We will start in just a few minutes. Tell us…

What questions do you have about pandemic preparedness?

Please go to **slido.com** and use event code **#DOE** to submit your responses.

Minimizing Infectious Disease Spread in Buildings: How HVAC Guidance has Evolved

Monday, January 25, 2021

1:00 – 2:00 pm ET

Mariana Egea-Casalduc

U.S. Department of Energy

U.S. DEPARTMENT OF ENERGY

Agenda & Housekeeping

1. Introduction & Polls
2. Presentation from Dr. Bill Bahnfleth
3. Q&A

You have joined on a muted line.

Questions for the speakers? Join the conversation at slido.com #DOE

Chat Technical Support through the GTW Chat function.

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using your mobile device, or by opening a new window

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Polls 1 - 6

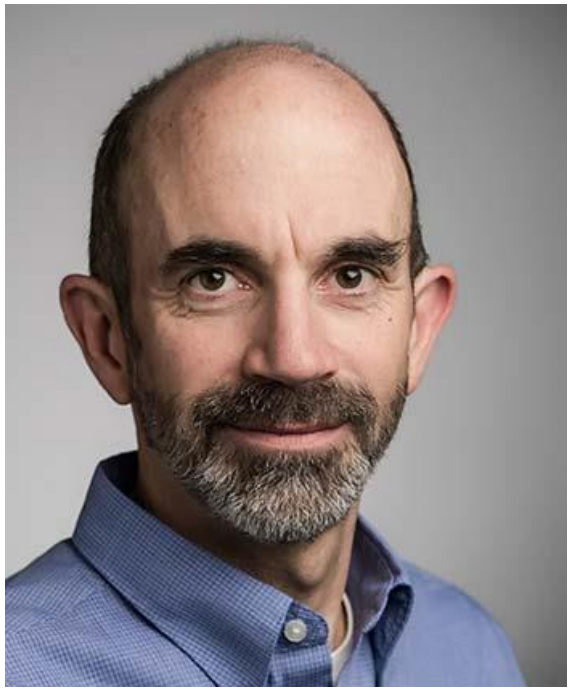
We'd like to hear more about you!

Please go to www.slido.com and enter code **#DOE** to respond

Better Buildings HVAC Technology Research Team at NREL

Marcus Bianchi
Senior Research Engineer

Greg Shoukas
Research Engineer



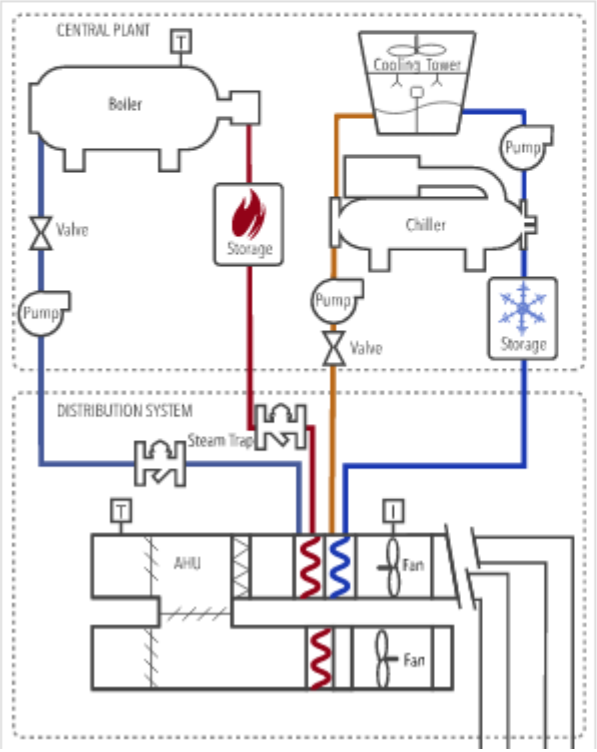
Michael Deru
Senior Research Engineer

HVAC Resource Map

https://hvacresourcemap.net

HVAC Home | Central Plant | Distribution | Space Loads | Contributors

HVAC Resources



What is this resource?

The Central Plant Resource Map is an intuitive graphical interface that provides quick access to a broad array of quality information on operations and maintenance best practices and energy and water efficiency measures. The resources cover the central plant, distribution systems, and zone systems. The primary audiences for this resource are facility managers, operations staff, and design engineers who are looking to improve central plant and distribution efficiency but don't have time to search for these resources.

This Resource Map is not a repetition of guidance provided in codes and standards. It should not be used in lieu of professional engineering services.

Explore HVAC Resources

Use the horizontal navigation above or the interactive diagram to dive into resources on different HVAC components.

The resources listed on this site have been carefully selected to help narrow your search for helpful information.

Today's Presenter

Dr. Bill Bahnfleth

The Pennsylvania State University

PennState College of Engineering | ARCHITECTURAL ENGINEERING

MINIMIZING INFECTIOUS DISEASE SPREAD IN BUILDINGS: HOW HVAC GUIDANCE HAS EVOLVED

William P. Bahnfleth, PhD, PE, FASHRAE, FASME, FISIAQ
Professor, The Pennsylvania State University
Chair, ASHRAE Epidemic Task Force

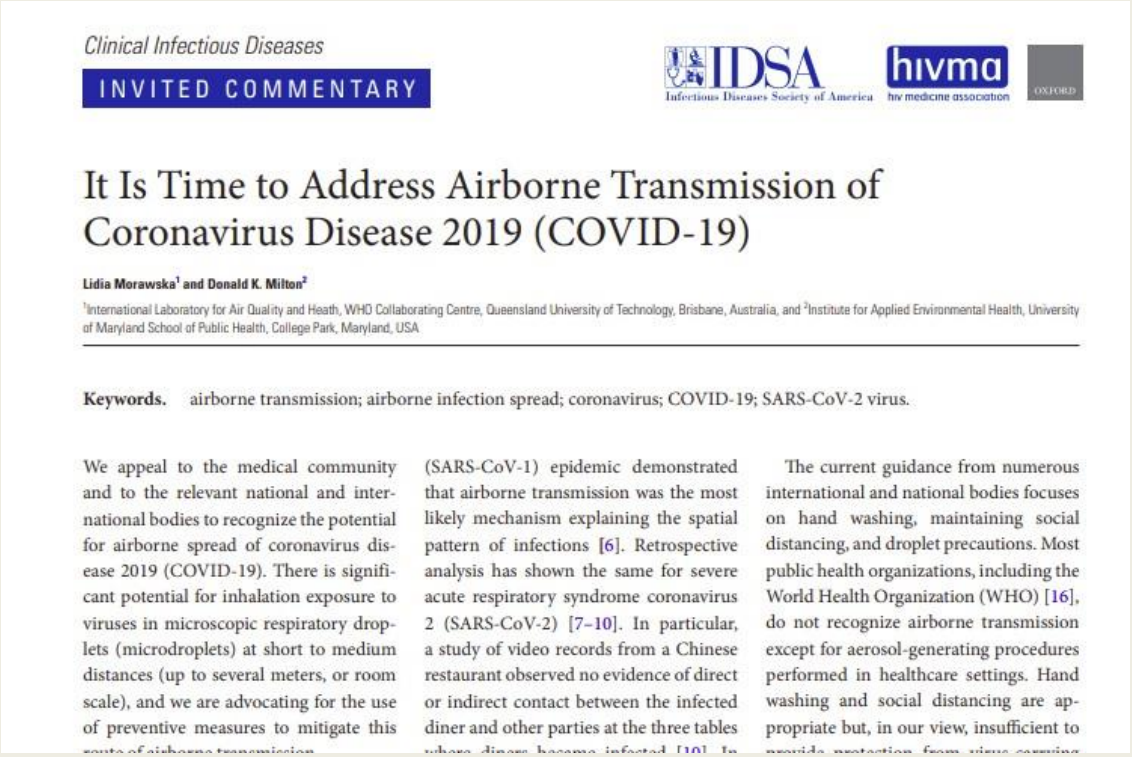
Better Buildings®
U.S. DEPARTMENT OF ENERGY

THE BEGINNING

Key initial question #1
Is airborne transmission of COVID-19 possible?

- World Health Organization, Centers for Disease Control and Prevention, and other public health groups (as of March 2020)
  - *No conclusive evidence of airborne transmission*
  - *Infections are explained by droplet (primarily) and fomite modes*
- ASHRAE position

  Transmission of SARS-CoV-2 through the air is sufficiently likely that airborne exposure to the virus should be controlled. Changes to building operations, including the operation of heating, ventilating, and air-conditioning systems, can reduce airborne exposures.



