This MTG is developing a white paper on ACH. A research project 1833 is nearly complete with the PMS voting on now. The MTG is developing a work statement on relationship between ACH and layout of diffusers, etc. on ventilation effectiveness (seeking outside co-funding).

I. MTG.VIC Ventilation for Infection Control (*Hermans*)
This MTG is meeting Tuesday morning and will discuss EIBs, research protocols for ASHRAE RPs and a research result reporting template.

J. TG2.RAST (*Zaatari*)
This committee is now organized with membership and has held a kickoff meeting. The committee aims to meet frequently.

K. TC 2.1 (*Yang*)
A study on sleeping and ventilation is wrapping up with results expected soon.

11. NEW BUSINESS

A. NEXT MEETING
EHC will continue to hold monthly meetings with the next one in February. The next face to face meeting for EHC is scheduled in Toronto, ON Canada on June 27, 2022.

B. OTHER
Bohanan addressed EHC about a proposal to request SSPC 62.1 to change to MERV 13 filter minimums asking EHC for co-sponsorship. This would be consistent with ETF recommendations. Bohanon is seeking feedback and would send draft proposal to EHC ahead of EHC's February meeting for consideration (**Action Item 5**).

12. ADJOURNMENT

The EHC meeting adjourned at just before 6:15 PM PST. All attendees were thanked for their participation.

MBO Submission to Planning Updated 1/31/2022

Council:	**Technology Council**	**Chair:**	**Luke Leung**
Committee:	**Environmental Health Committee (EHC)**	**Vice-chair:**	**Nicholas Clements**

MBO #		Description	Metric (how do we determine success?)	Initiative #	Goal #	Completion % / Date	Financial Assist Req'd?	MBO Comments	Strategic Plan Tally: Initiative # 1	2	3	4	Goal 1 a	b	Goal 2 a	b	c	Goal 3 a	b	c
1		**Execute the Envireonmental Health Strategic Plan as Coordinated with Tech Council**																		
Policy Subcommittee (Herman)																				
a		Work Plan and Specification for IEQ Deliverables:	Coming up with a work plan for IEQ deliverables	1,2	1a,b; 2c, 3a		No	a. Follow up on the report from MTG Health and Wellness report dated June 2021 - *EHC commented on final report. Revised MTG report with EHC for EHC consideration and implementation as appropriate.* b. Identify the ASHRAE value adds - *ongoing* c. Decide the need for a IEQ standard - *ongoing* d. Framework of an IEQ knowledge center and guidelines - *ongoing*	x	x			x	x			x	x			x
b		Start identifying funding sources on IEQ research gaps	# of funding sources on IEQ identified	2,4	2a, b, c; 3a, b, c		No	Will need to identify a list of potential funders - *ongoing*		x		x			x	x	x	x	x	x
c		Identify future potenital health threats, similar to pandemic, and potential mitigation plan	Coming up with a report	1,2	2b, c; 3a, 3c		No	The focus of this is more about pandemic and similar health threats - ongoing through emerging issue briefs, programs, implementation of ETF guidance and revision of current PDs.	x	x			x	x		x	x	x		x
d		Draft a short report to Tech Council which identifies major trends impacting environmental health related with IEQ	Coming up with a report	1,2	1a, b; 3a, c		No	The focus of this is more about general trends *Report sent to TecH Council with last Annual Meeting report. EIB on Dogs in Offices approved. Two more EIBs in development.*	x	x			x	x				x		x
2		**Lead Health Discussion and Educational Programs**																		
Education Subcommittee (Burley)																				
a		Lead health discussion by proposing education program to inform latest trends impacting enviornmental health in ASHRAE meetings and regular scheduled Webinars	# of programs and quality of programs through feedback	2,4	1 a, b, 2a, b, c, 3a		No	lead health programs in ASHRAE regular meetings, set up additional webinars where required *Working to develop next internal EHC webinar. Last EHC sponsored webinar is posted on EHC webpage. Seminar for Toronto on emerging issues is planned. Panel on emerging issues planned for Atlanta.*		x		x	x	x	x	x	x			
b		Work with ETF to develop material for future pandemic	A written report on progress	1,2	1a, b; 2b, c; 3a, b		No	This will be a close working relationship with ETF to work on channeling the lessons learn from pandemic to ASHRAE TCs and publications. *Working with ETF to find home for ETF developed guidance and to serve as resource for future issues.*	x	x			x	x		x	x	x	x	
3		**Tighten the Connections with External and Internal Health Related Entities**																		
Outreach Subcommittee (Weekes)																				
a		Refine the list of EHC-related external experts	A list of external experts	1,2,4	1b; 2a, b; 3 a, c		No	To form an informal discussion group which will regularly in touch to share the latest technical information and trend on what is on the horizon. This could result in policy suggestions, papers, conference programs, research ideas, etc., but is a function of Outreach subcommittee. *Met Nov. 2 new members added from AIHA and ACGIH*	x	x		x		x	x	x		x		x
b		Document the interaction plan with IEQ-GA for future IAQ meetings, potential modification of MOP	Potential changes in MOP, if any	1,2,3	2 b, c; 3 b, c		No	We need to review and document the relationship between IEQ-GA and ASHRAE. In order to put in a documented procedure, it is possible to put in MOP, or other documents, to be determined. *Currently detailed in IEQ-GA bylaws. IEQ-GA will have a representative from ASHRAE determined by ASHRAE plus annual fee to participate.*	x	x	x					x	x		x	x
c		Update an interaction plan with Epidemic Task Force (ETF), potential modifications of MOP	A docmented plan with ETF	1,2,3	3b		No	This will require working closely with ETF, to document a relationship into the future, including the sunse of ETF and future pandemics *Not currently formalized in EHC MOP*	x	x	x								x	
d		Develop a short list of knowledge gaps with brief descriptions during each society meeting to document and disseminate emerging research ideas to TCs through TAC as inspiration for potential researches.	Documents before each meeting	1,2	1a, b; 2, c; 3 a, b, c		No	Summarize of the latest findings will be important. *Document developed within EHC*	x	x			x	x			x	x	x	x
4		**Improvments to Management and Procedures**																		
Administration (Leung/Clements/Hammerling)																				
13		Review the EHC Scope and Manual of Procedures, recommend to maintain or to revise, present recommendation for new language at annual meeting.	Potential changes in MOP, if any	2,3	3 b		No	This is to align the MOP with the latest strategic plan changes *ROB change approved December, sent to OPS at Winter Meeting*		x	x								x	
14		Develop new EIB for concerned items to be published in short order and on ASHRAE website.	# of E1B, if any	1,2	1a, b; 2 c; 3 a, b, c		No	*New EIB on Dogs in Offices approved and published on EHC webpage. Two EIBs in development for first half of 2022 publication*	x	x			x	x			x	x	x	x
15		Develop priorities in the area of IEQ research based on review Society initiatives related to IEQ to identify gaps and overlaps and consults outside experts.	A report	1,2	1 a, b; 2 b, c; 3 a, b, c		No	This priority on IEQ gap is building on a document of IEQ research gaps from last yeat. *Met in November. EHC polled and prioritized research priorities.*	x	x			x	x		x	x	x	x	x
									10	**15**	**3**	**3**	**8**	**9**	**3**	**7**	**9**	**10**	**8**	**8**

	Better Indoor Air Quality	Increasing use of air cleaners	Unvented combustion	IEQ as an aspect of resilience	Ventilation rates	Infectious Aerosols	Indoor agriculture	Temporary Indoor Environments	Climate Change	Financial – Cost/Benefit
Luke Leung	6	5	9	10	1	7	8	3	4	2
Brendon Burley	2	1	8	7	3	5	10	9	6	4
Claressa Lucas										
Corey Metzger										
Don Weekes	1	6	5	3	8	4	7	9	2	10
Mark ereth	6	3	5	10	7	1	8	4	9	2
Rick Hermans	6	3	5	10	7	1	8	4	9	2
Jon Cohen										
junjing yang	7	5	6	4	1	3	10	8	2	9
Karel Kabele										
Linda Lee	5	2	4	7	3	1	8	9	6	10
Marwa Zaatari	1	4	7	6	5	3	10	9	8	2
Stephanie Taylor										
Nicholas Clements	7	4	8	5	3	2	10	9	6	1
Hammerling, Steve										
Bahnfleth, William P	1	4	8	5	6	3	10	9	7	2
Total*	42	37	65	67	44	30	89	73	59	44
*** Lower score is better**	**3**	**2**	**7**	**8**	**4**	**1**	**10**	**9**	**6**	**5**

Filtration

A Review of Requirements for Senior Living Facilities

Senior Living Landscape

- Independent Living Facility (ILF)
- Assisted Living Facility (ALF)
- Skilled Nursing Facility (SNF)

ICC and IAPMO Code Requirements

- International Mechanical Code 2021 - 605 Air Filters: Heating and AC systems shall be provided with approved filters
  - Filters shall comply with UL 900 (flame and smoke development limitations)
  - Filters used within dwelling units shall not be required to be listed and labeled
- Uniform Mechanical Code 2021 – very similar to IMC 2021

Independent Living Facilities

- ANSI/ASHRAE/ASHE Standard 170-2021 – Does not have any requirements for ILF facilities; not referenced for compliance in ICC documents
- Facilities Guidelines Institute - 2018 – References ASHRAE 62.1 and 62.2 based on number of floors in the building ; not referenced for compliance in ICC documents
- ASHRAE 62.2 – 2019 – Requires MERV 6 or AHRI Standard 680 50% efficiency when ductwork length is >10 ft and through a thermal conditioning component; not referenced for compliance in ICC documents

- While filters are required at equipment, there is no code required minimum filter rating based on adopted codes

Assisted Living Facilities

- ANSI/ASHRAE/ASHE Standard 170-2021 – Requires MERV 8 for outdoor air and recirculated air going to multiple spaces; In room recirc units do not have minimum filter requirement; not referenced for compliance in ICC documents
- Facilities Guidelines Institute - 2018 – Requires MERV 7 for central systems serving resident care areas; In room recirc units do not have minimum filter requirement; not referenced for compliance in ICC documents
- ASHRAE 62.2 – 2019 – Requires MERV 6 or AHRI Standard 680 50% efficiency when ductwork length is >10 ft and through a thermal conditioning component; not referenced for compliance in ICC documents

- For ICC while filters are required at equipment, there is no code required minimum filter rating based on adopted codes
- IAPMO requires health care facilities to comply with ASHRAE Standard 170; if AHJ consider ALF a health care facility then minimum filter compliance would apply in states adopting UMC, otherwise similar to ICC adoption.

Skilled Nursing Facilities

- ANSI/ASHRAE/ASHE Standard 170-2021 – Requires MERV 13 for outdoor air and recirculated air going to multiple spaces; In room recirc units do not have minimum filter requirement; referenced for compliance in ICC documents
- Facilities Guidelines Institute - 2018 – Requires MERV 13 for central systems serving resident care areas; In room recirc units do not have minimum filter requirement; not referenced for compliance in ICC documents, maybe adopted by department of health
- ASHRAE 62.2 – 2019 – Requires MERV 6 or AHRI Standard 680 50% efficiency when ductwork length is >10 ft and through a thermal conditioning component; not referenced for compliance in ICC documents

- As an I-2 facility both ICC and IAPMO require filter compliance with ASHRAE Standard 170

Environmental Health Committee (EHC) Emerging Issue Brief

January 22, 2022

Dynamic Thermal Environment

What is the issue? (Gail? Thomas?????)

1. Introduction: constant versus dynamic thermal environment
2. Dynamic thermal environment
    a. comfort
    b. health
    c. infectious diseases and semi outdoor environment

What does this mean for ASHRAE? (Luke Leung….others??)

1. ASHRAE strategic plan
2. ASHRAE research plan
3. Needs of the ASHRAE Members
4. Impacts to ASHRAE Standards and Guides

What Action Should ASHRAE Considered? (????)

1. Research
2. Developing/supplementing standards and guides
3. Working with other global entities
4. Which TCs and committees own this topic?

ASHRAE 2022 WINTER CONFERENCE
Jan 29-Feb 2 | AHR EXPO Jan 31-Feb 2

Paper Session 21 – Refining ASHRAE COVID Guidelines and Standard 100

Meghan McNulty, PE, LEED AP O+M
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From Guidance to Implementation: Applying ASHRAE Epidemic Task Force Building Readiness Strategies in 95 Commercial Office Buildings

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Learning Objectives

- **Apply a building readiness assessment framework to identify buildings with opportunities to improve ventilation, filtration, and water systems to reduce risk of disease transmission.**
- **Explain how a typical office building can adapt to meet the Epidemic Task Force core recommendations for ventilation, filtration, unoccupied flushing, and Legionella water management practices.**
- **Identify low-cost and low-effort strategies that can address underventilation caused by O&M issues and identify systems needing retrofit or replacement to address original design deficiencies and meet current ventilation standards.**
- Understand the steps required for ASHRAE Standard 100 compliance.
- Use EUI targets to evaluate building performance.
- Understand the significance of percentile ratio in determining the Standard 100 default EUI targets.

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Risk mitigation and improved health outcomes are achievable.
We must start by assessing our existing buildings.

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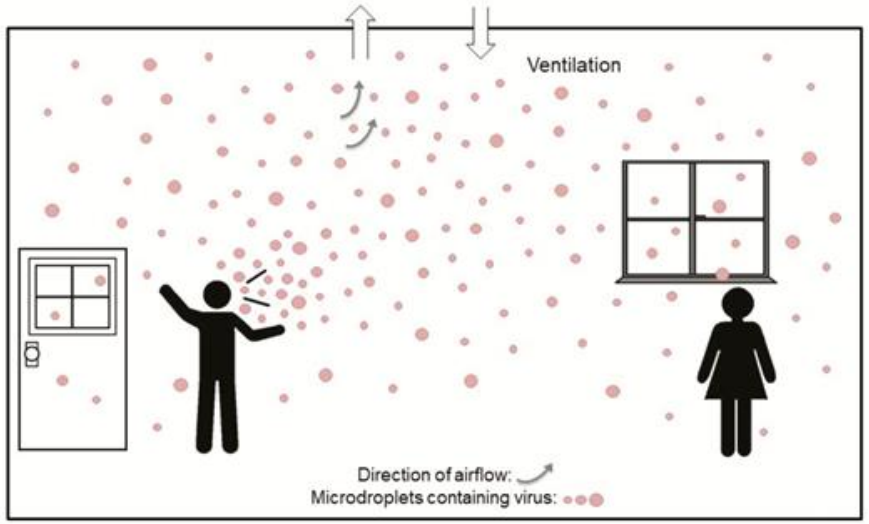
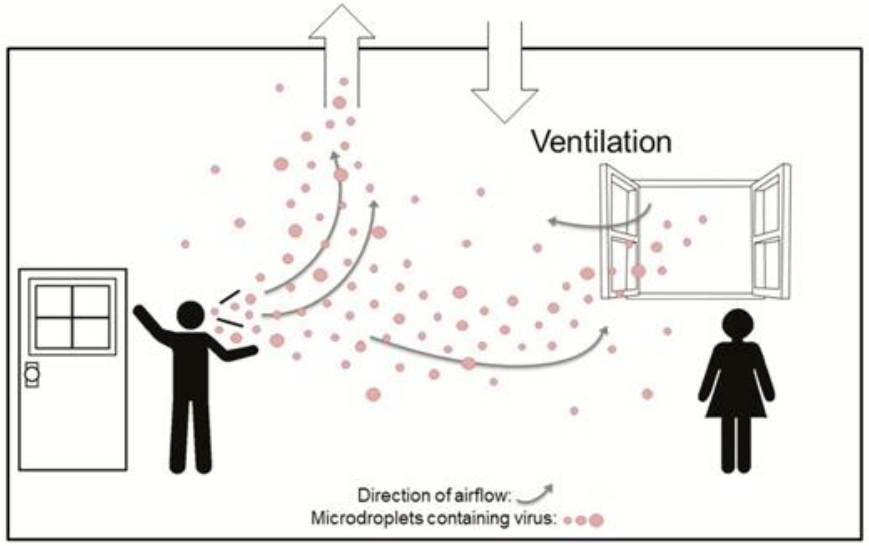
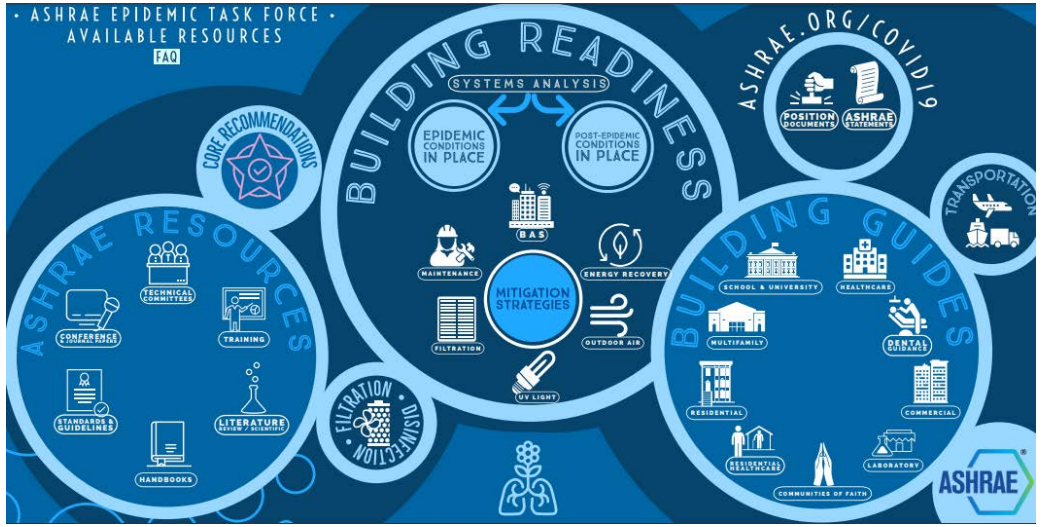
2020: ASHRAE identified role of HVAC in pandemic response and created the Epidemic Task Force (ETF).





Airborne transmission of SARS-CoV-2 is significant and should be controlled.