Clinical Infectious Diseases

INVITED COMMENTARY

IDSA Infectious Diseases Society of America · hivma hiv medicine association · OXFORD

It Is Time to Address Airborne Transmission of Coronavirus Disease 2019 (COVID-19)

Lidia Morawska[1] and Donald K. Milton[2]

[1]International Laboratory for Air Quality and Heath, WHO Collaborating Centre, Queensland University of Technology, Brisbane, Australia, and [2]Institute for Applied Environmental Health, University of Maryland School of Public Health, College Park, Maryland, USA

Keywords. airborne transmission; airborne infection spread; coronavirus; COVID-19; SARS-CoV-2 virus.

We appeal to the medical community and to the relevant national and international bodies to recognize the potential for airborne spread of coronavirus disease 2019 (COVID-19). There is significant potential for inhalation exposure to viruses in microscopic respiratory droplets (microdroplets) at short to medium distances (up to several meters, or room scale), and we are advocating for the use of preventive measures to mitigate this

(SARS-CoV-1) epidemic demonstrated that airborne transmission was the most likely mechanism explaining the spatial pattern of infections [6]. Retrospective analysis has shown the same for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [7–10]. In particular, a study of video records from a Chinese restaurant observed no evidence of direct or indirect contact between the infected diner and other parties at the three tables

The current guidance from numerous international and national bodies focuses on hand washing, maintaining social distancing, and droplet precautions. Most public health organizations, including the World Health Organization (WHO) [16], do not recognize airborne transmission except for aerosol-generating procedures performed in healthcare settings. Hand washing and social distancing are appropriate but, in our view, insufficient to

https://doi.org/10.1093/cid/ciaa939

The Precautionary Principle

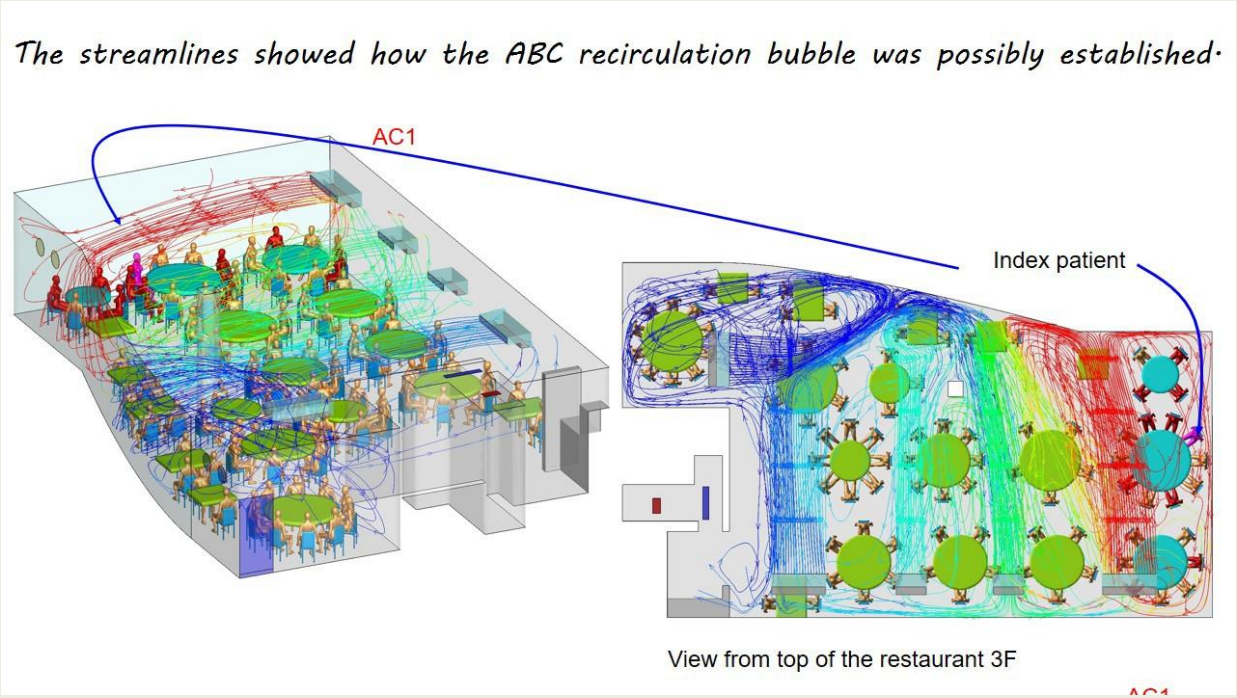
“One should take reasonable measures to avoid threats that are serious and plausible.”

D. Resnik. 2004. The Precautionary Principle and Medical Decision Making. Journal of Medicine and Philosophy, 29(3):281-299.

- ASHRAE position based on a number of case studies suggesting airborne transmission available at the time
  - *Diamond Princess cruise ship*
  - *Skagit Valley choir practice*
  - *Guangzhou restaurant…*

The Guangzhou restaurant incident was the most influential evidence of airborne spread

- No ventilation air supply
- Measured ventilation rate ~0.75 – 1 L/s per patron
- Four exhaust fans, none running
- No close contact observed on video
- Split system air-conditioning – airflow patterns a secondary factor
- Conclusions: "*aerosol transmission of SARS-CoV-2 due to poor ventilation may explain the community spread of COVID-19.*"



Li, et al. (2020) https://doi.org/10.1101/2020.04.16.20067728

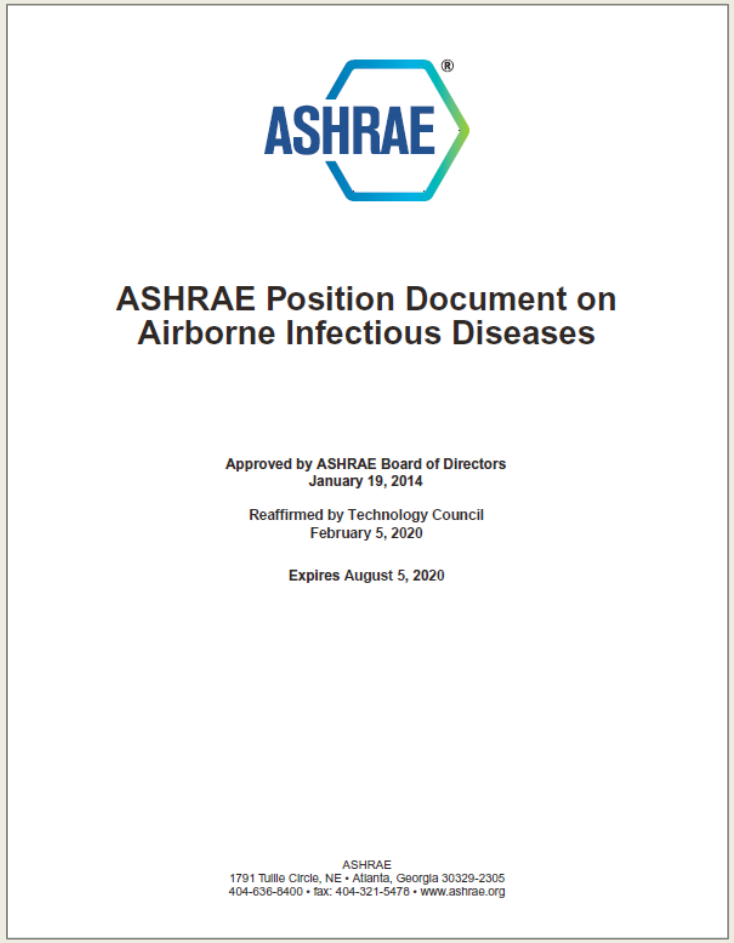
Key initial question #2
Do HVAC systems spread COVID-19?

- ASHRAE position:

  Ventilation and filtration provided by heating, ventilating, and air-conditioning systems can reduce the airborne concentration of SARS-CoV-2 and thus the risk of transmission through the air. Unconditioned spaces can cause thermal stress to people that may be directly life threatening and that may also lower resistance to infection. In general, disabling of heating, ventilating, and air-conditioning systems is not a recommended measure to reduce the transmission of the virus.

ASHRAE Infectious Aerosols Position Document predated task force

- Generic
- Not intended to be a guidance document or standard
- Control recommendations generally conservative
- Little consideration for factors other than effectiveness
- *Now superseded by task force guidance*



ASHRAE Position Document on Airborne Infectious Diseases

Approved by ASHRAE Board of Directors
January 19, 2014

Reaffirmed by Technology Council
February 5, 2020

Expires August 5, 2020

ASHRAE
1791 Tullie Circle, NE • Atlanta, Georgia 30329-2305
404-636-8400 • fax: 404-321-5478 • www.ashrae.org

Initial ASHRAE guidance based on Infectious Aerosols Position Document recommendations

- *Increase outdoor air to 100% or highest amount possible*
- *Disable demand controlled ventilation*
- Improve central air and other HVAC filtration to MERV 13 or highest possible
- *Operate HVAC systems 24/7*
- Add in-room air cleaners if necessary
- Add airstream or upper-room ultraviolet germicidal irradiation systems
- *Bypass energy recovery systems that may permit re-entry*
- Maintain temperature and humidity ranges that reduce viral survival time

Heavy emphasis on efficacy, not a lot on costs and energy use

WHAT'S NEW

WHO and CDC acknowledge potential for airborne transmission

(10/5/2020)

- COVID-19 most commonly spreads during close contact
- COVID-19 spreads less commonly through contact with contaminated surfaces
- Airborne transmission of SARS-CoV-2 can occur under special circumstances
  - *Enclosed spaces*
  - *Prolonged exposure to respiratory particles*
  - *Inadequate ventilation and air-handling*

"Ventilation represents a very important aspect, a very important factor to prevent the virus from spreading indoors."

WHO Science in 5
https://www.youtube.com/watch?v=XJC1f7F4qtc

The effort to clarify what airborne transmission is continues

THE JOURNAL OF Hospital Infection
Healthcare Infection Society

REVIEW ARTICLE | ARTICLES IN PRESS

Dismantling myths on the airborne transmission of severe acute respiratory syndrome coronavirus (SARS-CoV-2)

Julian W. Tang • William P. Bahnfleth • Philomena M. Bluyssen • Giorgio Buonanno • Jose L. Jimenez • Jarek Kurnitski • Yuguo Li • Shelly Miller • Chandra Sekhar • Lidia Morawska • Linsey C. Marr • Arsen Krikor Melikov • William W. Nazaroff • Peter V. Nielsen • Raymond Tellier • Pawel Wargocki • Stephanie J. Dancer • Show less

Published: January 12, 2021 • DOI: https://doi.org/10.1016/j.jhin.2020.12.022

Summary
Key words
Introduction
Conclusions

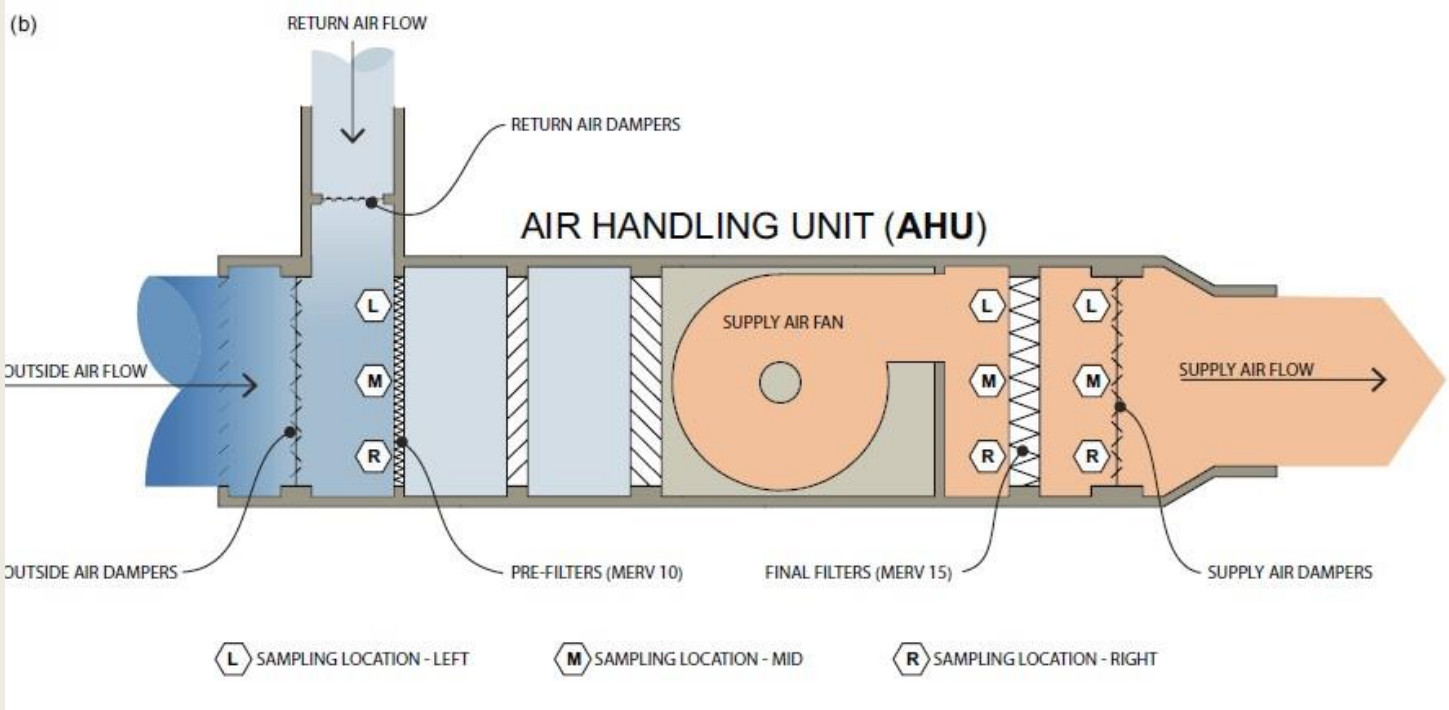
Summary

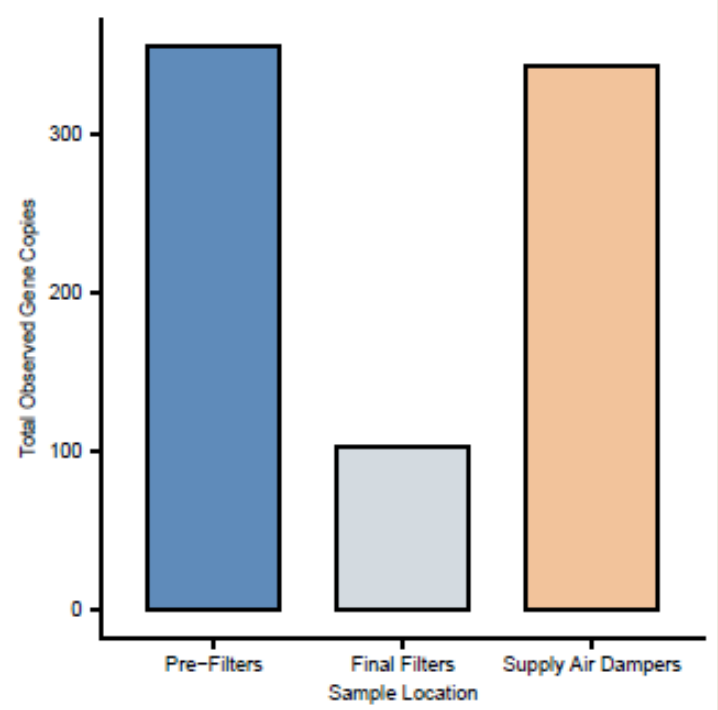
The Covid-19 pandemic has caused untold disruption and enhanced mortality rates around the world. Unde
mechanisms for transmission of SARS-CoV-2 is key to preventing further spread but there is confusion ove
"airborne" whenever transmission is discussed. Scientific ambivalence originates from evidence published r
which has generated mythological beliefs that obscure current thinking. This article gathers together and ex

Feedback –questions and challenges…

- Glad to have recommendations from ASHRAE
- Do I have to do all of these things?
- What if I can’t do some of these things?
- What is the justification for each recommendation?
- Was there a cost-benefit analysis for recommendations?
- Was energy use impact considered?
- Will these recommendations become the new standard?
- Why follow recommendations if not consistent with WHO and CDC positions?