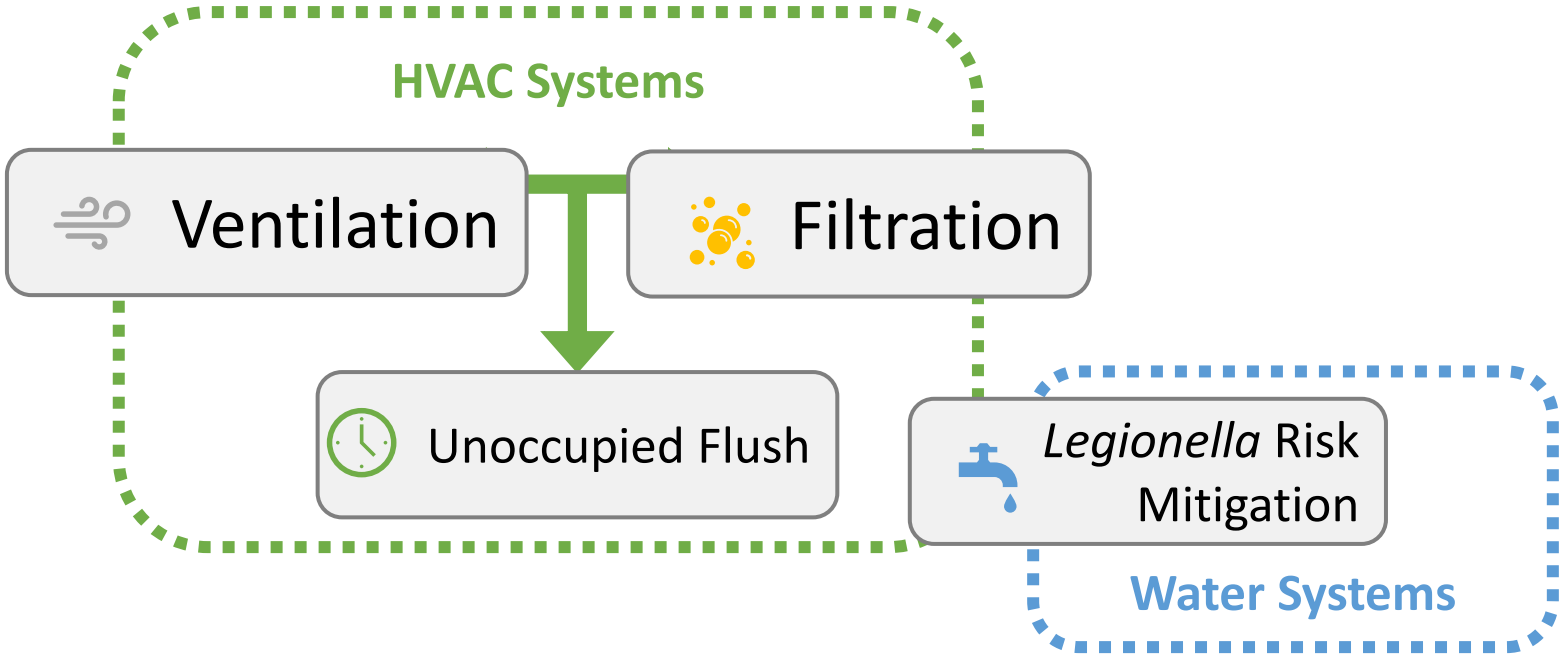
Changes to building operations, including the operation of heating, ventilating, and air-conditioning systems, can reduce airborne exposures.



We evaluated 95 office buildings for alignment with ETF guidance, and recommended changes where additional risk reduction was needed.

Assessment Goals:

- Identify deficiencies in systems and practices
- Proactively intervene
- Reduce the spread of COVID-19 and other respiratory illnesses



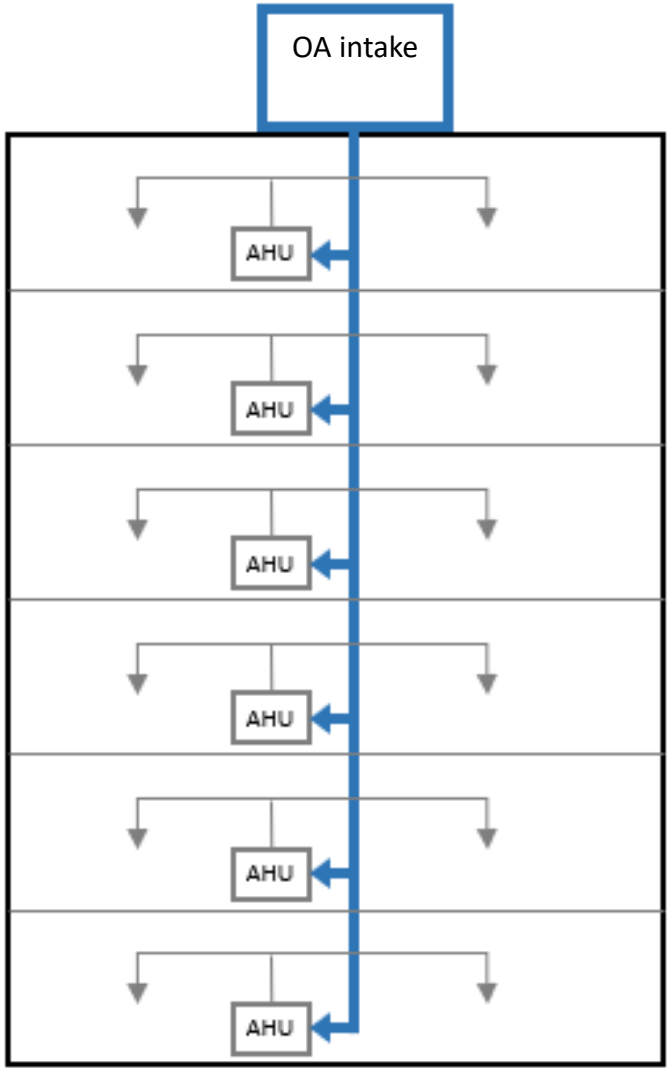
95 office buildings represent a broad sample of 60 years of HVAC design (1964 to 2018) in the US.

Buildings from 40,000 SF to 1.4M SF (4k-130k m^2)

Constant, variable air volume

100% economizer, min OA only with or without fans, dampers, louvers

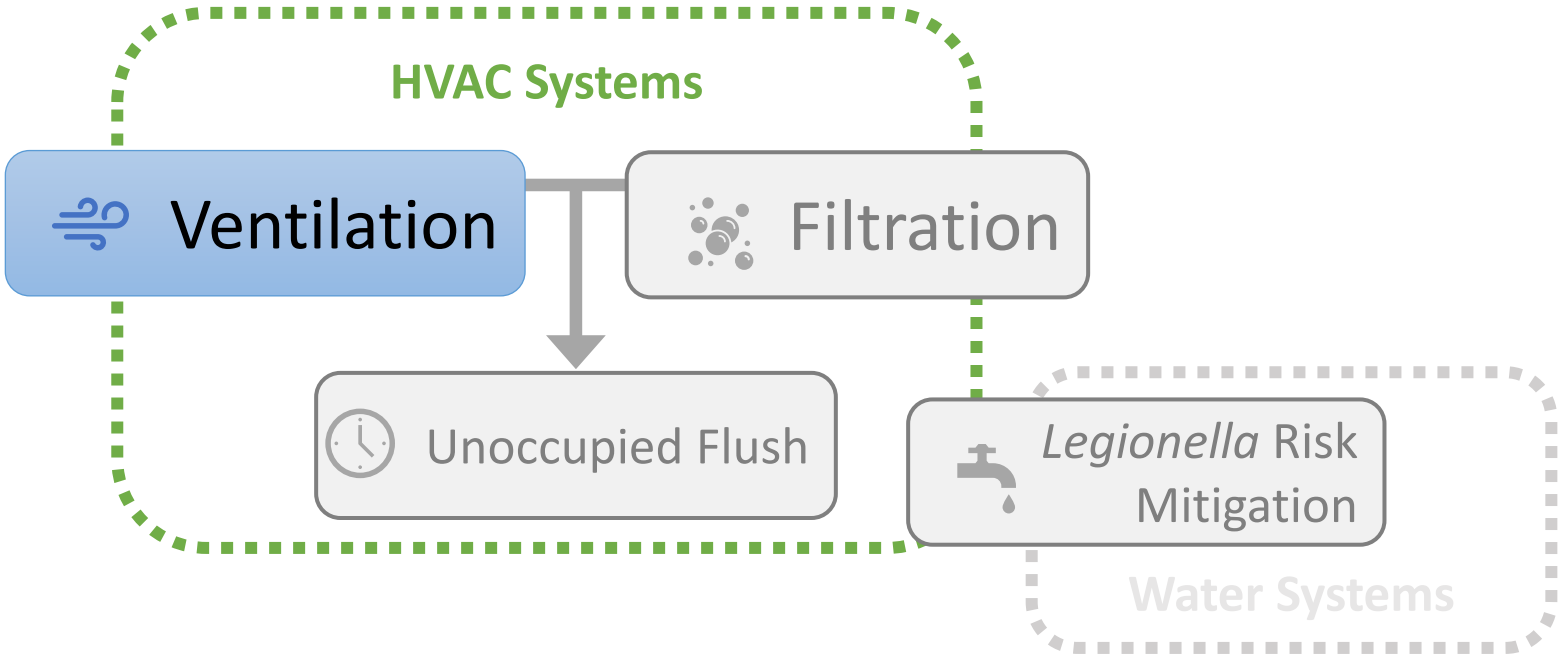
Built-up AHUs, floor-by-floor, packaged, perimeter induction units, water source heat pumps



Remote assessments were possible with help from great facility operators

+ our knowledge from pre-pandemic site visits.

Focus Areas


HVAC Systems
Ventilation
Filtration
Unoccupied Flush
Legionella Risk Mitigation
Water Systems

Ventilation

ETF: Provide and maintain at least the required minimum outdoor airflow rates

ASHRAE 62.1-2019 Ventilation Rate Procedure

Calculate required airflow

Base building systems for office areas

Default occupant density

Typical air distribution effectiveness

Threshold for these buildings: 0.09 cfm/SF (0.46 L/s-m^2)

Determine actual airflow

Design capacities, expected minimums

Measurements, TAB reports, sensor readings

Control sequences, trend data, BAS screenshots

Triage

Already in Compliance

Action Needed: O&M

Action Needed: Retrofit

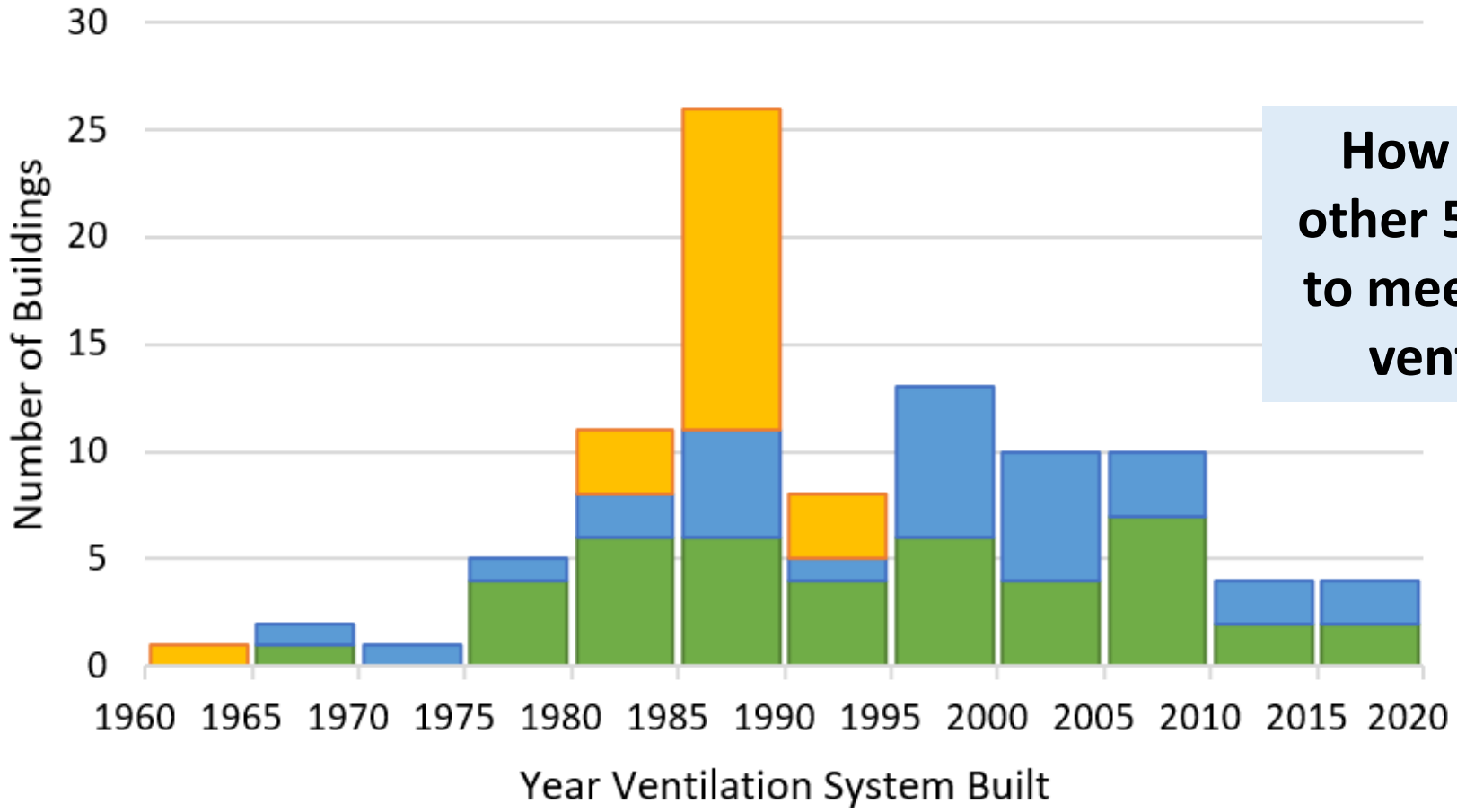
Ventilation

About half of buildings already met minimum ventilation requirements, across age of system.

44% Already in Compliance

33% Action Needed: O&M

23% Action Needed: Retrofit



How do we get the other 56% of buildings to meet the minimum ventilation rate?

Ventilation

Action Needed: O&M

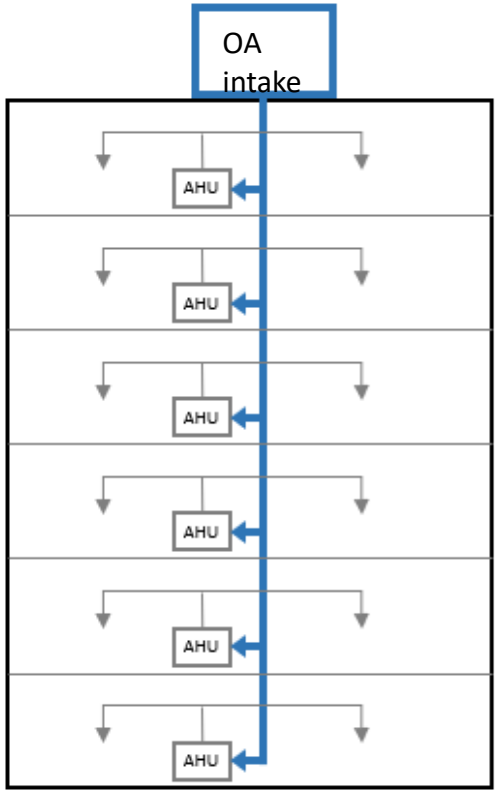
33% were under-ventilated, but could meet or exceed the minimum ventilation rate <u>without significant effort or cost.</u>

- Adjust min. OA damper position
- OA lockouts for peak cold/heat
- CO_2-controlled reductions in OA
- Local fan control to ON, not AUTO
- Broken or missing components, setpoint overrides

Ventilation

Action Needed: Retrofit

23% were under-ventilated and unable to increase ventilation with operational changes alone.