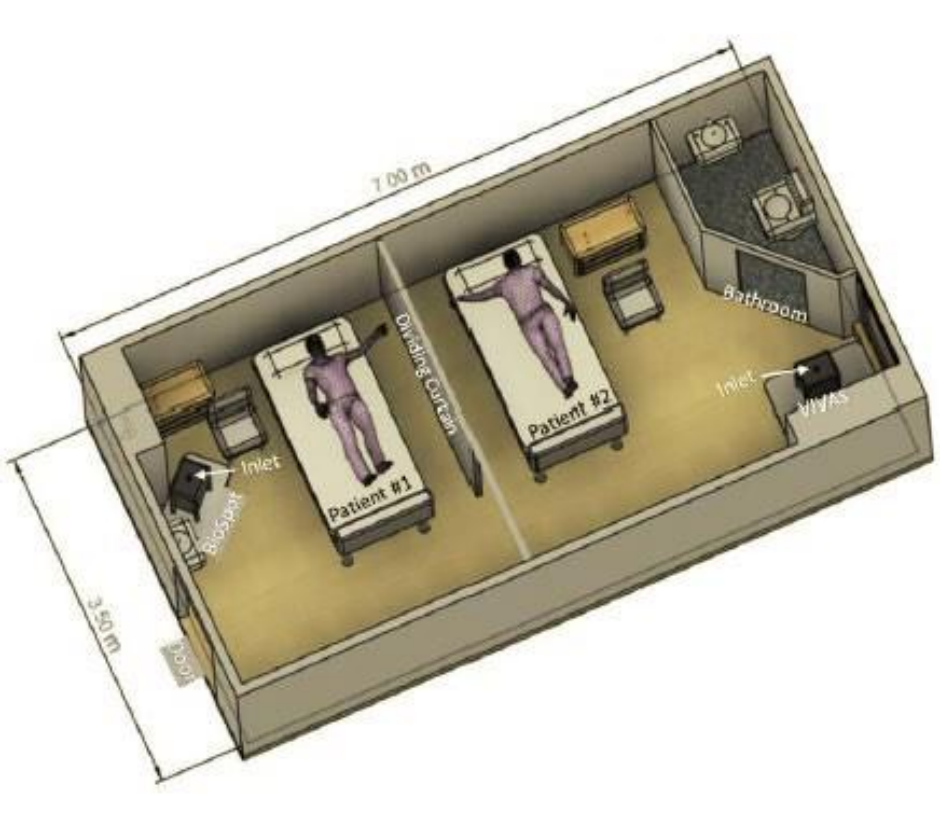
SARS-CoV-2 penetrates HVAC Systems, but still no evidence of space to space transmission

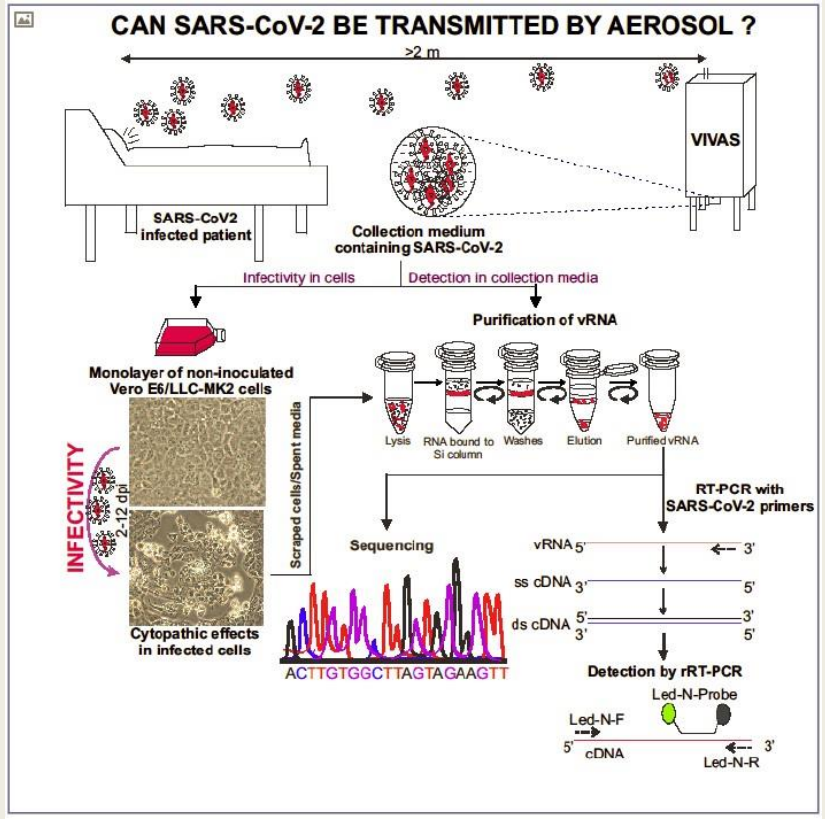




Horve, P., et al. 2020. Identification of SARS-CoV-2 RNA in Healthcare Heating, Ventilation, and Air Conditioning Units doi.org/10.1101/2020.06.26.20141085

Active SARS-CoV-2 found in air



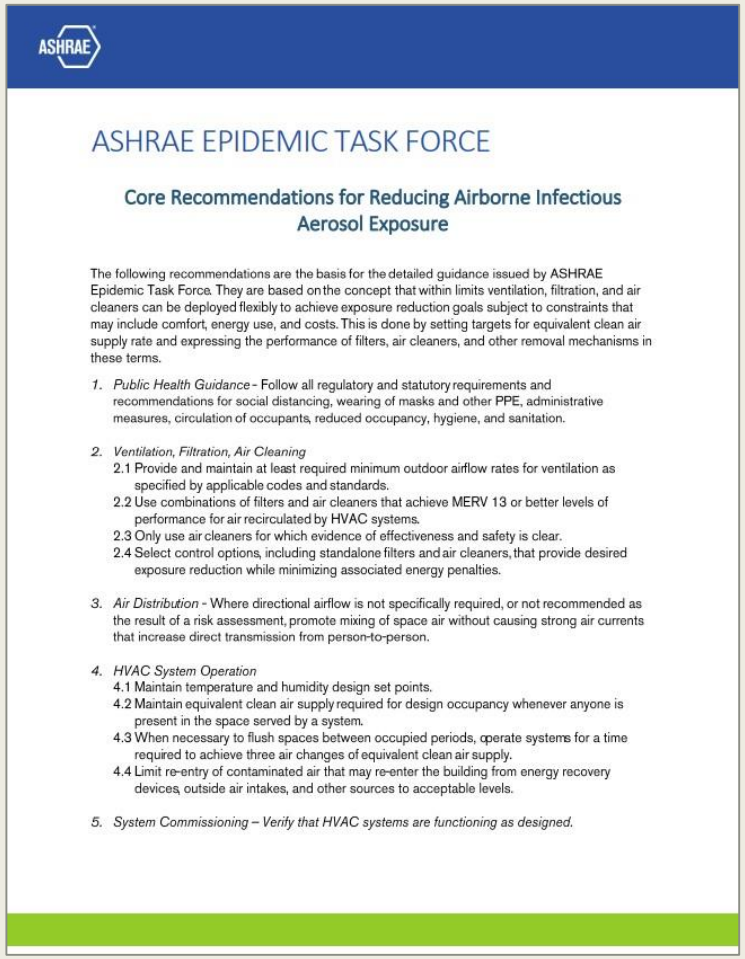


Lednicky, J., eta al. 2020 Viable SARS-CoV-2 in the air of a hospital room with COVID-19 Patients. Int. J. of Infectious Diseases. doi.org/10.1016/j.ijid.2020.09.025

CURRENT STATUS

Core Recommendations (1/4/2021)

- Concise summary of the framework for detailed ASHRAE guidance
- Inward-facing purpose: ensure fundamental consistency across all guidance documents
- Outward-facing purposes:
  - *Communicate basics of airborne risk reduction*
  - *Document current status of ASHRAE guidance*



ASHRAE

ASHRAE EPIDEMIC TASK FORCE

Core Recommendations for Reducing Airborne Infectious Aerosol Exposure

The following recommendations are the basis for the detailed guidance issued by ASHRAE Epidemic Task Force. They are based on the concept that within limits ventilation, filtration, and air cleaners can be deployed flexibly to achieve exposure reduction goals subject to constraints that may include comfort, energy use, and costs. This is done by setting targets for equivalent clean air supply rate and expressing the performance of filters, air cleaners, and other removal mechanisms in these terms.

1. *Public Health Guidance* - Follow all regulatory and statutory requirements and recommendations for social distancing, wearing of masks and other PPE, administrative measures, circulation of occupants, reduced occupancy, hygiene, and sanitation.

2. *Ventilation, Filtration, Air Cleaning*
   2.1 Provide and maintain at least required minimum outdoor airflow rates for ventilation as specified by applicable codes and standards.
   2.2 Use combinations of filters and air cleaners that achieve MERV 13 or better levels of performance for air recirculated by HVAC systems.
   2.3 Only use air cleaners for which evidence of effectiveness and safety is clear.
   2.4 Select control options, including standalone filters and air cleaners, that provide desired exposure reduction while minimizing associated energy penalties.

3. *Air Distribution* - Where directional airflow is not specifically required, or not recommended as the result of a risk assessment, promote mixing of space air without causing strong air currents that increase direct transmission from person-to-person.

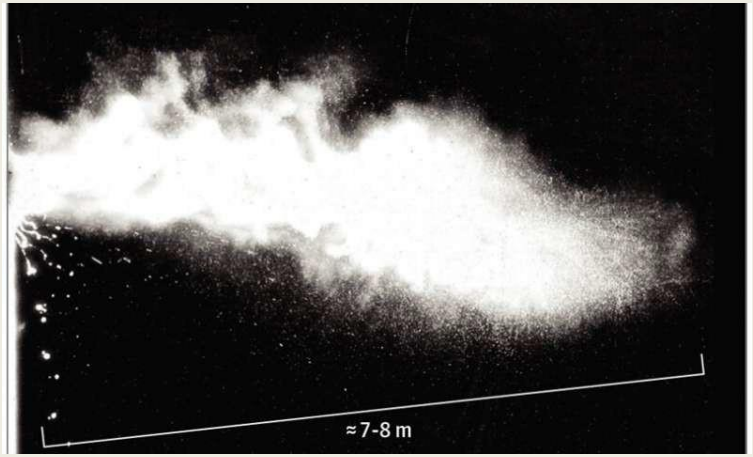
4. *HVAC System Operation*
   4.1 Maintain temperature and humidity design set points.
   4.2 Maintain equivalent clean air supply required for design occupancy whenever anyone is present in the space served by a system.
   4.3 When necessary to flush spaces between occupied periods, operate systems for a time required to achieve three air changes of equivalent clean air supply.
   4.4 Limit re-entry of contaminated air that may re-enter the building from energy recovery devices, outside air intakes, and other sources to acceptable levels.

5. *System Commissioning – Verify that HVAC systems are functioning as designed.*

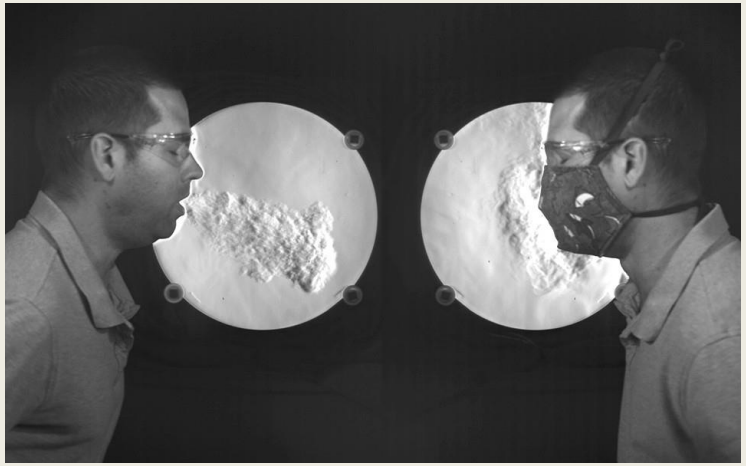
ashrae.org/covid19

1. Public Health Guidance

- *Follow all regulatory and statutory requirements and recommendations for social distancing, wearing of masks and other PPE, administrative measures, circulation of occupants, reduced occupancy, hygiene, and sanitation.*
- Why it's important
  - *COVID-19 is transmits by multiple modes*
  - *Mask use indoors helps control airborne transmission*



Bourouiba, L. JAMA. 2020;323(18):1837-1838. doi:10.1001/jama.2020.4756



https://www.nist.gov/blogs/taking-measure/my-stay-home-lab-shows-how-face-coverings-can-slow-spread-disease

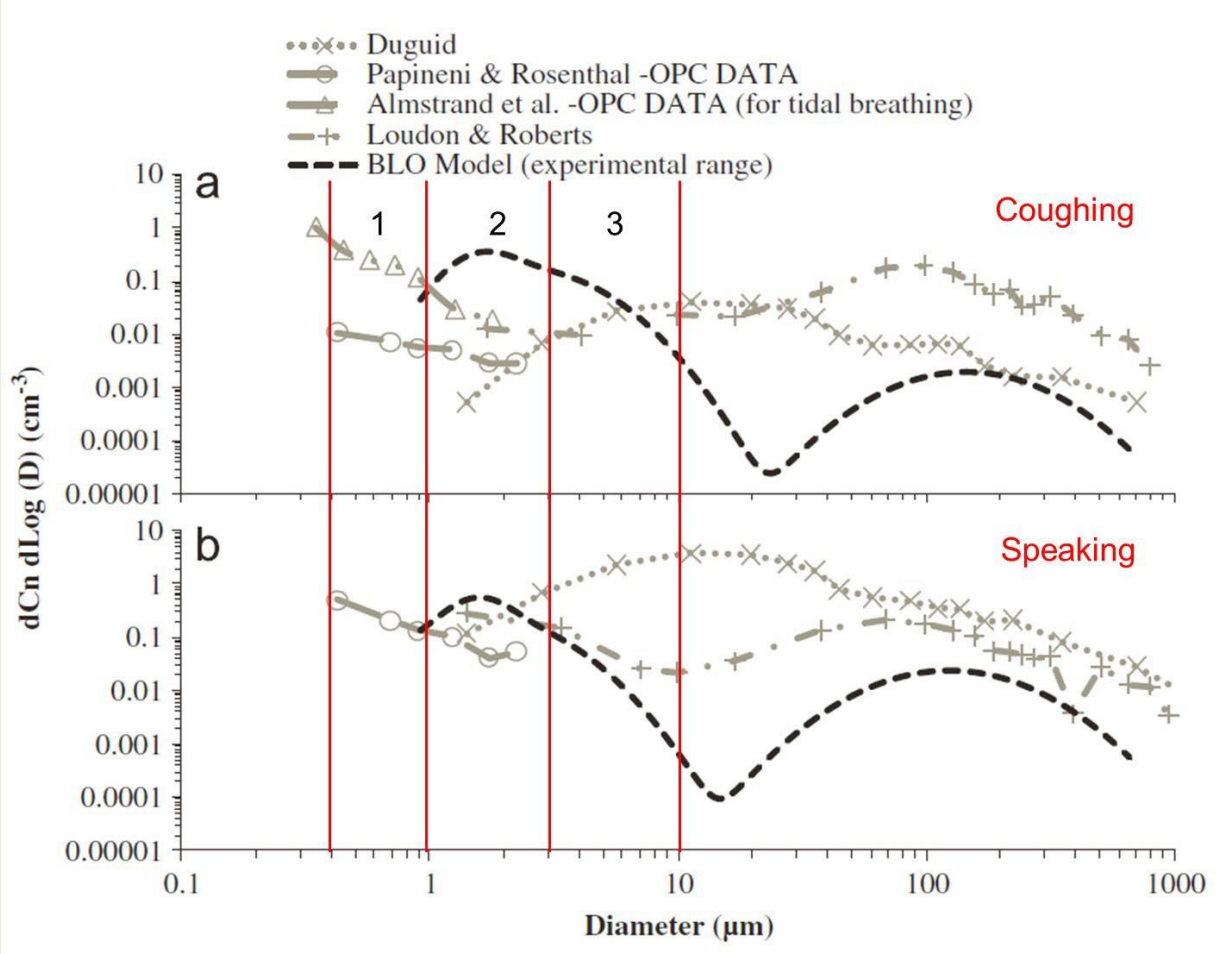
2. Ventilation, Filtration, Air Cleaning
Outdoor Air

- *2.1 Provide and maintain at least required minimum outdoor airflow rates for ventilation as specified by applicable codes and standards.*
- Why it's important
  - *Early guidance from ASHRAE/others recommended maximizing outdoor air flow*
  - *Energy intensive, expensive, possible impacts on indoor environmental control*
  - *ETF has concluded that other controls may be equally effective and more acceptable*
  - *Code minimum ventilation should be mandatory for general air quality control*
- Note – code outdoor air is not necessarily sufficient to achieve acceptable risk for COVID-19