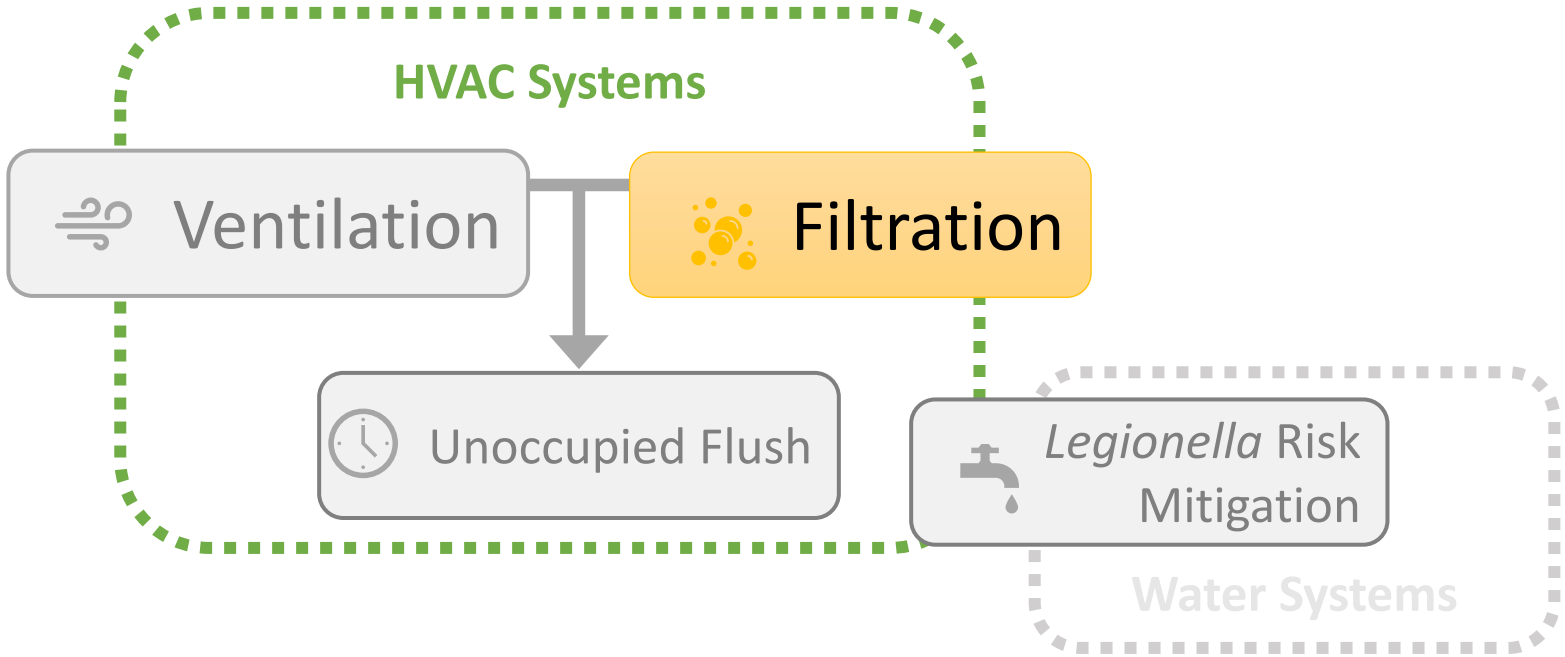
Floor-by-floor AHUs with central OA shaft (no fan)

Installed between 1981 and 1992

62.1 Edition	Office Vent. Rate	Driving Factor
1973	0.11 cfm/SF	First version
1981	0.03 cfm/SF	1970s oil crisis
1989	0.10 cfm/SF	Sick building syndrome

Generally exceeded expected service lives

Find, retrofit/replace deficient ventilation systems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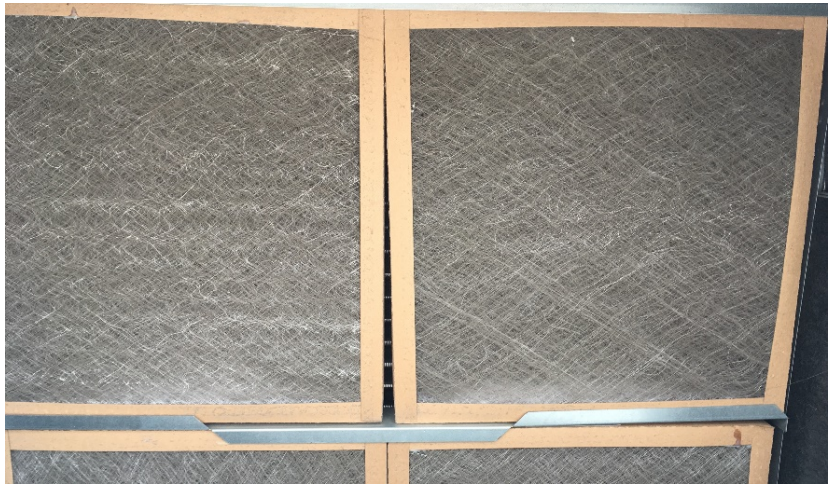
Filtration

ETF: Use filters & air cleaners to achieve MERV-13 (or better) performance on recirculated air

Review existing filter specs

If <MERV-13, compare rated initial and final pressure drops of MERV-13 alternatives

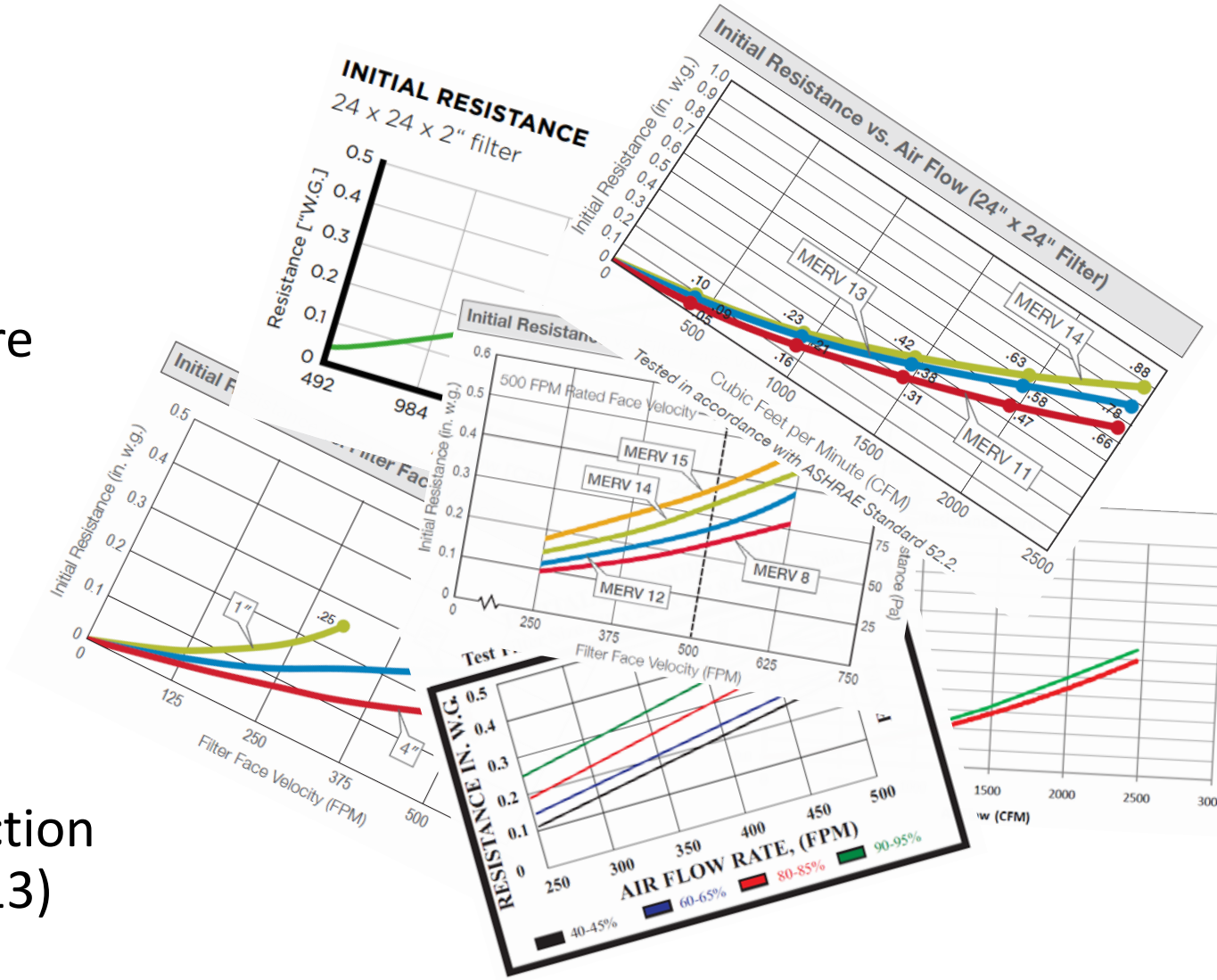
Address potential air bypass around filters



Filtration

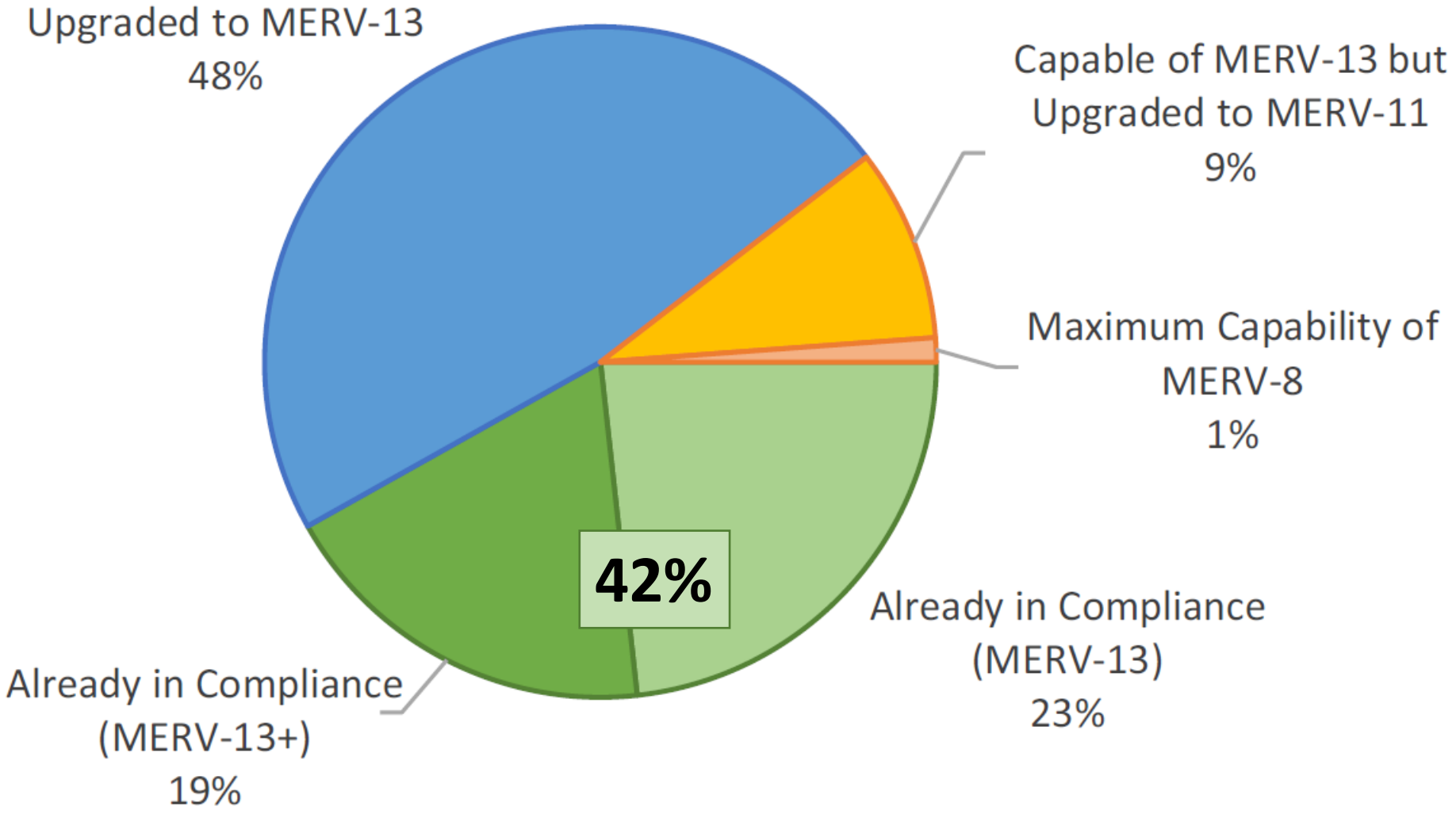
Operators' concerns about physical limitations and cost were primary barriers to filter upgrades.

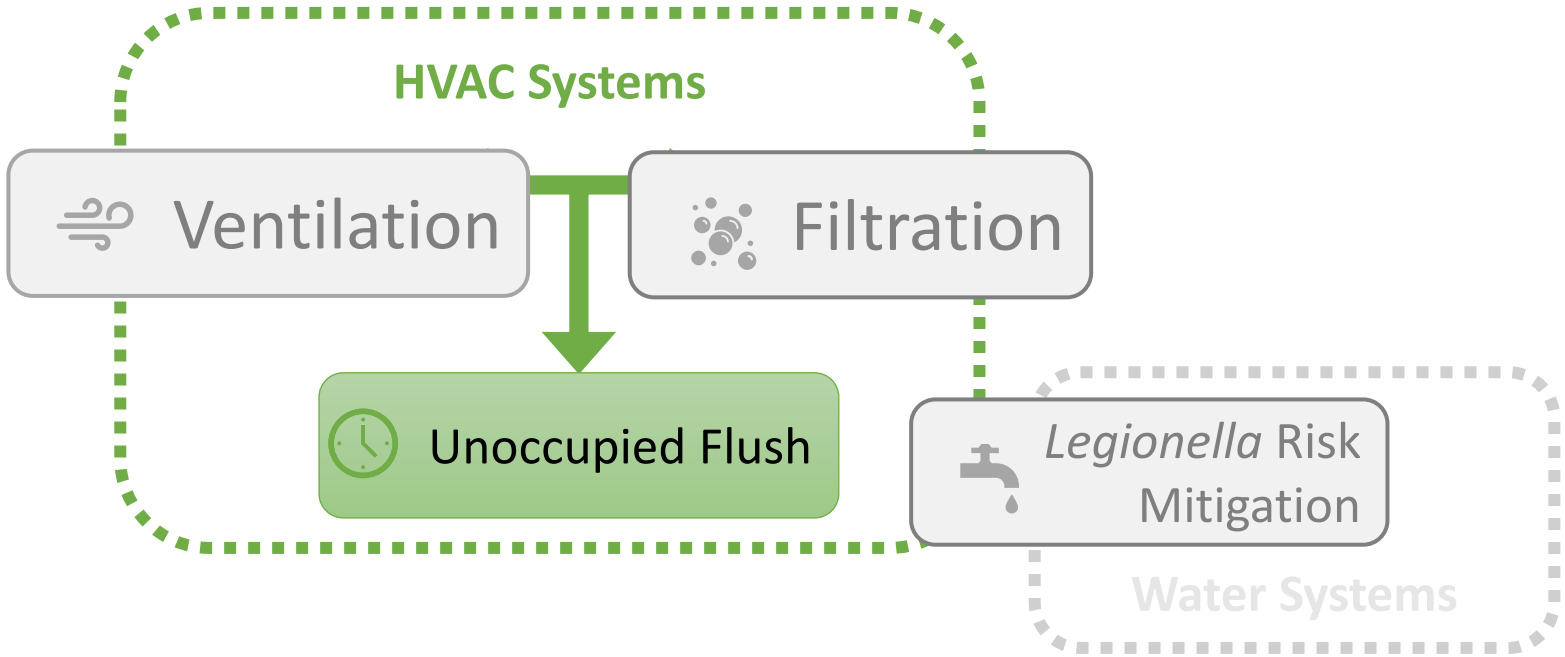
- Physical limitations
  - Filter rack size
  - Concern that higher MERV automatically means higher pressure drop (myth!)
- Cost/benefit
  - 2020 upfront cost: 2-4x more $
  - Higher replacement frequency
  - MERV-13 = best infection risk reduction to cost ratio (Azimi & Stephens, 2013)



Filtration

90% of buildings upgraded to or already used MERV-13; 99% were technically capable.

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Unoccupied Flush

ETF: To flush spaces between occupied periods, supply 3 equivalent clean air changes.

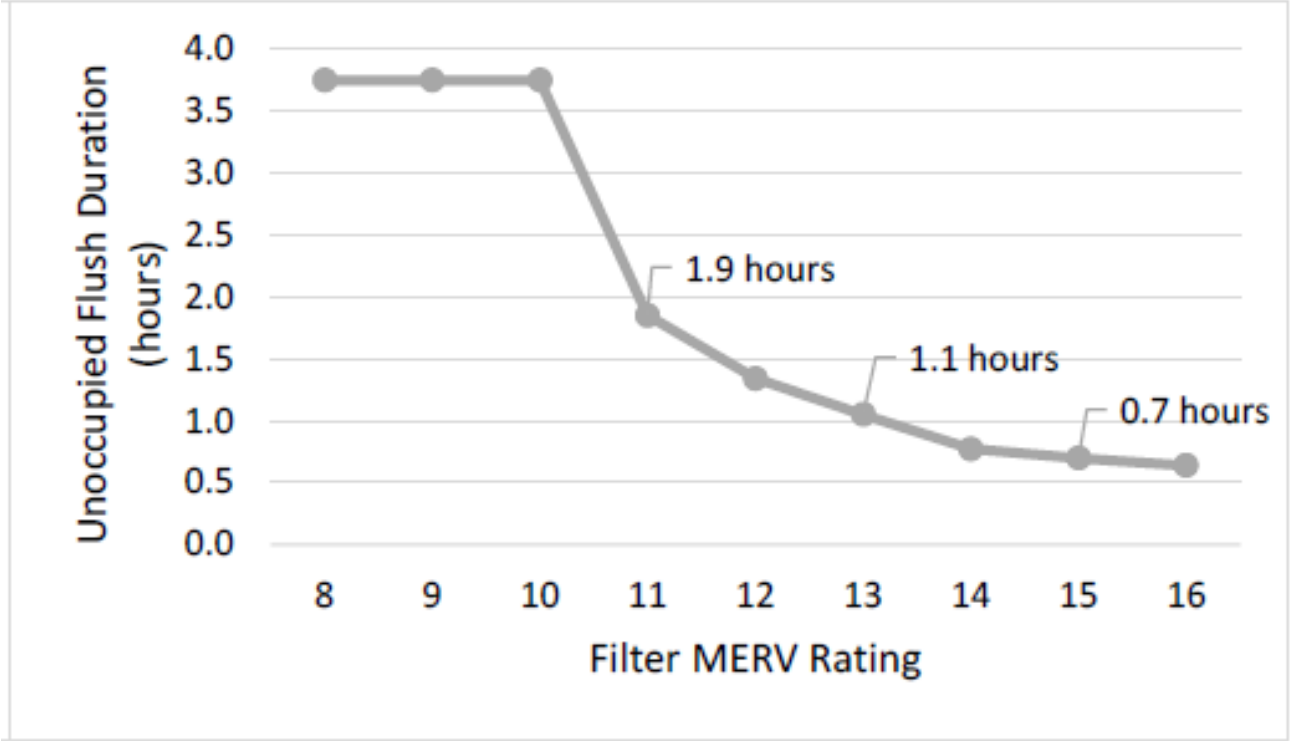
eACH = ventilation + filtration

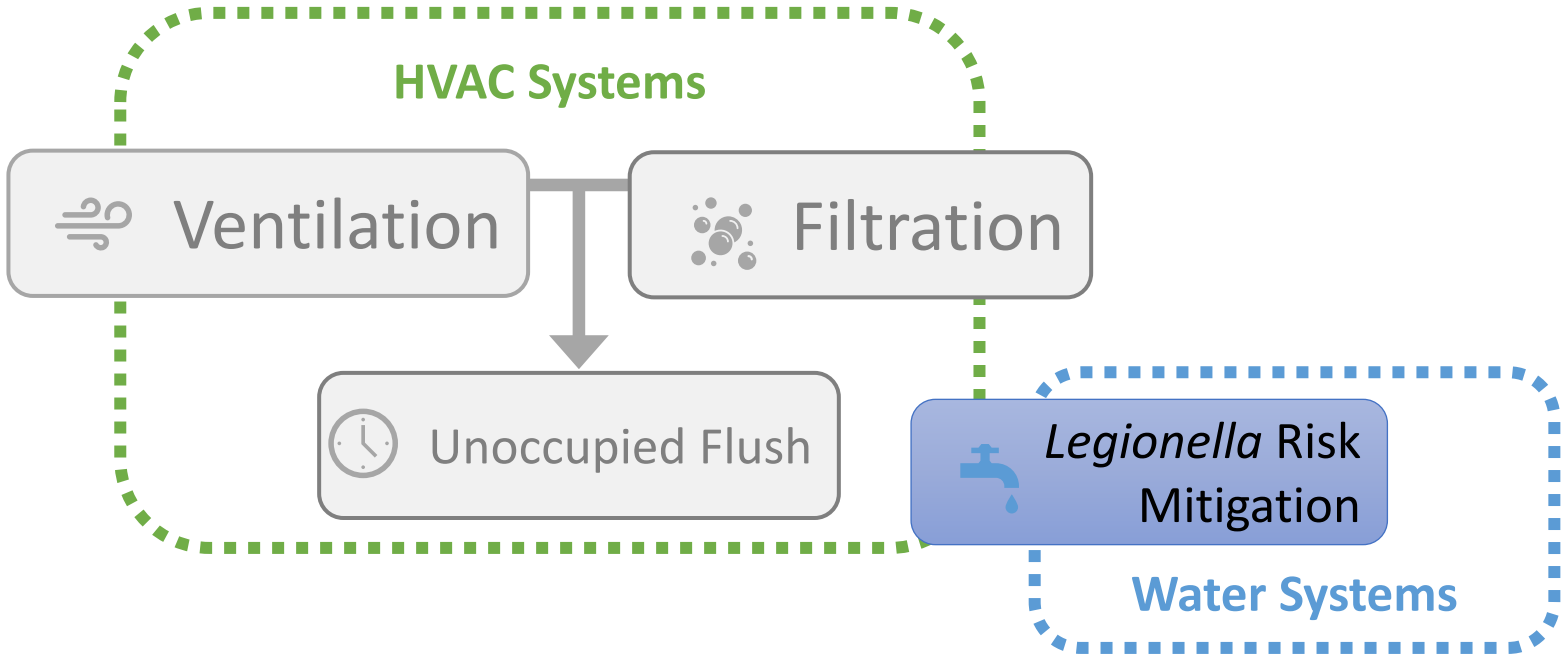
Conservative assumptions:

- minimum system airflow
- filter efficiency for 0.3-1 µm particles

3 / eACH = time to 95% reduction

With better filters, 1-2 hours aligned with morning warmup

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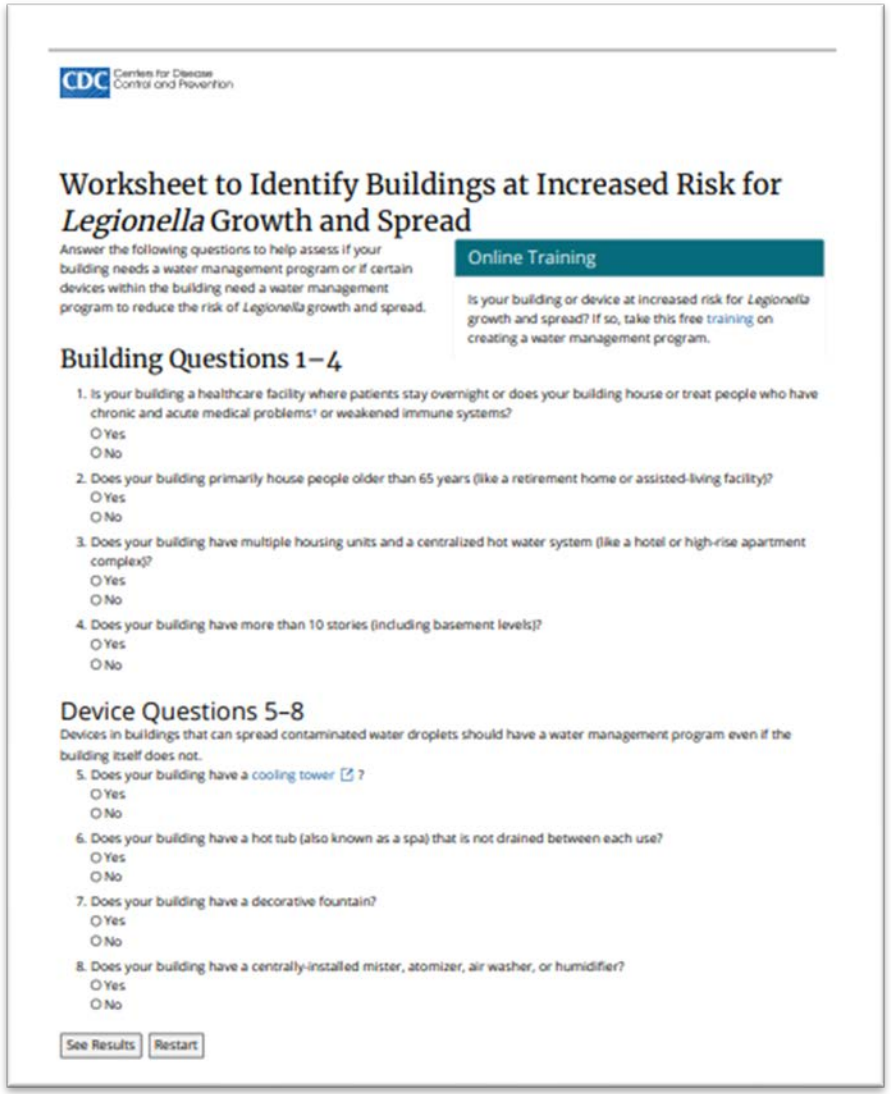
Legionella Risk Mitigation

ETF: Follow CDC Toolkit for developing a Water Management Program.



CDC Centers for Disease Control and Prevention

Worksheet to Identify Buildings at Increased Risk for *Legionella* Growth and Spread

Answer the following questions to help assess if your building needs a water management program or if certain devices within the building need a water management program to reduce the risk of *Legionella* growth and spread.

Online Training

Is your building or device at increased risk for *Legionella* growth and spread? If so, take this free training on creating a water management program.

Building Questions 1–4

1. Is your building a healthcare facility where patients stay overnight or does your building house or treat people who have chronic and acute medical problems[1] or weakened immune systems?
   - ○ Yes
   - ○ No
2. Does your building primarily house people older than 65 years (like a retirement home or assisted-living facility)?
   - ○ Yes
   - ○ No
3. Does your building have multiple housing units and a centralized hot water system (like a hotel or high-rise apartment complex)?
   - ○ Yes
   - ○ No
4. Does your building have more than 10 stories (including basement levels)?
   - ○ Yes
   - ○ No

Device Questions 5–8

Devices in buildings that can spread contaminated water droplets should have a water management program even if the building itself does not.

5. Does your building have a cooling tower ?
   - ○ Yes
   - ○ No
6. Does your building have a hot tub (also known as a spa) that is not drained between each use?
   - ○ Yes
   - ○ No
7. Does your building have a decorative fountain?
   - ○ Yes
   - ○ No
8. Does your building have a centrally-installed mister, atomizer, air washer, or humidifier?
   - ○ Yes
   - ○ No

See Results | Restart

Identify systems with increased risk for *Legionella* growth and spread:

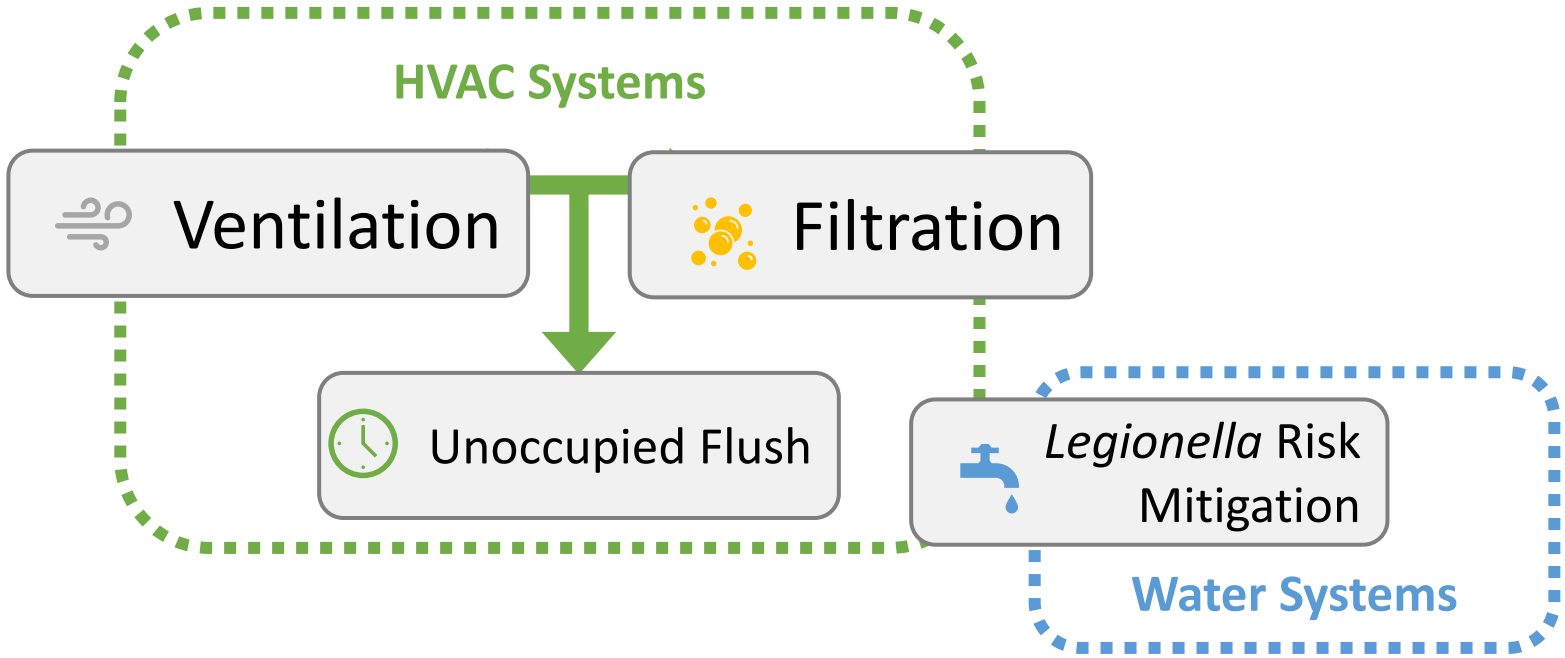
- Cooling Towers
- Domestic water systems >10 stories

Review any Water Management Plans

Review risk mitigation practices:

- Potable system flushing, including tenant plumbing fixtures and appliances
- DHW recirculation above 120 °F

Conclusions



Assessments allow for action, identifying systems with short-term opportunities and long-term needs.

Ventilation

44% Already in Compliance

33% Action Needed: O&M

23% Action Needed: Retrofit

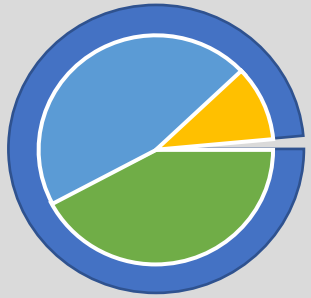
Equipment fully functional? Controls appropriate?

1980s systems need upgrade?

Filtration

90% upgraded to or already used MERV-13 or higher

99% capable of upgrading to MERV-13



Bypass easily avoidable

Unoccupied Flush

3 clean air changes in 1-2 hrs with better filters, aligned with morning warmup

Legionella Risk Mitigation

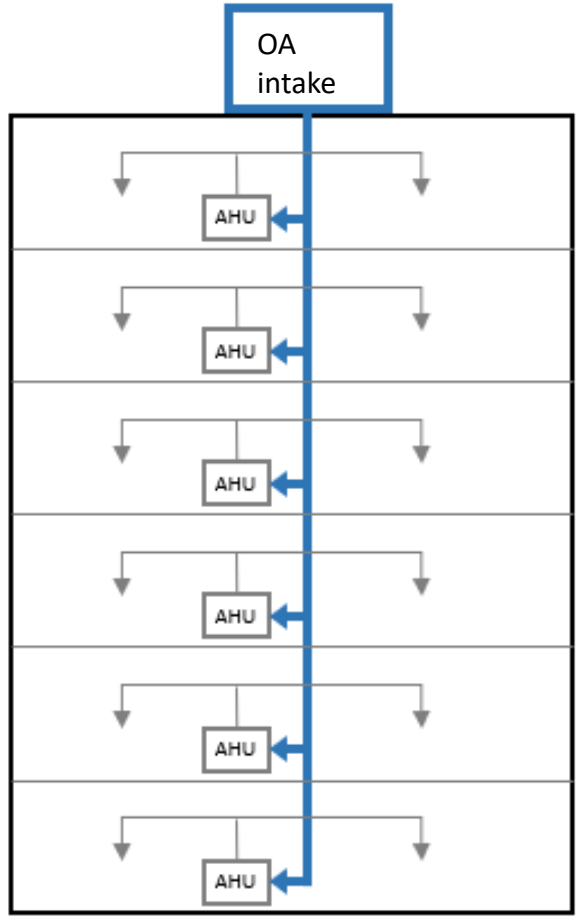
WMPs not widespread, but greater awareness of simple operational practices

Risk mitigation and improved health outcomes are achievable.

Most buildings are **highly adaptable** to COVID risk reduction strategies, even if not designed for infection control.

Better ventilation, filtration, and *Legionella* risk mgmt. are possible **without extreme cost or effort**.

Assessments can be **customized** by building type (schools, multifamily, etc.) and **applied at scale**.



We must start by assessing our existing buildings.

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Questions?

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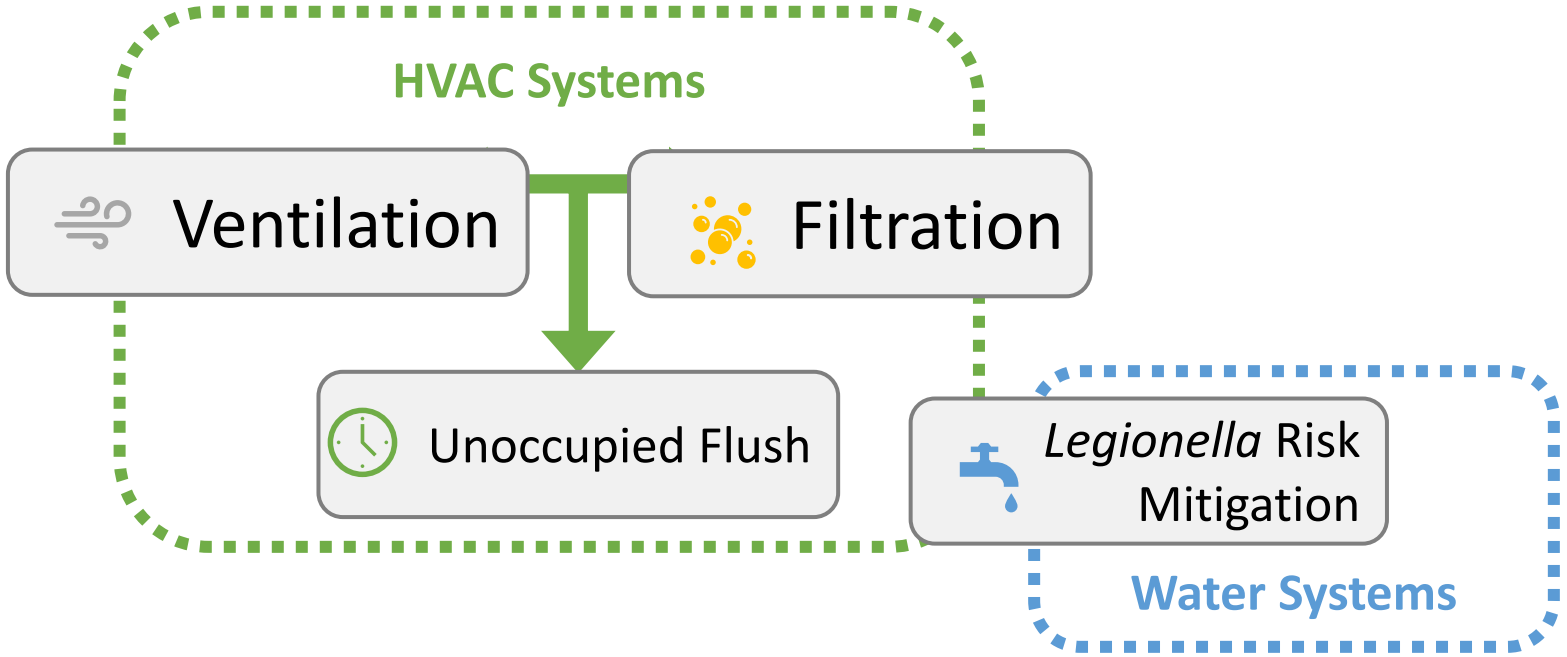

Risk mitigation and improved health outcomes are achievable.

We must start by assessing our existing buildings.

WORK STATEMENT COVER SHEET

Date: January 25, 2022

(Please Check to Insure the Following Information is in the Work Statement)

A. Title	X
B Executive Summary	X
C. Applicability to ASHRAE Research Strategic Plan	X
D. Application of the Results	X
E. State-of-the-Art (background)	X
F. Advancement to State-of-the-Art	X
G. Justification and Value to ASHRAE	X
H. Objective	X
I. Scope	X
J. Deliverables/Where Results will be Published	X
K. Level of Effort	
Project Duration in Months	X
Professional-Months: Principal Investigator	X
Professional-Months: Total	X
Estimated $ Value	X
L Proposal Evaluation Criteria & Weighting Factors	X
M. References	X
N. Other Information to Bidders (Optional)	

Title:

Improving test methods to measure air cleaner performance against airborne pathogens.