2. Ventilation, Filtration, Air Cleaning *Filtration*

- *2.2 Use combinations of filters and air cleaners that achieve MERV 13 or better levels of performance for air recirculated by HVAC systems.*
- Why it's important
  - *Minimum standard filters are not effective for infectious aerosols*
  - *HEPA filters not necessary in most cases/expensive and difficult to retrofit*
  - *MERV 13 has good efficiency for respiratory aerosols*
  - *Allows trade-offs when MERV 13 mechanical filter is not feasible*

Why MERV 13 filters are recommended

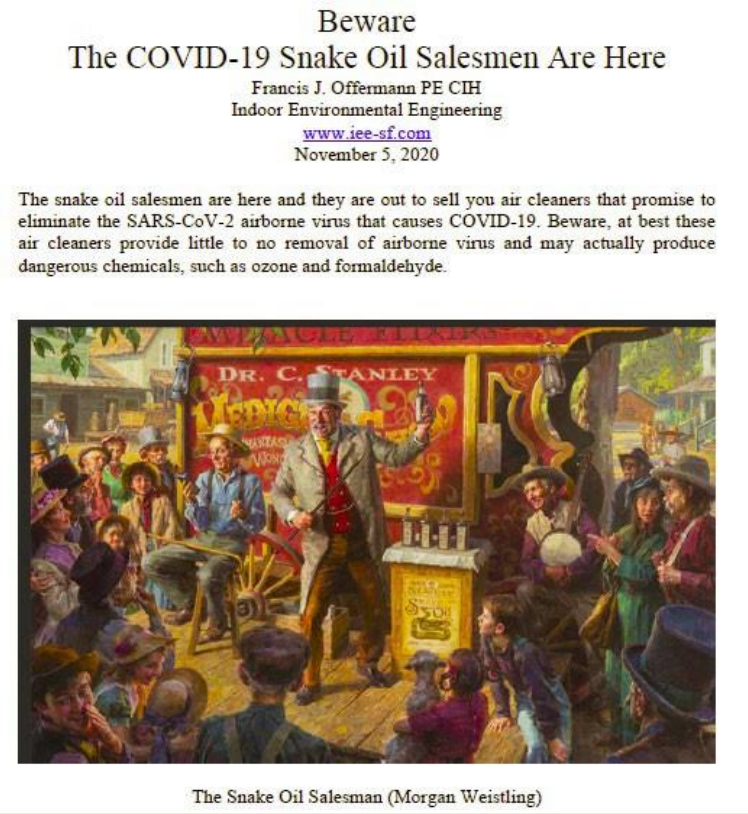


	MERV 6	MERV 8	MERV 13
1 (0.3-1µm)	N/A	N/A	≥ 50%
2 (1-3 µm)	N/A	≥ 20%	≥ 85%
3 (3-10 µm)	≥ 35%	≥ 70%	≥ 90%

Johnson, et al. 2011. Modality of human expired aerosol size distributions. Journal of Aerosol Science 42:839-851.

2. Ventilation, Filtration, Air Cleaning
Air Cleaners

- *2.3 Only use air cleaners for which evidence of effectiveness and safety is clear.*
- Why it's important
  - *Many air cleaners, purifiers, etc. in the marketplace for which manufacturers claims are not well established*
  - *ASHRAE identifies only ultraviolet germicidal irradiation as a technology with a high level of evidence*
  - *Until issues are resolved, users must decide whether a technology is demonstrated to be effective and safe. Caveat emptor*



Beware

The COVID-19 Snake Oil Salesmen Are Here

Francis J. Offermann PE CIH
Indoor Environmental Engineering
www.iee-sf.com
November 5, 2020

The snake oil salesmen are here and they are out to sell you air cleaners that promise to eliminate the SARS-CoV-2 airborne virus that causes COVID-19. Beware, at best these air cleaners provide little to no removal of airborne virus and may actually produce dangerous chemicals, such as ozone and formaldehyde.

The Snake Oil Salesman (Morgan Weistling)

http://www.iee-sf.com/pdf/TheCOVID19SnakeOilSalesmenAreHere.pdf.new

2. Ventilation, Filtration, Air Cleaning *Combining Controls*

- *2.4 Select control options, including standalone filters and air cleaners, that provide desired exposure reduction while minimizing associated energy penalties.*
- Why it's important
  - *Recognizes approach of selecting controls to meet overall airborne risk target*
  - *Consistent with equivalent clean air delivery rate approach – working on values*
  - *A way to develop infection control strategies that is cognizant of energy use, cost, and other factors*

The Wells-Riley model became widely used to analyze risk

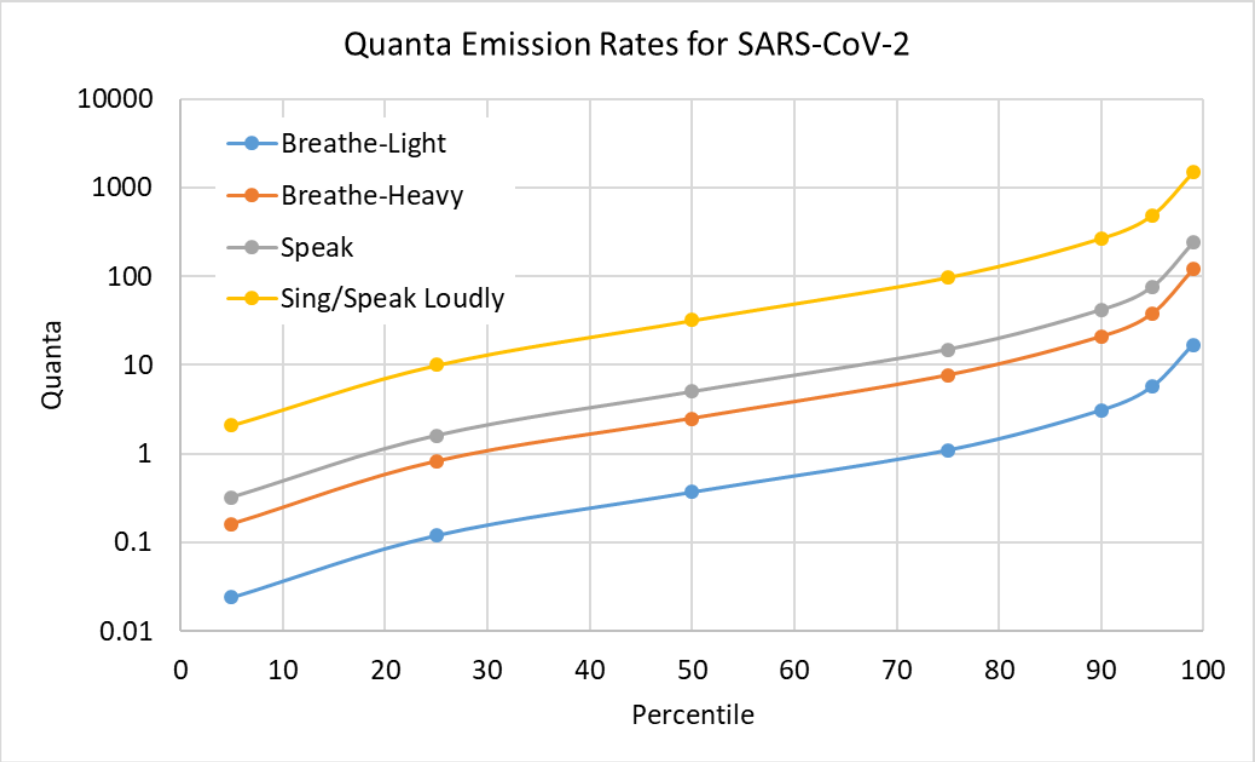
$$P = 1 - \exp\left(-\frac{Iqpt}{Q}\right)$$