WS# 1928

(To be assigned by MORTS - Same as RTAR #)

Results of this Project will affect the following Handbook Chapters, Special Publications, etc.:

Chapter 29 – Air Cleaners for Particulate Contaminants, HVAC Systems and Equipment Handbook.
Chapter 47 – Air Cleaners for Gaseous Contaminants, HVAC Applications Handbook.
Epidemic Task Force Publications and Recommendations

Responsible TC/TG: **TC 02.09**

Date of Vote:

For		
Against	*	
Abstaining	*	
Absent or not returning Ballot	*	
Total Voting Members		

This W/S has been coordinated with TC/TG/SSPC (give vote and date):

TC 02.03	**EHC**
TC 02.04	**TG2.RAST**

Has RTAR been submitted? **Yes**

Strategic Plan Theme/Goals

Work Statement Authors: **

Lead: **Matt Middlebrooks**
Others: **Kathleen Owen** **Joe Pessa**
Chang-Seo Lee **Gemma Kerr**

Proposal Evaluation Subcommittee:

Chair:
Members:

Project Monitoring Subcommittee:
(If different from Proposal Evaluation Subcommittee)

Recommended Bidders (name, address, e-mail, tel. number): **

Blue Heaven Technologies – Bobby Singer, Louisville/KY,
info@blueheaventech.com, 502-357-0132

LMS Technologies – Kevin Kwong, Bloomington/MN,
info@lmstechnology.com, 952-918-9060

Illinois Institute of Technology – Brent Stephens PhD, Chicago, IL
brent@iit.edu, 312-567-3629

(**Three qualified bidders must be recommended, not including WS authors.**)

Potential Co-funders (organization, contact person information):

	Yes	No	How Long (weeks)
Is an extended bidding period needed?		x	
Has an electronic copy been furnished to the MORTS?	X		
Will this project result in a special publication?		x	
Has the Research Liaison reviewed work statement?	X		

* Reasons for negative vote(s) and abstentions

** Denotes WS author is affiliated with this recommended bidder
Use additional sheet if needed.

WORK STATEMENT# 1928

Title:

Improving test methods to measure air cleaner performance against airborne pathogens.

Sponsoring TC/TG/MTG/SSPC:

TC 02.09

Co-Sponsoring TC/TG/MTG/SSPCs (List only TC/TG/MTG/SSPCs that have voted formal support)

TC 02.03
TC 02.04
EHC?
TC 9.7?
TC 9.6?

Plain English Abstract:

Existing industry test methods for air cleaners take one of two approaches – passing the air through the cleaner a single time in a sealed duct or repeatedly recirculating the air through the cleaner in a sealed chamber. Neither reflects many office or home environments. This research will begin to explore the air cleaner performance in a combined system, with a circulating duct attached to a room-sized chamber. The results will highlight how this combination system can be operated and controlled to give meaningful and repeatable measurements of air cleaner performance.

Executive Summary:

Existing test methods for air cleaning devices use simplistic systems such as single-pass efficiency in ducts or single dose decay rates in chambers. Most applications involve more complex scenarios combining HVAC ducts and rooms (chambers). Advancing testing methods will provide critical data for more relevant applications and industry standards. This research will lay the foundation for test methods using a test rig with a duct connected to a chamber by identifying critical parameters for measurement and control, using airborne pathogens as the primary contaminant. The research will also provide key insight into various control methods for airborne pathogens.

Applicability to the ASHRAE Research Strategic Plan:

This project will help address the needed research laid out in the ASHRAE Research Strategic Plan 2021, specifically in the IEQ Initiative:

2. Human-centric and inclusive design and control, considering diversity.
    c. Development of sensing and control solutions to secure high IEQ at the environment level (building, space) and the personal level that considers preferences and behavior and allows adjustments based on occupants' continuous feedback.
3. Requirements beyond the minimum design and development of engineering solutions for substantial improvement of IEQ in spaces occupied by people, plants, or animals.
    d. Development of engineering solutions for removing existing and new man-made and

persistent pollutants (trapping at source, air cleaning, etc.).

4. Protection against the transmission of infectious diseases and future pandemic outbreaks.
    c. Developing advanced systems for improving protection against airborne transmission of infectious diseases and exposure to airborne pollutants, particularly eliminating infection risks at source (breathing zone), but also effective air cleaning technologies and the methods for their certification.

Application of Results:

Direct applications of results from this project include:

- Development of a realistic performance method of test for in-room air cleaners that remove microbial contaminants from air;
- Modification of this MOT to cover removal performance of in-room air cleaners against particulate and gaseous contaminants;
- Modification to other test methods based on data that crosses into related testing;
- Test results can be used by air-cleaner manufacturers to improve device performance;
- Results can be used to update HVAC Systems and Equipment Handbook Chapter 29 *Air cleaners for particulate contaminants* and a new chapter on in-room air cleaners planned for the HVAC Applications Handbook.

This project will also lay groundwork for more realistic performance test methods for in-duct air cleaning devices including particulate and gaseous contaminant filters and electrically-powered technologies.

State-of-the-Art (Background):

The COVID-19 crisis has highlighted the need for high quality data on the effectiveness of air cleaners. The sharp rise in marketing and sales of new devices without applicable standard testing leaves the ASHRAE community with no way to estimate the effectiveness of many air cleaners, and users with the potential for unexpected outcomes when installing unvetted air cleaners.

The existing industry and society test methods for testing air cleaners are based on simplified environmental situations, either ducts (with single-pass efficiency) or enclosed chambers (inject contaminant and measure "draw-down"). The duct tests have also predominantly excluded certain types of air cleaning devices, specifically those that use reactive species or create byproducts when operated. These devices often claim that most of the work of the devices is done, not in the device, but in the rooms. For in-duct devices, this means that current duct-mounted testing is likely to miss the efficacy (Blondeau et al., 2021). For in-room units that do not remove a constant percentage of the contaminant, draw-down testing with the assumption of exponential decay of chamber concentration with time will not capture the removal rates correctly. In addition, byproduct species that are created by the air cleaners need to be identified and quantified, in addition to the removal rate for the injected contaminant (Siegel, 2016; Zhang et al., 2011). However, little work has been done at full-scale levels to determine reliable, practical methods of test.

See below for the most prominent existing air cleaner test methods:

Particles and Dust

ASHRAE 52.2 (duct, single-pass)
ISO 16890 (duct, single-pass)
AHAM AC-1 (chamber, draw-down)

Gases and Molecular Contaminants

ASHRAE 145.2 (duct, single-pass)
ISO 10121-2 (duct, single-pass)
AHAM AC-4 (chamber, draw-down, in development)

Microbial Contaminants

ASHRAE 185.1 (duct, single-pass, UV-C devices only)
AHAM AC-5 (chamber, draw-down, in development)
ASHRAE 185.3 (chamber, draw down with no side duct, early in development)

Advancement to the State-of-the-Art:

Given the current awareness of bioaerosol spread of disease, the many new and newly-popular products coming to market in response, and the likelihood of future potential pandemics, ASHRAE and the Epidemic Task Force plan to emphasize future preparedness. Access to air cleaner efficacy and safety information will be crucial to this effort as it is now. This research project will move us toward having that information before the next pandemic and even to help fight recurring non-pandemic infections such as flu. This information will provide reliable data to enhance the formulation of recommendations going forward, including the ASHRAE Position documents on Airborne infection control and air cleaners.

Justification and Value to ASHRAE:

To develop test methods that are more applicable to actual applications and are appropriate for reactive air cleaning devices, we need data on how various parameters influence the testing and performance. This will allow us to provide test standards that give useful, understandable, and repeatable results. Parameters that need to be examined include device location, airflow, chamber and duct sizes relative to the devices' intended usage, contaminant generation and injection schema, etc. Comparison of realistic results with different setups and different devices will allow better understanding of which parameters are important to specify and their influence on the data product resulting from the testing.

As discussed above, chamber testing is common for some types of in-room air cleaners via the AHAM-1 test with the result expressed as clean air delivery rate (CADR). Testing using a side duct attached to a similar chamber is currently being used and has been proposed for testing such as that proposed here (Burkhead, 2018). PI will be expected to review these approaches and adapt useful portions to the work proposals for this research. Thus, the research needs to build on existing and understood test methods to produce new, more widely applicable test standards as well as the basic data on the air cleaners to be tested to verify the methodology.

Objectives:

1. Using a test rig composed of a duct like that in ASHRAE 52.2 connected to a chamber of at least 1000 cubic feet:
    a. Measure active microbial contamination level in the air and on surfaces within the chamber for various air cleaning devices (including some or all of: pleated media filters of various MERV levels, "electronic" devices such as UVGI, bipolar ionization and others).
    b. Measure byproducts produced during testing including: particles (including inactive microbials), ultrafine particles, ozone and other reactive intermediates, VOCs (including aldehydes), and others as agreed to by the PI and the PMS.
    c. Evaluate impact of contaminant introduction within the chamber and in the duct.
    d. Evaluate impact of contaminant introduction as a single event, intermittent injection, and continuous injection.
    e. Evaluate impact of different air cleaner locations within the chamber only.
    f. Evaluate methods for controlling environmental conditions within the chamber (T, RH).
    g. Evaluate the impact of ventilation rate of the chamber (compared to flow rate of the air cleaner).

Scope/Technical Approach:

To meet the objectives outline above, this project is divided into multiple tasks. Some of the tasks need to be performed in sequence, while others may be performed in parallel. The task deliverables are spelled out in the next section. This section describes the needed work. Some leeway has been given to allow potential PIs to bring their expertise to the project. Many of the questions discussed below for the project will be reasonably addressed in the proposal including likely sampling and analysis techniques. The expectation is that the project will include the test plan development and not sampling or analysis technique development that the PI should already be versed in.

The overall project includes testing 4 types of air cleaners with two challenge organisms and sampling for these organisms within the chamber in air and on chamber surfaces and byproducts/produced species produced during testing including at least: particles (including inactive microbials), ultrafine particles, ozone and other reactive intermediates, and VOCs (including formaldehyde). Testing variables will include injection locations and types (single dose, intermittent, and continuous

Task 1. Test Rig Construction. Construct or modify a test rig to comprise a duct like that described in ASHRAE 52.2 connected to a chamber of at least 1000 cubic feet. Height of chamber to be at least 8 feet to accommodate upper room air cleaning devices, if chosen. The design of the chamber or modifications to an existing chamber must be shared with the PMS either in the proposal or by email/virtual meeting/in-person meeting before the construction is done. PMS must be allowed to give advice and approve the final design before anything other than minor changes are made.

Task 2. Experimental Design. A test plan will be developed and shared with the PMS for their input. This test plan may be done in sections to meet the needs of each layer of testing allowing building on what is learned or presented as one overall test matrix. This plan must include, at least, the choice of devices, surrogate organisms, the locations for air cleaners in the chamber and the other necessary parameters. Organism generation and sampling methods (air and surface), byproduct and intended species sampling and analysis plans, length of tests, sampling schema (# of replicates at each time, # of times, choice of times) must be determined and included. The test design should take into account the manufacturers' instructions for proper use.

Data analysis methods should also be discussed with the understanding that the data may change the needed analysis. Likely efficiencies for the chosen devices or technologies should be considered Once each test plan section that is required for each of the testing subtasks is approved by the PI and PMS, that testing may be performed.

Task 3. Baseline Testing. Test 3-4 air cleaning technologies which may include media filter, UV-C, "ionization," and/or a second reactive type device. Devices should be tested in the chamber in the location(s)s approved through Task 2. The injection shall be a single dose injection. Data with plots shall be shared with the PMS as the data is available. Data analysis such as CADR or percent reduction calculations should also be done and shared with the PMS. This data set shall be discussed with the PMS to determine if it is adequate before moving to task 4.

Task 4. Organism and Injection Testing. Test the air cleaning devices using a minimum of two surrogate microbial agents injected into 2 locations – within the chamber or within the duct. Test the air cleaning devices using three modes of injection – single dose, intermittent dose, and continuous injection. The data from Task 3 may be counted as one organism at one location, single dose testing. Data will be shared with the PMS as it is received. Data analysis to determine that the individual runs are reasonable and other metrics which are developed based on the actual data shall be performed and shared with the PMS. PMS input shall be requested to help the PI determine that the data set is acceptable.

Task 5. Data Analysis and Reporting. Data analysis to determine the influence of the variables on the test results will be finished. Examination of the data to determine if intermittent or continuous injection gives equivalent or better results and whether the answer varies by the type of device. Modifications to the original testing schema based on the results should be made to produce a draft of a recommended test methods. As required by ASHRAE, a Final Report and a Journal Paper will be produced. The Final Report should be presented to the PMS at least a month before the end of the project for the report to be revised based on PMS input. In addition, the PI should review both Chapter 29 – Air Cleaners for Particulate Contaminants, HVAC Systems and Equipment Handbook and Chapter 47 – Air Cleaners for Gaseous Contaminants, HVAC Applications Handbook and prepare suggested revisions based on this project. These recommendations may be included in the Final Report or presented separately.

Deliverables/Where Results Will Be Published:

Deliverables for the tasks include:

Task 1. Report on the design of the chamber or modifications to an existing chamber. Requires PMS approval of the final design before project continues.

Task 2. Test plans must be provided to the PMS and approved before the testing begins.

Task 3. Data and graphs from Baseline testing must be shared with PMS. PMS must decide that data is acceptable before Task 4 begins.

Task 4. Data and graphs from main testing must be shared with PMS. PMS must decide that data is acceptable before the data set is considered complete.

Task 5. Final Report, Journal Paper, and Handbook Chapter recommendations.

In addition to the Final Report to be published by ASHRAE and the Journal Paper also published by ASHRAE, results from the project will be published in ASHRAE Chapter 29 – Air Cleaners for Particulate Contaminants, HVAC Systems and Equipment Handbook, and Chapter 47 – Air Cleaners for Gaseous Contaminants, HVAC Applications Handbook.

The results will also be presented to committees advancing chamber test methods which will likely result in incorporation, and publication, in ASHRAE (e.g. 185.3, TG2.RAST), AHAM (e.g. AC-1, AC-4, AC-5), ISO (e.g. TC142/WG11), and/or ASTM test methods. Additional journal articles and/or conference papers may result from the project, but this is to be determined by the data and the PI.

Progress, Financial and Final Reports, Technical Paper(s), and Data shall constitute the only deliverables ("Deliverables") under this Agreement and shall be provided as follows:

a. Progress and Financial Reports

Progress and Financial Reports, in a form approved by the Society, shall be made to the Society through its Manager of Research and Technical Services at quarterly intervals; specifically on or before each January 1, April 1, June 1, and October 1 of the contract period.

Furthermore, the PI, subject to the Society's approval, shall, during the period of performance and after the Final Report has been submitted, report in person to the sponsoring Technical Committee/Task Group (TC/TG) at the annual and winter meetings, and be available to answer such questions regarding the research as may arise.

b. Final Report

A written report, design guide, test protocol, or manual, (collectively, "Final Report"), in a form approved by the Society, shall be prepared by the Institution and submitted to the Society's Manager of Research and Technical Services by the end of the Agreement term, containing complete details of all research carried out under this Agreement. Unless otherwise specified, six copies of the final report shall be furnished for review by the Society's Project Monitoring Subcommittee (PMS).

Following approval by the PMS and the TC/TG, in their sole discretion, final copies of the Final Report will be furnished by the Institution as follows:

- An executive summary in a form suitable for wide distribution to the industry and to the public;
- Two bound copies;
- One unbound copy, printed on one side only, suitable for reproduction; and
- Two copies on disks: one in PDF format and one in Microsoft Word.

c. Technical Paper

One or more papers shall be submitted first to the ASHRAE Manager of Research and Technical Services (MORTS) and then to the "ASHRAE Manuscript Central" website-based manuscript review system in a form containing such information as designated by the Society suitable for presentation at a Society meeting. The Technical Paper(s) shall conform to the instructions posted in "Manuscript Central" for a technical paper. The technical paper title shall contain the research project number (xxxx-RP) at the end of the title in parentheses, e.g., (1111-RP).

Note: A research or technical paper describing the research project must be submitted after the TC has approved the Final Report. Research or technical papers may also be prepared before the project's completion, if it is desired to disseminate interim results of the project. Contractor shall submit any interim papers to MORTS and the PMS for review and approval before the papers are submitted to ASHRAE Manuscript Central for review.

d. Data

All papers or articles prepared in connection with an ASHRAE research project, which are being submitted for inclusion in any ASHRAE publication, shall be submitted through the Manager of Research and Technical Services first and not to the publication's editor or Program Committee.

The Institution agrees to maintain true and complete books and records, including but not limited to notebooks, reports, charts, graphs, analyses, computer programs, visual representations etc., (collectively, the "Data"), generated in connection with the Services. Society representatives shall have access to all such Data for examination and review at reasonable times. The Data shall be held in strict confidence by the Institution and shall not be released to third parties without prior authorization from the Society, except as provided by GENERAL CONDITION VII, PUBLICATION. The original Data shall be kept on file by the Institution for a period of two years after receipt of the final payment and upon request the Institution will make a copy available to the Society upon the Society's request.

e. Project Synopsis

A written synopsis totaling approximately 100 words in length and written for a broad technical audience, which documents 1. Main findings of research project, 2. Why the findings are significant, and 3. How the findings benefit ASHRAE membership and/or society in general shall be submitted to the Manager of Research and Technical Services by the end of the Agreement term for publication in ASHRAE Insights. The Society may request the Institution submit a technical article suitable for publication in the Society's ASHRAE JOURNAL. This is considered a voluntary submission and not a Deliverable. Technical articles shall be prepared using dual units; e.g., rational inch-pound with equivalent SI units shown parenthetically. SI usage shall be in accordance with IEEE/ASTM Standard SI-10.

Level of Effort:

It is expected that the Tasks above will take approximately two (2) years to complete. The expected total cost for this work is $199,000.