- Steady-state conditions
- Time-dependent risk
- Quanta determined from data

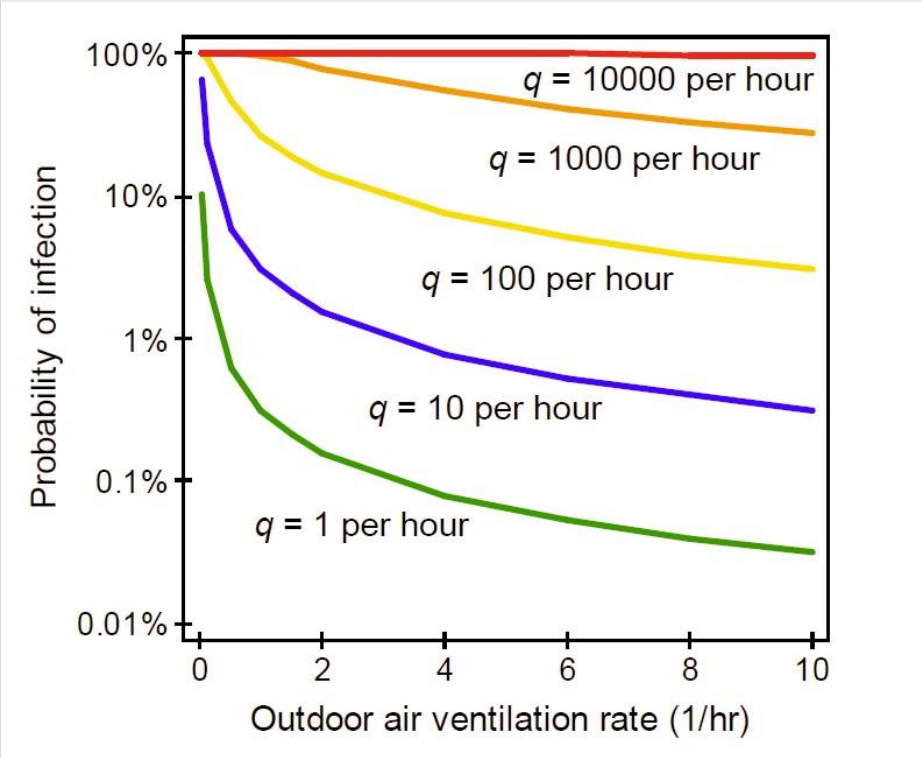
- P = probability of new infections
- I = number of infectors
- q = quanta (infectious dose) emission rate [1/hr]
- p = pulmonary ventilation rate per susceptible [m^3/h]
- t = exposure time [hr]
- Q = flow rate of uncontaminated air [m^3/h]

Given source and occupancy characteristics, can calculate required uncontaminated air flow rate

…but not very accurately for COVID-19



Office, 8-hr occupancy



Buonanno, et al. 2020. Quantitative assessment of the risk of airborne transmission of SARS-CoV-2 infection: Prospective and retrospective applications. Environment International, 145

Stephens. 2012. HVAC filtration and the Wells-Riley approach to assessing risks of infectious airborne diseases. Final report to NAFA.

Equivalent non-infectious air concept provides a quantitative approach to control

$$P = 1 - \exp\left[-\frac{ipqt}{Q}\right] = 1 - \exp\left[-\frac{ipqt}{V} \Big/ \alpha_{OA}\right]$$

Can express Q in clean air changes, α if desired

For an air cleaner with CADR = Q_{AC}, $\alpha_{AC} = \frac{Q_{AC}}{V}$

Equivalent ACH = $\alpha_{OA} + \alpha_{AC}$, so $P = 1 - \exp\left[-\frac{ipqt}{V} \Big/ (\alpha_{OA} + \alpha_{AC})\right]$

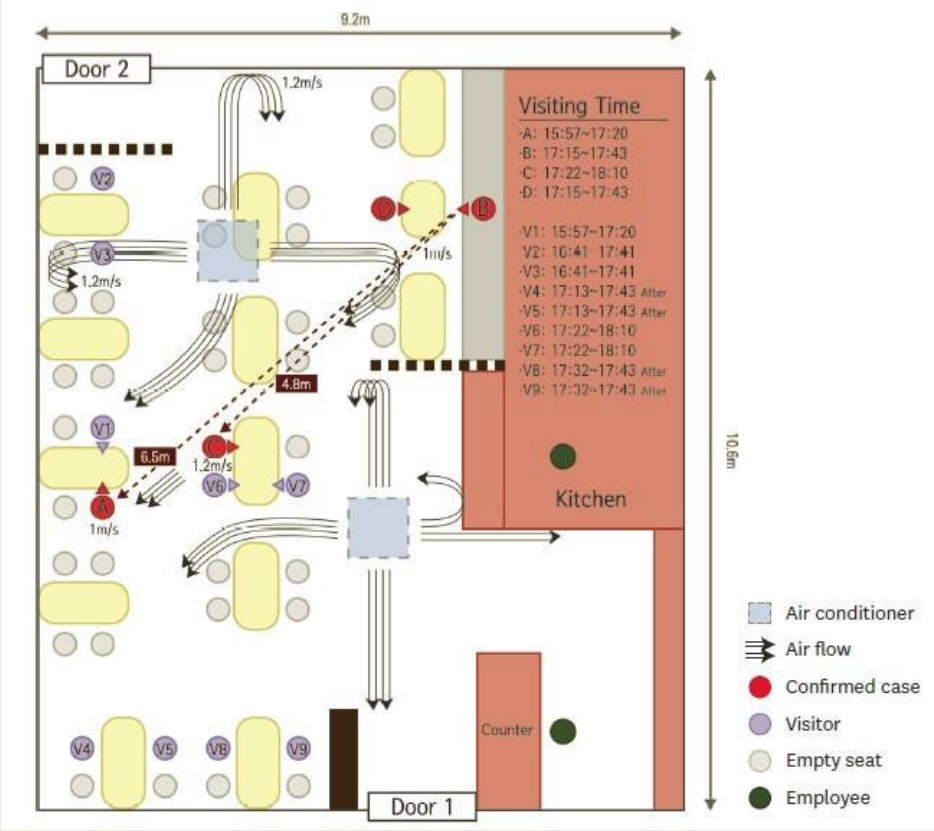
Effect of other controls and removal mechanisms can be expressed as equivalent clean air flows

$$Q = \sum \alpha_{OA} + \alpha_{Filter} + \alpha_{AC} + \alpha_{Deposition} + \alpha_{Inactivation} + \ldots$$

3. Air Distribution
Mixing, Drafts

- *Where directional airflow is not specifically required, or not recommended as the result of a risk assessment, promote mixing of space air without causing strong air currents that increase direct transmission from person-to-person.*
- Why it's important
  - *Stratified ventilation can trap infectious aerosols in inversion layers and increase risk*
  - *Strong drafts can move even large infectious aerosol droplets long distances*

Rationale for air distribution recommendations

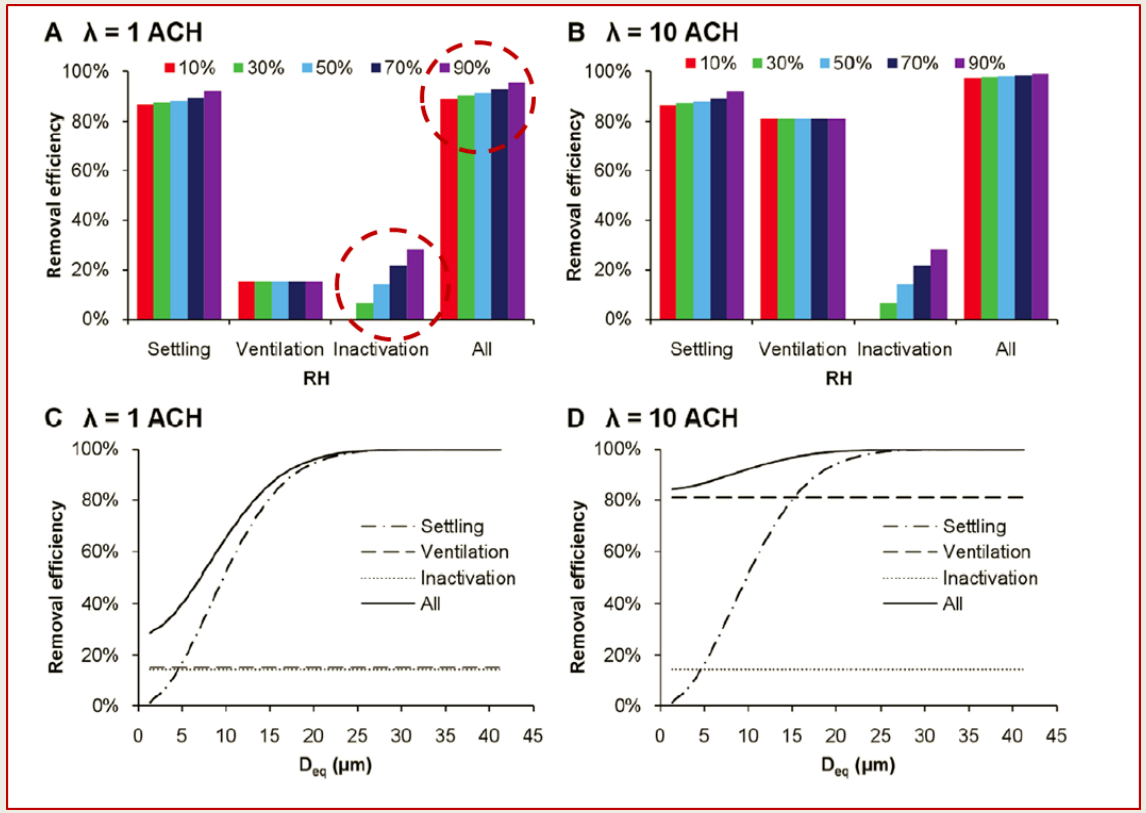


J Korean Med Sci. 2020 Nov 30;35(46):e415
https://doi.org/10.3346/jkms.2020.35.e415

Li, Y., P. Nielsen, M. Sandberg. 2011. ASHRAE J. 53(6): 86-88

4. HVAC System Operation
Humidity and Temperature

- *4.1 Maintain temperature and humidity design set points.*
- Why it's important
  - *Impact of humidity not same order as other controls*
  - *Some buildings are poorly suited to addition of humidification*
  - *Central humidification relatively expensive*
  - *consequences*
  - *Limited ability to adjust occupied temperature set points*



Yang W, Marr LC (2011) Dynamics of Airborne Influenza A Viruses Indoors and Dependence on Humidity. PLoS ONE 6(6): e21481.