Principal Investigator/Microbiologist (~13 person weeks):	$50,000
Graduate Students/Technicians (~38 person weeks):	$90,000
Facility cost with upgrades (assuming have duct and chamber):	$20,000
Acquisition of test devices (and replaceable components):	$10,000
Other Supplies (microbiology, HVAC, etc.):	$23,800
Miscellaneous items (travel, etc.):	$5,200

Proposal Evaluation Criteria:

No.	Proposal Review Criterion	Weighting Factor
1	Contractor's understanding of Work Statement as revealed in proposal	15%
2	Quality of methodology proposed for conducting research	25%
3	Contractor's capability in terms of facilities (chamber, duct, aerosol generation, microbial monitoring, etc.)	15%
4	Qualification of personnel for this project (especially with respect to airborne microbial contamination).	20%
5	Student involvement	5%
6	Probability of contractor's research plan meeting the objectives of the Work Statement	15%
7	Performance of contractor on prior ASHRAE or other projects. (No penalty for new contractors)	5%

Project Milestones:

No.	Major Project Completion Milestone	Deadline Month
1	Test Rig Construction	4
2	Experimental Design	6
3	Baseline Testing	12
4	Organism and Injection Testing	20
5	Data Analysis and Reporting	23

Authors:

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Others:	Kathleen Owen
	Joe Pessa
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	Gemma Kerr

References:

AHAM 2020. Standard AC-1-2020: Method For Measuring Performance Of Portable Household Electric Room Air Cleaners.

ASHRAE 2017. Standard 52.2-2017: Method of testing general ventilation air-cleaning devices for removal efficiency by particle size.

ASHRAE 2016. Standard 145.2-2016: Laboratory Test Method for Assessing the Performance of Gas-Phase Air Cleaning Systems: Air Cleaning Devices.

ASHRAE 2020. Standard 185.1-2020: Method of Testing UV-C Lights for Use in Air-Handling Units or Air Ducts to Inactivate Airborne Microorganisms.

Burkhead, R. 2018. Presentation to ASHRAE SSPC 52.2 on Side Duct Addition to a Chamber for testing duct-mounted devices' influence on in-room air.

ISO 2013. Standard 10121-2:2013 Test methods for assessing the performance of gas-phase air cleaning media and devices for general ventilation – Part 2: Gas-phase air cleaning devices (GPACD).

ISO 2016. Standard 16890(parts -1, -2, -3, -4, -5): 2016: Air filters for general ventilation.

Y. Zhang, J. Mo, Y. Li, J. Sundell, P. Wargocki, J. Zhang, J.C. Little, R. Corsi, Q. Deng, M.H.K. Leung, L. Fang, W. Chen, J. Li, Y. Sun, Can commonly-used fan-driven air cleaning technologies improve indoor air quality? A literature review, Atmospheric Environment 45 (2011) 4329-4343, 10.1016/j.atmosenv.2011.05.041.

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Other Information for Bidders (Optional):

Feedback to RAC and Suggested Improvements to Work Statement Process

Now that you have completed the work statement process, RAC is interested in getting your feedback and suggestions here on how we can improve the process.

Executive Summary

The formation of this multidisciplinary task group (MTG) in 2018 by President Sheila Hayter was to acknowledge the growing trend of the wellness movement and its relationship within the built environment, and to address this area of opportunity for ASHRAE members.

One of the two main objectives of the MTG on Health and Wellness in the Built Environment (HWBE) was to coordinate with various Technical Committees (TCs), task groups (TGs) and Technical Resource Groups (TRGs) within ASHRAE on the topic of enhancing health and wellness of the occupants in the built environment. The other main objective of the MTG was to help foster and expand internal and external organizational partnerships in this subject area, particularly with organizations developing building rating systems focused on various aspects of sustainability. Some of the ratings systems included occupants' health, wellness, and wellbeing (e.g., ASHRAE; LEED; WELL; Living Building Challenge; RESET, etc.). The MTG was in favor also of expanding external communications with government agencies and research institutes.

The purposes of the MTG's coordination effort are: 1) to increase ASHRAE's knowledge and expertise in this field; 2) to detect and act on potential opportunities; and 3) to become more effective in disseminating research results and practical experience in this field to ASHRAE members and others. These purposes will support the growing interest of ASHRAE members in health, wellness, and the wellbeing of the occupants in buildings.

Based on the analysis of the MTG, these recommendations are made to ASHRAE:

1. Recognize that the principal purpose of most buildings is for human occupancy and that the health and wellness of occupants must be a priority.
2. Acknowledge that energy, resource conservation and other aspects of the 'carbon footprint' of a building are legitimate concerns for ASHRAE members. However, these concerns must not override concern about the health and wellness of occupants.
3. Realize that the design, construction, operation and occupancy of buildings have tangible impacts on the health and wellness of building occupants.
4. Understand that the built environment should function beyond 'minimal' or 'normal' conditions.
5. Accept the WHO definition of heath and recommend that this definition be used in all future ASHRAE documents concerning health in the built environment.
6. Improve coordination between the various ASHRAE efforts directed towards health and wellness in the built environment and should be overseen by ASHRAE Environmental Health Committee (EHC).
7. Appreciate that, relative to IEQ, certification programs vary in rigor and inclusion. None of the certification programs, however, provide an overall holistic assessment of IEQ.
8. Recommend that ASHRAE Environmental Health Committee (EHC) initiates a Position Document (PD) summarizing the impact of the built environment on occupant health and wellness. The MTG.HWBE further recommends that the Position Document include recommendations for further action to be taken by ASHRAE to fill knowledge gaps pertaining to health and wellness in the built environment.
9. Leverage the knowledge and experience of ASHRAE membership to pursue a process for the assessment of IEQ that can be referenced by certification schemes.

1. Context

ASHRAE President Sheila Hayter spearheaded the formation of this multidisciplinary task group (MTG) in 2018 to acknowledge the growing trend of the wellness movement and its relationship within the built environment, and to address this area of opportunity for ASHRAE members.

The purposes of the MTG's coordination effort are: 1) to increase ASHRAE's knowledge and expertise in this field; 2) to detect and act on potential opportunities; and 3) to become more effective in disseminating research results and practical experience in this field to ASHRAE members and others. These purposes will support the growing interest of ASHRAE members in health, wellness, and the wellbeing of the occupants in buildings[1].

The scope of work includes:

1. Review existing definitions of health that address health and wellness as a concept. The objective is to develop or recommend a usable definition of health and wellness, and to determine their defining parameters.
2. Assemble a body of knowledge of existing ASHRAE documents and standards on the topic of indoor air quality, indoor environmental quality, health, and wellness.
3. Compare existing building certification and rating systems worldwide as they relate to indoor environmental quality (IEQ) parameters, and their known or potential impacts on health and wellness.
4. Provide a summary report and recommendations to the Environmental Health Committee (EHC). The recommendations should address how can ASHRAE help mitigate untoward impacts from the built environment on occupant health/wellness. The summary report will also promote research on topics such as the impacts of IEQ parameters and their synergies on health and wellness, as well as changes in the built environment. Recommendations shall include how to expand internal and external organizational partnerships in this subject area.

2. Background

In the 21st century, the impact of the built environment on the health and wellness of building occupants has become widely recognized. However, it is important to note that this is not new information. Ancient Romans, and perhaps Greeks and east Asians, vented exhausts from hypocaust furnaces through flues a full millennium prior to any knowledge of carbon monoxide and its harmful effects. However, energy conservation efforts, among other building trends in the late 20th century, have often resulted in adverse effect on occupant health and wellness, habitually referred to as Sick building syndrome (SBS). The hallmark of these occupant complaints is their tight temporal association with building occupancy, and their rapid resolution, within minutes to hours, when affected occupants leave implicated buildings. Sick building syndrome is distinguished from more medically serious building-related illness by its subjective nature, reversibility, and high prevalence within implicated buildings across the nonindustrial building stock in North America and Europe [2].

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[1] https://www.sciencedirect.com/science/article/pii/S0360132313002539
[2] https://www.cdc.gov/niosh/nioshtic-2/20000157.html

Occupant health and comfort are still not always included in balancing the costs and benefits inherent in the design, construction, and operation of buildings. Thus, the occupants often bore the decline in the indoor environmental quality in the buildings they occupy. Evidence documenting the occupant-related adverse health and discomfort issues continues to grow. This has resulted in the rise of indoor air quality (IAQ) as a consulting discipline and the development of an industry of IAQ specialists since the 1980s. Studies by Fisk, Mendell and others are focusing on the tangible costs of IAQ-related sickness and hospitalization while other costs such as loss of productivity and alertness at tasks are still to be quantified [3, 4].

The ASHRAE Terminology document (www.ashrae.org/ashraeterms) defines indoor environmental quality (IEQ) as "a perceived indoor experience of the building indoor environment that includes aspects of design, analysis, and operation of energy efficient, healthy, and comfortable buildings. Fields of specialization that contribute to that perceived experience include architecture, heating, ventilation and air-conditioning (HVAC) design, thermal comfort, indoor air quality (IAQ), lighting, acoustics, and control systems" [5]. Based on this definition, the work of the MTG revolved around these specializations and their relationship to the perception of health and wellness. They are further explained in more detail below.

2.1 Architecture

Architecture is defined as the art and technique of designing a building, as opposed to the skills associated with the construction of a building. The practice of architecture usually fulfills both the utilitarian and aesthetic ends, although different societies have different views on their relative importance. Because every society has a spatial relationship to the natural world and to other societies, the structures they produce reveal much about their environment (including climate and weather), history, ceremonies, and artistic sensibility, as well as many aspects of daily life.

Opinions differ as to what are basic principles on which architectural design should be based on, from durability to beauty, symmetry to empty (or negative) space. However, the characteristics that seem to distinguish a work of architecture from other built structures are: (1) the suitability and the adaptability of it to a particular human activity; (2) the stability and permanence of the work's construction; and (3) the emotions and ideas expressed through its form. If the function is chiefly utilitarian, as in a factory, emotions are of less importance. If the function is chiefly expressive, as in a monumental tomb, permanence and emotions are important criteria [6].

In recent years, additional benefits and needs related to the Built Environment (BE) have been recognized and studied. Studies have shown that a perceived good BE by its occupants help to increase productivity, reduce detrimental health effects, reduce healthcare costs, reduce sick leave, and reduce employee turnover rates.

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[3] http://doas.psu.edu/fisk.pdf

[4] https://www.theguardian.com/commentisfree/2021/nov/06/student-hall-from-hell-hath-no-windows-to-distract-from-study-or-sleep

[5] *Interactions Affecting the Achievement of Acceptable Indoor Environments*, ASHRAE Guideline 10 – 2016.

[6] https://www.britannica.com/topic/architecture

When discussing public health, architecture is not generally the first thing that springs to mind. Yet, its influence on human health and emotional comfort is inescapable [7,8]. Numerous studies, especially in healthcare settings, show that a healthcare design that helps patients deal with stress can increase their recovery rate and reduce their hospital stay [9, 10]. The same positive health effect can probably be said for the architecture of most buildings [11]. The effect on the health and wellness of the occupants of a building design for human occupancy should then be paramount in any concept. For example, views of the outdoors can connect occupants with nature, and can help to reduce stress. Open and accessible stairways can encourage use of stairs rather than elevators, thereby promoting an active lifestyle. Material selection in a building can affect pollutant concentrations found in indoor air. On the other hand, unintended consequences of well-meaning measures must also be considered when evaluating a building material. Materials that are, for example, less chemically treated to lessen pollutant emission can get moldy more rapidly if not installed and maintained properly.

In natural disasters, the BE can serve as a refuge, such as from wildfire smoke, or the BE can remain functional during a region wide loss of power. Additionally, the role of the BE in either promoting or reducing the spread of infectious aerosols is now made tragically evident by the COVID-19 pandemic. Although infrequent, these aspects of the BE cannot be ignored since it can become a peril to the occupants during these events. The BE cannot be designed for only 'normal' conditions since this will serve as a multiplier of the hazard when an unexpected peril inevitably arrives. Conversely, the BE should maintain the health and wellness of the occupants during a peril.

2.2 HVAC Design and Controls

HVAC design has a substantial impact on health and wellness of building occupants. HVAC systems must provide enough clean, tempered ventilation air and acceptable thermal conditions as a minimum requirement. HVAC systems can affect the multiple aspects of IEQ in varying manners and to a varying extent. Inadequate filtration can allow introduction of outdoor particulates to the building, which could negatively impact occupants if the airborne levels become elevated. Noise and vibration that affect acoustic conditions may also be related to poor HVAC design. HVAC controls that depressurize buildings can foster dampness in interstitial spaces in hot, humid climates or pull unfiltered, unconditioned outdoor air in through leaks and cracks. This in turn can degrade IEQ and promote mold growth. The use of advanced HVAC controls can give high precision in the catering of IEQ to individual spaces based on occupancy and function. HVAC designers must consider the many ways that the HVAC system interacts with occupants and other building systems to create the overall IEQ conditions in a building.

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[7] Karl Johnson, The Guardian, 11 June 2013. https://www.theguardian.com/sustainable-business/public-health-architecture-impact-wellbeing

[8] Equipe ArchDaily Brasil. "Architecture and Health: How Spaces Can Impact Our Emotional Well-Being" [Arquitetura e saúde: como o espaço impacta no bem-estar emocional] 28 Aug 2021. ArchDaily. (Trans. Duduch, Tarsila). https://www.archdaily.com/967003/architecture-and-health-how-spaces-can-impact-our-emotional-well-being.

[9] Creasy, Timothy Michael, "The Wellness Clinic: A New Approach to Healthcare Design. " Master's Thesis, University of Tennessee, 2012. https://trace.tennessee.edu/utk_gradthes/1143

[10] Ulrich RS. Effects of interior design on wellness: theory and recent scientific research. Journal of Health Care Interior Design: Proceedings From the ... Symposium on Health Care Interior Design. Symposium on Health Care Interior Design. 1991 ;3:97-109. PMID: 10123973.

[11] Petermans, Ann & Pohlmeyer, Anna. (2014). Design for subjective well-being in interior architecture. 10.13140/2.1.1584.2241.

A well-designed and operated HVAC system can provide optimal IAQ. However, to contribute fully to health and wellness, the HVAC must also be integrated with overall building design. For example, how the HVAC systems effectively control the relative humidity will affect the performance of the building envelope. [12] Also, some natural ventilation might increase the perception of good indoor air by allowing personal control for the occupant. However, it must be noted that natural ventilation can possibly counter the effectiveness of the HVAC system.

2.3 Thermal Comfort

The thermal environment of a building affects health, performance, and comfort of its occupants. ASHRAE Standard 55, Thermal Environmental Conditions for Human Occupancy, addresses the minimal requirements for the thermal environment of a building with regards to human comfort. A commonly used model for thermal comfort is predicted mean vote (PMV) and predicted percentage dissatisfied (PPD), which was established by Professor Ole Fanger in 1970 and modified in 1986[13]. This model is based on a large sample of human response as well as physical equations, including six key parameters for thermal comfort: ambient temperature, radiant temperature, relative humidity, clothing level, metabolic rate, and air velocity. ASHRAE 55 uses an adaptive thermal comfort acceptability model based on PMV-PPD.

To maximize thermal comfort in buildings, some key parameters of the model such as radiant temperature can be controlled by analyzing the placement, configuration, and type of windows and skylights. The windows and skylights can also provide appropriate shading to avoid "hot spots" caused by direct sunlight [14]. Other factors related to the thermal comfort such as clothing level and activities can vary significantly between individuals. Also, humans can adapt somewhat to a wide range of thermal conditions by development adjustment, acclimatization, cultural practices and use of technology [15].

2.4 Indoor Air Quality (IAQ)

ASHRAE 62.1 defines 'acceptable IAQ' as having no known harmful contaminants, and also when most occupants report that they are not dissatisfied. The IAQ in a building can be compromised by many different airborne pollutants of concern including volatile organic compounds (VOCs), chemicals such as carbon monoxide and ozone, mould and particulate matter [16]. Poor IAQ can have short-term and/or long-term effects to occupants, depending on the pollutant, the quantity, and the duration of exposure. Individuals can react differently to air pollutant exposure, depending on their sensitivities, such as asthma or pre-existing medical conditions, as well as their personal demographics, such as age [17].

IAQ is directly impacted by the activities inside and outside the building, including by occupants' work inside the building. Activities that are outside the building that impact IEQ include road construction or wildfires. IAQ relies on the adequacy of the building operation and maintenance,

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[12] Seppänen O, Kurnitski J. Moisture control and ventilation. In: WHO Guidelines for Indoor Air Quality: Dampness and Mould. Geneva: World Health Organization; 2009. https://www.ncbi.nlm.nih.gov/books/NBK143947/

[13] https://www.sciencedirect.com/science/article/pii/S1364032113003535

[14] https://www.wbdg.org/design-objectives/productive/provide-comfortable-environments

[15] https://www2.palomar.edu/anthro/adapt/adapt_1.htm

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

[17] https://www.cpsc.gov/Safety-Education/Safety-Guides/Home/The-Inside-Story-A-Guide-to-Indoor-Air-Quality

including maintaining a proper ventilation rate, air distribution effectiveness, and filtration. IEQ also relies on the proper operation of other building systems such as localized exhausts and water features.

It is noted that standards such ISO, CIBSE, and ASHRAE Standard 62 series contain minimum requirements for acceptable IAQ for commercial and residential buildings with set ventilation rates based on odor control. In addition, the ASHRAE Standards have made provisions for sampling indoor air for contaminants, and also for asking about occupant satisfaction in its IAQ procedure (IAQP) [18].

2.5 Lighting

Lighting can refer to daylighting or electric lighting, both of which are important factors for human visual and non-visual needs. There are multiple components to lighting including illumination for visual task performance, glare from direct light, flicker, color, duration, and contrast between interior surfaces for navigation purposes.

The absence of quality light exposure can decrease alertness, adequate sleep, and a positive mood, and it can increase the risk for mood disorders such as seasonal affective disorder, as well as the ability to set and maintain circadian rhythms or natural daily rhythm [19].

When it comes to lighting in buildings, the focus has been recently on reducing energy consumption from conventional fluorescent lighting with more energy-efficient LED lighting. Recently, new studies are being initiated to investigate its effect on health and sleep [20]. However, few standards exist that provide guidance as to how lights should be controlled to provide health benefits [21].

2.6 Acoustics

Good acoustic conditions are fundamental to the quality and enjoyment of the occupied spaces either in homes, workplaces, or other building types. Sound, either from outside of the building or from another place within the building, can affect both the human physiology and psychology. Noise, or "unwanted sound", is associated with various mental and physical health symptoms. [22, 23] It can increase heart and respiration rate as well as increased blood pressure. Noise can also be a cause of sleep disturbance and reduced learning and performance. Conversely, pleasant sounds can help create a sense of wellbeing and relaxation.

For example, a Finnish study found that open office occupants suffered more from difficulties in concentration and tiredness. In open offices, a greater percentage of those suffering from

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[18] *Ventilation and Acceptable Indoor Air Quality in Residential Buildings.* ASHRAE Standard 62.2 – 2019. https://www.osti.gov/servlets/purl/1635274

[19] https://www.researchgate.net/publication/283459751_The_importance_of_light_to_health_and_well-being

[20] https://www.ledsmagazine.com/lighting-health-wellbeing/article/14209139/doe-backs-study-looking-at-lightings-effect-on-health-and-sleep

[21] Halper, M., (2017), European lighting regulations could help usher in human centric lighting. LEDs Magazine, March 2017, pp. 39-42

[22] https://www.bregroup.com/bretrust/wp-content/uploads/sites/12/2019/02/Acoustic-design-and-testing-Trust-report-online-version-1.pdf

[23] H. A. R. Jensen, B. Rasmussen and O. Ekholm, "Neighbour noise annoyance is associated with various mental and physical health symptoms: results from a nationwide study among individuals living in multi-storey housing," *BMC Public Health,* pp. 1-10, 2019.

symptoms attributed symptoms to office noise [24]. A meta-analysis published in 2015 found that building acoustics was the one IEQ parameter that did not consistently score better even in green buildings [25].

Acoustical comfort, including the ability to focus, collaborate, or have confidential conversations, should be addressed in a way that is both effective and aesthetically pleasing. Ultimately, the objective must shift away from specifications only (e.g., Sound Transmission Class [STC], or weighted overall sound pressure level [dBA]) towards psychoacoustic metrics (i.e., privacy, intelligibility, comfort). These metrics better evaluate the collective outcome of acoustical parameters (e.g., architectural, environmental, electronic, etc.) for the occupant in the built environment.

2.7 Controls Systems and Personal Control

Control systems play an important role in the operation of a building, and these controls can determine whether many of the design aspects included in the original plan function as intended. Control systems for heating, ventilating, air-conditioning (HVAC) and related systems are at the core of building performance. The control systems can assist in conserving resources through the scheduling, staging, and modulation of equipment to meet the needs of the occupants, as well as the systems that they are designed to serve**.** When the systems work well, the indoor environment promotes productivity with the light, comfort, and ventilation that occupants need to carry out their tasks [26].

There are interactions among the individual IEQ categories that influence overall IEQ and complicate the ability of engineers and practitioners to design controls systems that operate buildings for human health. There is a significant interaction between thermal comfort and IAQ. For example, higher temperature can increase the emission of Volatile Organic Compounds (VOCs) from materials, but lower temperature create discomfort for some occupants. Low relative humidity levels can worsen the health effects of particulate matter and virus transmission, and increase discomfort while higher humidity can support mould growth in some cases. High air velocity creates a cooler thermal environment, and it can also reduce or redistribute local air pollutant concentrations.

Another important factor as shown by a study in 2019 is that occupants with a higher level of personal control were reported to be more productive within their working environment [27]. Moreover, occupants who maintained high degrees of personal control over their indoor environment reported higher levels of IEQ satisfaction. However, it is noted that allowing more personal control by the occupants can also complicate the operation of the building by the control systems.

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[24] Haapakangas, Annu & Helenius, Riikka & Keskinen, Esko & Hongisto, Valtteri. (2008). Perceived acoustic environment, work performance and well-being–survey results from Finnish offices.

[25] G. J. Allen, P. MacNaughton, J. G. Cendeno Laurent, S. S. Flanigan, E. S. Eitland and J. D. Spengler, "Green buildings and health," *Global Environmental Health and Sustainability,* vol. 2, pp. 250-258, 2015.

[26] https://www.sciencedirect.com/book/9781933742076/the-ashrae-greenguide

[27] Sakellaris I, Saraga D, Mandin C, de Kluizenaar Y, Fossati S, Spinazzè A, Cattaneo A, Szigeti T, Mihucz V, de Oliveira Fernandes E, Kalimeri K, Carrer P, Bartzis J. Personal Control of the Indoor Environment in Offices: Relations with Building Characteristics, Influence on Occupant Perception and Reported Symptoms Related to the Building—The Officair Project. *Applied Sciences*. 2019; 9(16):3227. https://doi.org/10.3390/app9163227.

3. Definition of Health and Wellness

One of the objectives of the MTG.HWBE is to develop or recommend a usable definition of health and wellness and its defining parameters.

The criteria defined by the MTG.HWBE to develop or recommend a definition for health and wellness were to:

- Provide a broad/high level and inclusive definition of health.
- Use an existing definition so not to add unwanted 'noise' to the field and to the definition of health.
- Show that health is a spectrum that goes beyond 'acceptable' or critical conditions. and that health can be improved, not just maintained.
- Include people in the definition, not just buildings.
- Include both perceived health (comfort), mental health, physiological and psychological health.
- Avoid ambiguous and redundant terminology (e.g., wellness, well-being) and focus on the word 'health' as an umbrella term.
- Keep it simple.

The relationship between the physical characteristics of the built environment and the health of its occupants is not completely understood. However, there is ongoing research connecting the productivity, cognitive capabilities, satisfaction, and physiological health of occupants to various building design elements and attributes. Among the topics of interest, each with varying degrees of known causality, are clean air and surfaces, humidity, properly controlled temperature, access to daylight, light intensity and distribution, sound and vibrations, opportunities for social interactions, access to adequate nutrition, water quality, opportunities for exercise, connection to the outdoors, and exposure to nature. Moreover, as noted before, the interactions or synergies of these parameters are not well understood either.

According to the World Health Organization (WHO): "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." [28]

Beyond the WHO definition, the task group reviewed various papers and definitions by the Center for Disease Control and Prevention (CDC), as well by the National Institute for Occupational Safety and Health (NIOSH). Some of these definitions are listed below:

- "Health is more than the absence of disease; it is a resource that allows people to realize their aspirations, satisfy their needs and to cope with the environment in order to live a long, productive, and fruitful life."[29]

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[28] World Health Organization. (N.d.). "Constitution." https://www.who.int/about/who-we-are/constitution.

[29] Centers for Disease Control and Prevention. (Updated October 2018). "Well-being Concepts." https://www.cdc.gov/hrqol/wellbeing.htm#:~:text=There%20is%20no%20consensus%20around,with%20life%2C%20fulfillment%20and%20positive.

- "Employee health affects an organization in various ways, as direct costs such as healthcare costs or as indirect costs such as productivity and engagement. When it comes to workplace health, there are seven key performance indicators (KPI's) to consider. These include physical fitness, physical comfort, physical nourishment, cognitive well-being, social well-being, emotional well-being, and environmental well-being. Various environmental attributes of these seven KPIs in the workplace affect not only health but also performance and engagement of employees via their physical, mental, and social interactions within the environment. For instance, ergonomics, acoustics, lighting, thermal comfort, and olfactory comfort address the overall physical comfort while biophilic components contribute to employee cognitive functions as well as their capacity to cope with mental stress and fatigue. These seven KPIs of workplace health ultimately contribute to five positive organizational outcomes, including healthy organizational culture, higher productivity, improved individual health and safety, financial savings, and enhanced reputation of the organization." [30]
- "Well-being is a positive and unifying concept that captures multiple factors that contribute to workers' health and quality of life. This work lays the foundation for larger well-being measurement efforts and will provide tools for NIOSH partners to help workers flourish". [31]
- "The *Total Worker Health* (TWH) approach prioritizes a hazard-free work environment for all workers. It also brings together all aspects of work in integrated interventions that collectively address worker safety, health, and well-being. Traditional occupational safety and health protection programs have primarily concentrated on ensuring that work is safe and that workers are protected from the harms that arise from work itself. TWH builds on this approach through the recognition that work is a social determinant of health. Job-related factors such as wages, work hours, workload, interactions with coworkers and supervisors, and access to paid leave impact the well-being of workers, their families, and their communities. The long-term vision of the TWH program is to protect the safety and health of workers and advance their well-being by creating safer and healthier work". [32]

While there is a lot of similarity among the definitions reviewed and discussed, the WHO definition is the most succinct and inclusive. Hence, the recommendation from the MTG was to accept the WHO definition of health.

The task group decided to use an existing definition of health instead of 'reinventing the wheel'. The task group focused on the connection to the built environment as a contributing factor to health and well-being. The WHO definition recognizes that health extends beyond 'acceptable' conditions or critical health issues. The WHO definition is a broad, umbrella definition that covers physical, mental, and social aspects of health. This definition thus reflects the complexity of the subject.

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[30] Lee, Young. (2019). "Workplace health and its impact on human capital: seven key performance indicators of workplace health. *Indoor Environment and Health*. DOI: 10.5772/intechopen.85936.
[31] Chari R, Chang CC, Sauter SL, et al. Expanding the Paradigm of Occupational Safety and Health: A New Framework for Worker Well-Being. *J Occup Environ Med*. 2018;60(7):589-593. doi:10.1097/JOM.0000000000001330
[32] https://www.cdc.gov/niosh/twh/totalhealth.html

The term health is often used synonymously or in conjunction with terms like comfort, well-being, and wellness. The task group did not find a consensus that makes a clear distinction between these terms. For example, CDC states: "There is no consensus around a single definition of well-being, but there is general agreement that, at a minimum, well-being includes the presence of positive emotions and moods (e.g., contentment, happiness), the absence of negative emotions (e.g., depression, anxiety), satisfaction with life, fulfillment and positive functioning" [33]. Since the task group did not see a significant difference between this definition of well-being and the WHO and CDC definitions of health, it was agreed that it is not productive to distinguish between these terms.

It is noteworthy that, in September 1988, an inter-ministerial committee of the Ontario Canada government reached a similar conclusion [34]. Beginning in 1976, various provincial ministries collectively had investigated over 2,000 indoor air complaints. In response to the then emerging concerns about 'sick building syndrome' or 'tight building syndrome', this committee was formed and charged with developing a coordinated response to indoor air quality issues. These responses included identifying associated hazards, developing protocols, and recommending acceptable criteria. Since the impetus for the committee concerned health effects of IAQ, an early goal was to adopt a definition of health. The WHO definition, which includes both health and comfort, was adopted. Due to the prevalence of IAQ complaints that related to comfort rather than clinically significant diseases, including comfort in the definition was key to the committee's preference of the WHO definition.

4. Review of Resources related to Health and Wellness

At the same time as the review of various health and wellness definitions, a compilation of relevant literature within ASHRAE, and of rating systems from other organizations was performed to provide a basis for review and comparison. The focus was on organizations developing building rating systems focused on various aspects of sustainability, some including health, wellness and wellbeing (e.g., ASHRAE; LEED; WELL; Living Building Challenge; RESET, etc.).

Criteria for comparison of different certification systems and standards were also compiled. These criteria are primarily based on a recent review paper from Wei et. al. (2020) [35] and are generally included in best practice rating systems on the topic of health and wellness in the built environment. This list includes most aspects of IEQ within the scope of ASHRAE as discussed earlier such as architecture, HVAC design, thermal comfort, indoor air quality (IAQ), lighting, acoustics, and control systems. It was important to adopt a set of criteria to provide a basis for comparison between different documents and different rating systems. However, it is expected that there will be some subjectivity depending to the specific topic of their interest.

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[33] Centers for Disease Control and Prevention. (Updated October 2018). "Well-being Concepts." https://www.cdc.gov/hrqol/wellbeing.htm#:~:text=There%20is%20no%20consensus%20around,with%20life%2C%20fulfillment%20and%20positive.

[34] https://www.aivc.org/sites/default/files/airbase_4009.pdf

[35] Wei, W., Wargocki, P., Zirngibl, J., Bendžalová, J. and Mandin, C. (2020) 'Review of parameters used to assess the quality of the indoor environment in Green Building certification schemes for offices and hotels', *Energy and Buildings*. Elsevier B.V., 209, p. 109683. doi: 10.1016/j.enbuild.2019.109683.

The review process undertaken by the MTG.HWBE is certainly not all encompassing. It is quite possible that existing documents might have been updated recently, that some relevant documents might have not been identified nor reviewed, or that new documents and rating systems have emerged since the beginning of the process and were not included.

4.1 Review of Resources within ASHRAE Related to Health and Wellness

A list of ASHRAE documents was compiled based on a search for the terms “indoor air quality” and “indoor environmental quality” in ASHRAE’s Guidelines, Standards and Position Documents. For Guidelines and Standards, terms such as IAQ, IEQ, air quality, contaminants, health-related impacts of indoor air and odor were used (see Table 1).

From this list, relevant documents that were reviewed are also indicated (see Table 1). Test methods were not included nor were standards only tangentially related to IEQ. For example, ASHRAE 90.1 which only notes that provisions of the standard should not be used in ways that contravene occupational health and safety.

In Appendix A, Table A-1 compares the standards and the best practices found in ASHRAE documents that also address health and wellness against the predetermined set of criteria. Not surprisingly, ASHRAE’s focus on indoor air is at the core of many of its best practice rating systems There were clear gaps in areas that are considered more broadly to be a part of the subject of indoor environmental quality: thermal comfort, acoustics, visual quality, and other wellness amenities. Whether these gaps represent essential topic areas for ASHRAE, and whether the core focus should not be diluted by a broadening of the mission, is still to be decided.

Table 1 - ASHRAE Documents Identified and ASHRAE Documents Reviewed by the MTG.HWBE

ASHRAE Documents Identified	ASHRAE Documents Reviewed
Guideline 1.2 – 2019 - Technical Requirements for the Commissioning Process for Existing HVAC&R Systems and Assemblies	
Guideline 10 – 2016- Interactions Affecting the Achievement of Acceptable Indoor Environments	
Guideline 23 – 2016- Guideline for the Design and Application of Heating, Ventilation, and Air-Conditioning Equipment for Rail Passenger Vehicles	
Guideline 27 – 2019- Measurement Procedures for Gaseous Contaminants in Commercial Buildings	
Guideline 28-2016 Air Quality within Commercial Aircraft	X
Guideline 29 - 2019 Guideline for the Risk Management of Public Health and Safety In Buildings	X
Guideline 32 – 2018 -Management for Sustainable High-Performance Operations and Maintenance	
Guideline 33 – 2013 (RA 2016) - Guideline for Documenting Indoor Airflow and Contaminant Transport Modeling	
Standard 34 -2019 – Designation and Safety Classification of Refrigerants	
Standard 55 - 2020 Thermal Environmental Conditions for Human Occupancy	X
Standard 62.1 - 2019 Ventilation for Acceptable Indoor Air Quality	X
Standard 62.2 - 2019 Ventilation and Acceptable Indoor Air Quality in Residential Buildings	X
Standard 129 - Standard Method of Measuring Air Change Effectiveness	

Table 1 - ASHRAE Documents Identified and ASHRAE Documents Reviewed by the MTG.HWBE

ASHRAE Documents Identified	ASHRAE Documents Reviewed
Standard 161- 2018 Air Quality within Commercial Aircraft	X
Standard 170 - 2017 Ventilation of Health Care Facilities	X
Standard 180 – 2018 – Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems	X
Standard 189.1 – 2020 – Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings	
Standard 189.3	
Position Document: Infectious Aerosols	
Position Document: Resiliency in the Built Environment	
Position Document: Limiting Indoor Mold and Dampness in Buildings	
Position Document: Combustion of Solid Fuels and Indoor Air Quality in Primarily Developing Countries	
Position Document: Environmental Tobacco Smoke	
Position Document: Filtration and Air Cleaning	
Position Document: Indoor Air Quality - updated July 2020	X
International Green Construction Code, 2018 - Third Printing, January 2021	X
Indoor Air Quality Guide: Best Practices for Design, Construction and Commissioning, 2009	X

4.2 Review of Building Certification Programs related to Health and Wellness

The first step was to compile all relevant literature and previous comparisons of green building rating systems. The next step was to evaluate how organizations, particularly those involved in the high-performance building rating systems, compare, define and measure health and wellness in the built environment.

There are currently over 600 green building rating systems in use globally [36]. Therefore, the MTG.HWBE decided to focus on those with most relevance to ASHRAE in terms of geographical regions, types of buildings, rating criteria and coverage (i.e. number of buildings / areas covered). Finally, a list of 17 rating systems was chosen for inclusion in this comparison. These systems cover USA, Europe (UK, Germany, France), Australia, Asia (Japan, China, Singapore) and Middle East (UAE). A full list of the rating systems reviewed, including country of origin, year of origin and version, is provided below in Table 2. The work was organised on Google Drive and Basecamp, with links provided here: Google Drive Link | Basecamp Link.

Table 2 - Green Building Certifications and Rating Systems included in MTG.HWBE Review

CERTIFICATION	Origin	Year of Origin	Version
LEED	USA	2020	v4.1
WELL	USA	2014	v2 (2020)
Living Building Challenge	USA	2009	v4.0 (2019)
BREEAM	UK	1990	
DGNB	Germany	2007	v2018
Three Star	China	2012	
CASBEE	Japan	2004	v2014
Pearl	Abu Dhabi	2009	
HQE	France	1995	
Green Star	Australia	2007	2020
Green mark	Singapore	2005	5th ed (2015)
RESET	China		
Green Globes	USA	2019	NC
Passivhaus	USA	2019	2.1
Fitwel	USA	2011	2.1
Enterprise Green Communities	USA	2004	2020
UL Verified Healthy Building	USA	2020	2020

The findings of the analysis are available in Appendix B - Table B.1, with additional notes in Appendix B - Table B.2.

[36] *Guide to Sustainable Building Certifications*. Danish Building Research Institute – SBI (2018).

5. Communication of MTG.HWBE Findings

The initial dissemination of information from the MTG.HWBE was an “IEQ Applications” column in the April 2020 issue of the ASHRAE Journal. In this column, MTG Chair Lan Chi Nguyen Weekes outlined the discussion of health and wellness criteria that must occur within ASHRAE, and how the MTG.HWBE was acting to foster this discussion.

The MTG.HWBE prepared this report for submittal to the ASHRAE Environmental Health Committee (EHC) to summarize the MTG.HWBE findings. Upon review and acceptance of this report by the EHC, the MTG.HWBE anticipates that the report will be forwarded through appropriate channels within ASHRAE for review, and then dissemination through publications and presentations to different audiences.

The MTG.HWBE recommends that EHC include the recommendations of this report into its strategic plan for implementation over a longer term. For a start, the MTG.HWBE suggest that an ASHRAE Position Document (PD) be prepared on the impact of the built environment on health and wellness of occupants. The MTG.HWBE anticipates that such a PD would be prepared at the direction of the ASHRAE Environmental Health Committee, and that it could incorporate content from this report.

6. Observations / Conclusions

The purposes of the MTG’s work were: 1) to increase ASHRAE's knowledge and expertise in this field; 2) to detect and act on potential opportunities; and 3) to become more effective in disseminating research results and practical experience in this field to ASHRAE members and others. These purposes will support the growing interest of ASHRAE members in health, wellness, and the wellbeing of the occupants in buildings.

The work included:

1. The review of existing definitions of health, and the recommendation of a usable definition of health and wellness.
2. The selection and review of relevant ASHRAE documents and standards on the topic of indoor air quality, indoor environmental quality, health, and wellness.
3. The selection and comparison of existing building certification and rating systems worldwide as they relate to indoor environmental quality (IEQ) parameters, and their known or potential impacts on health and wellness.
4. The creation of a summary report with recommendations for future actions under the guidance of the Environmental Health Committee (EHC), a General Standing Committee of ASHRAE Society. The recommendations address how ASHRAE can help mitigate untoward impacts from the built environment on occupant health/wellness, while promoting research on such topics as the impacts of IEQ parameters and their synergies on health and wellness, as well as changes in the built environment.

It should be noted that this was a high-level overview of various documents and certifications with an emphasis on IEQ by members of the MTG.HWBE.

Based on the analysis of the MTG, these recommendations are made to ASHRAE:

1. Recognize that the principal purpose of most buildings is for human occupancy and that the health and wellness of occupants must be a priority.
2. Acknowledge that energy, resource conservation and other aspects of the 'carbon footprint' of a building are legitimate concerns for ASHRAE members. However, these concerns must not override concern about the health and wellness of occupants.
3. Realize that the design, construction, and operation of buildings have tangible impacts on the health and wellness of building occupants.
4. Understand that the built environment should function beyond 'minimal' or 'normal' conditions.
5. Accept the WHO definition of heath and recommend that this definition be used in all future ASHRAE documents concerning health in the built environment.
6. Improve coordination between the various ASHRAE efforts directed towards health and wellness in the built environment and should be overseen by ASHRAE Environmental Health Committee (EHC).
7. Appreciate that, relative to IEQ, certification programs vary in rigor and inclusion. None of the certification programs, however, provide an overall holistic assessment of IEQ.
8. Recommend that ASHRAE Environmental Health Committee (EHC) initiates a Position Document (PD) summarizing the impact of the built environment on occupant health and wellness. The MTG.HWBE further recommends that the Position Document include recommendations for further action to be taken by ASHRAE to fill knowledge gaps pertaining to health and wellness in the built environment.
9. Leverage the knowledge and experience of ASHRAE membership to pursue a process for the assessment of IEQ that can be referenced by certification schemes.

At this point, the MTG.HWBE is not able to recommend specific action items with regards to collaboration within ASHRAE or with other organizations. However, it recognized that formal partnerships should be considered in the area of health and wellness particularly with organizations developing building rating systems focused on various aspects of sustainability, some including health (e.g., ASHRAE; LEED; WELL; Living Building Challenge; RESET, etc.). The MTG was in favor also of expanding external communications with government agencies and research institutes.

Appendix A

Table A1 - ASHRAE documents related to H&W in the built environment

Parameter \ ASHRAE Document	Guideline 28-2016 Air Quality within Commercial Aircraft	Guideline 29 - 2019 Guideline for the Risk Management of Public Health and Safety In Buildings	Standard 55 - 2020 Thermal Environmental Conditions for Human Occupancy	Standard 62.1 - 2019 Ventilation for Acceptable Indoor Air Quality	Standard 62.2 - 2019 Ventilation and Acceptable Indoor Air Quality in Residential Buildings	Standard 161- 2018 Air Quality within Commercial Aircraft	Standard 170 - 2017 Ventilation of Health Care Facilities	Standard 180 - 2018 Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems	Position Document: Indoor Air Quality - updated July 2020	International Green Construction Code, 2018 (Third Printing, January 2021)	Indoor Air Quality Guide: Best Practices for Design, Construction and Commissioning, 2009
Thermal Comfort											
In-operation testing / reporting?											X
Ambient Temperature (Air / Operative)	X	X	X			X					X
Air Velocity / Draughts	X		X	X	X	X	X				X
Relative Humidity (RH %)	X	X	X	X	X	X	X				X
Predicted Mean Vote (PMV / PPD)			X								X
Adaptive Comfort			X								X
Radiant Temperature / Asymmetry	X		X			X					X
Vertical air temperature difference	X		X			X					X
Surface Temperatures (Floor / Wall)			X								
Occupant satisfaction with thermal comfort	X	X	X			X					
IAQ - Pollutant limit											
Reference Standard (if applicable)											
Pollutant monitoring and verification (continuous or one-off)											
TVOC	X					X					X
Formaldehyde	X			X		X			X		X

Parameter / ASHRAE Document	Guideline 28-2016 Air Quality within Commercial Aircraft	Guideline 29 - 2019 Guideline for the Risk Management of Public Health and Safety In Buildings	Standard 55 - 2020 Thermal Environmental Conditions for Human Occupancy	Standard 62.1 - 2019 Ventilation for Acceptable Indoor Air Quality	Standard 62.2 - 2019 Ventilation and Acceptable Indoor Air Quality in Residential Buildings	Standard 161- 2018 Air Quality within Commercial Aircraft	Standard 170 - 2017 Ventilation of Health Care Facilities	Standard 180 - 2018 Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems	Position Document: Indoor Air Quality - updated July 2020	International Green Construction Code, 2018 (Third Printing, January 2021)	Indoor Air Quality Guide: Best Practices for Design, Construction and Commissioning, 2009
CO2	X					X			X		X
CO	X			X	X	X			X		X
PM10	X			X		X			X	X	X
PM2.5	X			X	X	X			X	X	X
Ozone	X			X		X			X	X	X
Visible mold	X	X		X		X	X	X	X		X
Other											
IAQ other											
Reference Standard (if applicable)											
Ventilation	X			X	X	X	X	X	X	X	X
Air filtration / cleaning	X	X		X	X	X	X	X	X	X	X
Moisture control	X	X		X	X	X	X	X	X	X	X
Low-emitting materials & products	X			X		X			X	X	X
Smoking control	X					X		X	X	X	
Outdoor air quality consideration	X	X		X	X	X	X	X	X	X	X
Source emission control	X	X		X	X	X	X	X	X	X	X
IAQ Management Plan	X	X		X		X			X		X
Occupant satisfaction with IAQ	X			X	X	X	X		X		X
Acoustical comfort											
Reference Standard (if applicable)											
In-operation testing / reporting?										X	
Ambient noise level										X	

ASHRAE Document Parameter	Guideline 28-2016 Air Quality within Commercial Aircraft	Guideline 29 - 2019 Guideline for the Risk Management of Public Health and Safety In Buildings	Standard 55 - 2020 Thermal Environmental Conditions for Human Occupancy	Standard 62.1 - 2019 Ventilation for Acceptable Indoor Air Quality	Standard 62.2 - 2019 Ventilation and Acceptable Indoor Air Quality in Residential Buildings	Standard 161- 2018 Air Quality within Commercial Aircraft	Standard 170 - 2017 Ventilation of Health Care Facilities	Standard 180 - 2018 Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems	Position Document: Indoor Air Quality - updated July 2020	International Green Construction Code, 2018 (Third Printing, January 2021)	Indoor Air Quality Guide: Best Practices for Design, Construction and Commissioning, 2009
Material Quality/Acoustic Performance										X	
Sound reducing barriers/technology										X	
Noise abatement plan/assessment										X	
Occupant satisfaction with acoustical comfort											X
Visual comfort											
Reference Standard (if applicable)											
In-operation testing / reporting?											
Exposure to artificial light											
Exposure to daylight										X	X
Lighting quality - circadian response											
Lighting quality - flickering											
Glare from direct sun										X	
Contrast (e.g., illuminance ratio between surfaces)											
Occupant satisfaction with visual comfort											X
Other Wellness Amenities											
Fitness / Exercise											
Occupant amenities											
Nutrition											
Controllability										X	X
Biophilia											
COVID-19 and Airborne Infection Control						X [1]					X

[1]Section on control of bacteria and viruses based on design (HEPA filters, airflow patterns, balancing), maintenance

Appendix B

Table B1 - Comparison of the H&W related elements of building rating systems (X indicates the parameter is addressed in the rating system, SN indicates the percentage or points related to this topic in the rating system and are related notes in the colored sections of the specific topics in Table B2)

Parameter \ Certification	LEED	WELL	Living Building Challenge	BREEAM	DGNB	Three Star	CASBEE	Pearl	HQE	Green Star	Green mark	RESET	Green Globes	Passivhaus	Fitwel	Enterprise Green Communities	UL Verified Healthy Building
Version Reviewed	v4.1	v2 (2020)	v4.0 (2019)		v2018		v2014			2020	V5 (2015)		NC	2.1	2.1	2020	
Thermal comfort	SN				SN								SN		SN		
In-operation testing / reporting?		X									X	X					
Ambient Temperature (Air / Operative)	X				X		X	X	X		X	X		X			X
Air Velocity / Draughts	X				X		X	X	X								
Relative Humidity (RH %)	X	X			X		X	X			X	X		X	X	X	X
Predicted Mean Vote (PMV / PPD)	X	X		X				X			X						
Adaptive Comfort	X																
Radiant Temperature / Asymmetry	X	X			X												

Parameter \ Certification	LEED	WELL	Living Building Challenge	BREEAM	DGNB	Three Star	CASBEE	Pearl	HQE	Green Star	Green mark	RESET	Green Globes	Passivhaus	Fitwel	Enterprise Green Communities	UL Verified Healthy Building
Version Reviewed	v4.1	v2 (2020)	v4.0 (2019)		v2018		v2014			2020	V5 (2015)		NC	2.1	2.1	2020	
Vertical air temperature difference							X										
Surface Temperatures (Floor / Wall)							X	X						X			
Occupant satisfaction with thermal comfort		X	X					X							X		X
Additional Comments / Info	X												X				
IAQ - Pollutant limit	SN				SN										SN		
Pollutant monitoring and verification (continuous or one-off)	SN	SN	SN					SN			X	X			X		
TVOC		A	X	X	X		X		X		X	X	X		X	X	X
Formaldehyde	X	X	X	X	X		X		X		X				X	X	X
CO2	X	X	X		X			X			X	X			X		X
CO	X	X	X					X	X			X	X		X	X	X
PM10	X	X	X					X	X				X				X
PM2.5	X	X	X						X			X	X		X		X
Ozone	X	X	X						X						X		X

Certification / Parameter	LEED	WELL	Living Building Challenge	BREEAM	DGNB	Three Star	CASBEE	Pearl	HQE	Green Star	Green mark	RESET	Green Globes	Passivhaus	Fitwel	Enterprise Green Communities	UL Verified Healthy Building
Version Reviewed	v4.1	v2 (2020)	v4.0 (2019)		v2018		v2014			2020	V5 (2015)		NC	2.1	2.1	2020	
Visible mold														X	X		X
Other	X	X	SN					SN	SN		X			X		X	X
Additional Comments / Info				SN											X		
IAQ other															SN		
Ventilation	X	X	X	X	X		X	X	X		X	X		X	X	X	
Air filtration / cleaning	X	X									X			X	X	X	X
Moisture control	X													X	X	X	X
Low-emitting materials & products	X	X	X	X			X	X						X	X	X	
Smoking control	X	X	X				X	X					X		X	X	X
Outdoor air quality consideration	X	X	X								X	X					X
Source emission control	X	X	X												X	X	
IAQ Management Plan	X		X	X			X	X							X		X
Occupant satisfaction with IAQ			X														

Certification / Parameter	LEED	WELL	Living Building Challenge	BREEAM	DGNB	Three Star	CASBEE	Pearl	HQE	Green Star	Green mark	RESET	Green Globes	Passivhaus	Fitwel	Enterprise Green Communities	UL Verified Healthy Building
Version Reviewed	v4.1	v2 (2020)	v4.0 (2019)		v2018		v2014			2020	V5 (2015)		NC	2.1	2.1	2020	
Additional Comments / Info												X	X		X		
Acoustical comfort	SN				SN								SN		SN		
In-operation testing / reporting?								SN			SN						
Ambient noise level	X	X		X	X		X	X	X		X		X			X	X
Material Quality/Acoustic Performance	X	X		X	X		X		X		X			X		X	
Sound reducing barriers/technology		X					X						X	X		X	
Noise abatement plan/assessment		X			X		X						X			X	X
Occupant satisfaction with acoustical comfort																	
Additional Comments / Info													X		X		
Visual comfort	SN				SN								SN		SN		
In-operation testing / reporting?		X						SN									
Exposure to artificial light	X	X		X	X		X	X	X		X		X	X		X	X
Exposure to daylight	X	X	X	X	X		X	X	X		X		X	X	X	X	X

Certification / Parameter	LEED	WELL	Living Building Challenge	BREEAM	DGNB	Three Star	CASBEE	Pearl	HQE	Green Star	Green mark	RESET	Green Globes	Passivhaus	Fitwel	Enterprise Green Communities	UL Verified Healthy Building
Version Reviewed	v4.1	v2 (2020)	v4.0 (2019)		v2018		v2014			2020	V5 (2015)		NC	2.1	2.1	2020	
Lighting quality - circadian response		X											X	X			
Lighting quality - flickering		X			X						X		X	X			X
Glare from direct sun	X	X		X	X		X	X			X		X		X		
Contrast (e.g., illuminance ratio between surfaces)		X					X	X					X				
Occupant satisfaction with visual comfort			X					X					X				
Additional Comments / Info													X				
Other Wellness Amenities					SN										SN		
Fitness / Exercise		X			X										X	X	
Occupant amenities		X		X			X	X							X	X	
Nutrition		X			X										X	X	
Controllability	X	X	X	X	X		X	X									
Biophilia		X	X								X					X	

Parameter \ Certification	LEED	WELL	Living Building Challenge	BREEAM	DGNB	Three Star	CASBEE	Pearl	HQE	Green Star	Green mark	RESET	Green Globes	Passivhaus	Fitwel	Enterprise Green Communities	UL Verified Healthy Building
Version Reviewed	v4.1	v2 (2020)	v4.0 (2019)		v2018		v2014			2020	V5 (2015)		NC	2.1	2.1	2020	
COVID-19 and Airborne Infection Control	X	X													X		
Additional Comments / Info								X							X		X

Appendix B

Table B2 - Notes for Table B1

Parameters	Notes
Thermal comfort	0.90% LEED 4.5% DGNB 23 points Green Globes 0.5 Fitwell
Occupant satisfaction with thermal comfort	Qualitative survey / feedback system/occupant control etc.
IAQ - Pollutant limit	7.27% LEED 5.10% DGNB 6.4 Fitwel
Pollutant monitoring and verification (continuous or one-off)	LEED - Continuous monitoring of CO_2 WELL - One-off Living Building Challenge C – Either method Pearl - Continuous Monitoring CO_2, CO, PM_{10}, NO_2
TVOC	WELL – As per ASHRAE 62 or international equivalent
Other	Living Building Challenge: NO2, 4-PCH Pearl: NO2 HQE: Benzene Radon NO2, SO2
Additional Comments / Info	BREEAM: avoidance of asbestos

Parameters	Notes
IAQ other	11.8 Fitwell
Ventilation	Outdoor and/or treated air rates Distribution Controls
Air filtration / cleaning	Minimum filter rating Gaseous air cleaning Air cleaner requirements, etc.
Moisture control	Intention to reduce mold, condensation
Low-emitting materials & products	Furniture Paints Cleaning Products
Outdoor air quality consideration	Ozone Pollen Particulate Matter from Wildfires, etc.
Source emission control	Pressurisation Combustion venting Garage direct exhaust, etc.
IAQ Management Plan	Construction, Operation, Maintenance, etc.

Parameters	Notes
Acoustical comfort	0.90% Leed 2.90% DGNB 35 points Green Globes 0.5 Fitwel
In-operation testing / reporting?	Pearl A - Field Tests/ Green Mark B - SS 553:2016 or GM NRB: 2015 Technical Guide and Requirements
Material Quality/Acoustic Performance	Sound insulation Transmission rating
Sound reducing barriers/technology	Screens Sealant Window films, etc.
Noise abatement plan/assessment	24 CFR 51B

Parameters	Notes
Visual comfort	5.45% LEED 3.40% DGNB 32 points Green Globes 2.5 Fitwel
In-operation testing / reporting?	Pearl - Occupancy sensors / photographs
Exposure to artificial light	Horizontal illuminance level Task lighting Color rendering index
Exposure to daylight	Window proximity Spatial daylight autonomy Daylight factor, etc.)
Lighting quality - circadian response	Circadien stimulus Equivalent melanopic lux Vertical illuminance, etc.
Glare from direct sun	Shades, blinds Desk layout
Occupant satisfaction with visual comfort	Visual connection to the outdoors
Other Wellness Amenities	5.4% DGNB 47.3 Fitwel
Fitness / Exercise	Gym, sauna Navigation system / information
Occupant amenities	Roof garden Balconies, etc.

Controllability	Ventilation Shading Temperature Light