4. HVAC System Operation
Maintain Ventilation During Occupancy

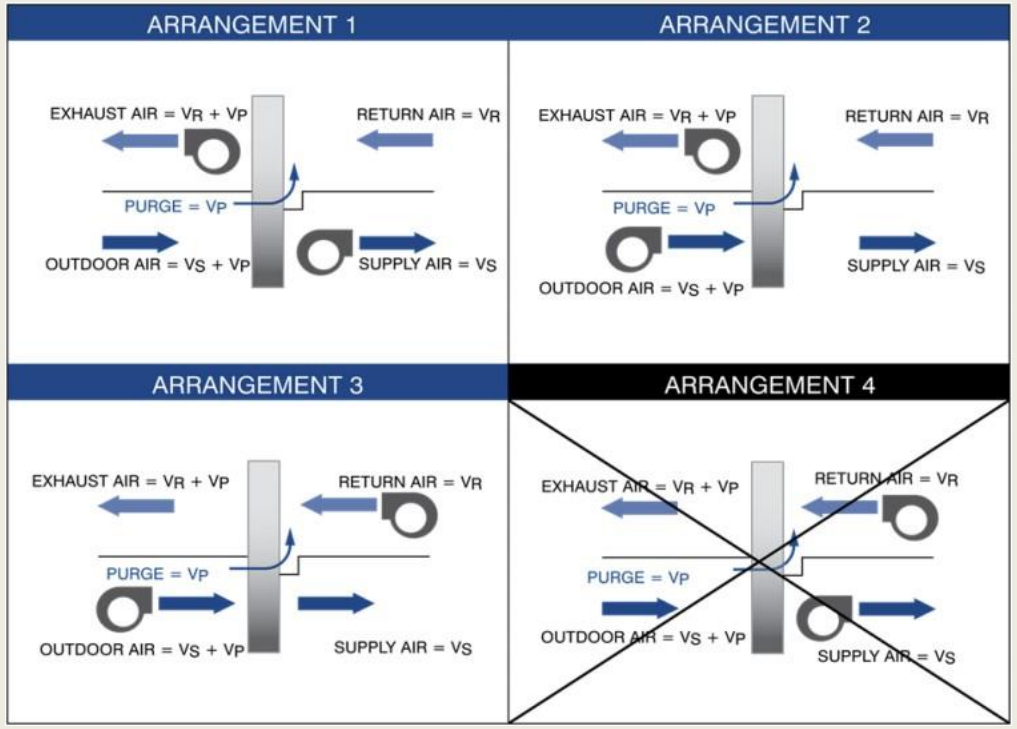
- *4.2 Maintain equivalent clean air supply required for design occupancy whenever anyone is present in the space served by a system.*
- Why it's important
  - *Discourages use of demand controlled ventilation, which reduces outdoor air to save energy and would increase infection risk*
  - *Underscores need to ventilate outside normal hours for cleaning and maintenance crews and others*

4. HVAC System Operation
Flushing Between Occupancies

- *4.3 When necessary to flush spaces between occupied periods, operate systems for a time required to achieve three air changes of equivalent clean air supply.*
- Why it's important
  - *May need to clear residual contamination between uses of a space or building to reduce risk*
  - *Early guidance from ASHRAE and others recommended 24/7 operation, with potentially high energy use and cost penalty*
  - *For a well-mixed space, 3 air changes will reduce initial concentration by 95% (5 air changes for 99% clearance)*
  - *Air changes can be equivalent non-infectious air supply*

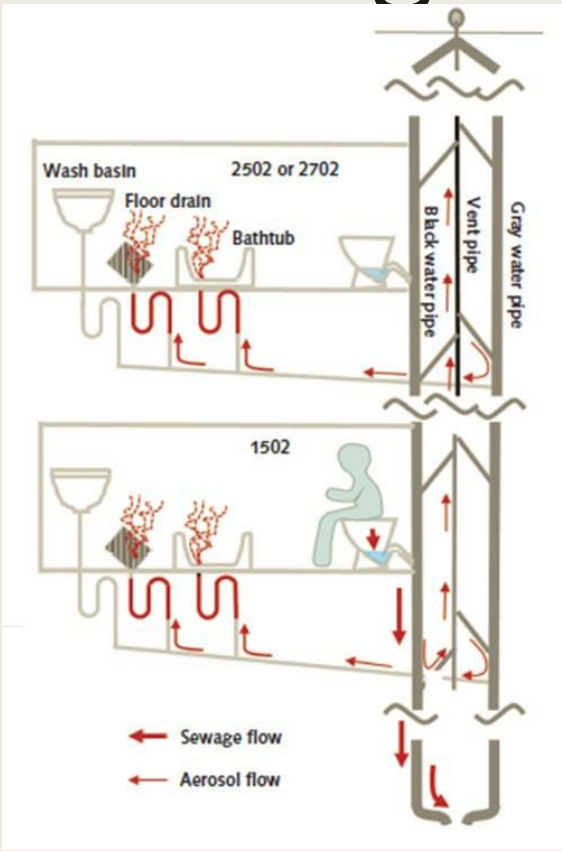
4. HVAC System Operation
Prevent Re-Entry

- 4.4 Limit re-entry of contaminated air that may re-enter the building from energy recovery devices, outside air intakes, and other sources to acceptable levels.
- Why it's important
  - *Initial recommendation by ASHRAE and others was to disable energy recovery ventilators, energy wheels, etc. that had any potential for re-entry*
  - *Current guidance addresses how to evaluate re-entry risk and assess ability to operate*
  - *Addresses other possible sources of re-entrant contamination*
- Note – may be updated to be more explicit about plumbing and ventilation shaft risk

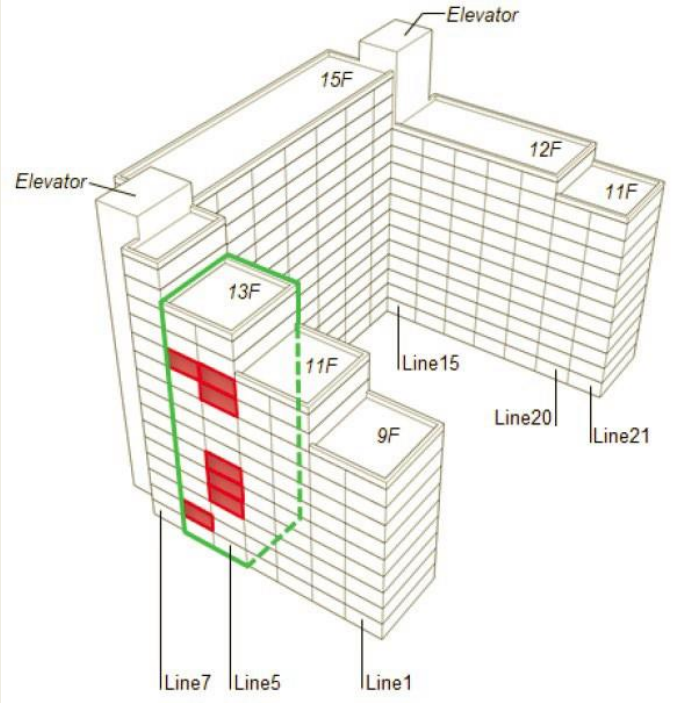


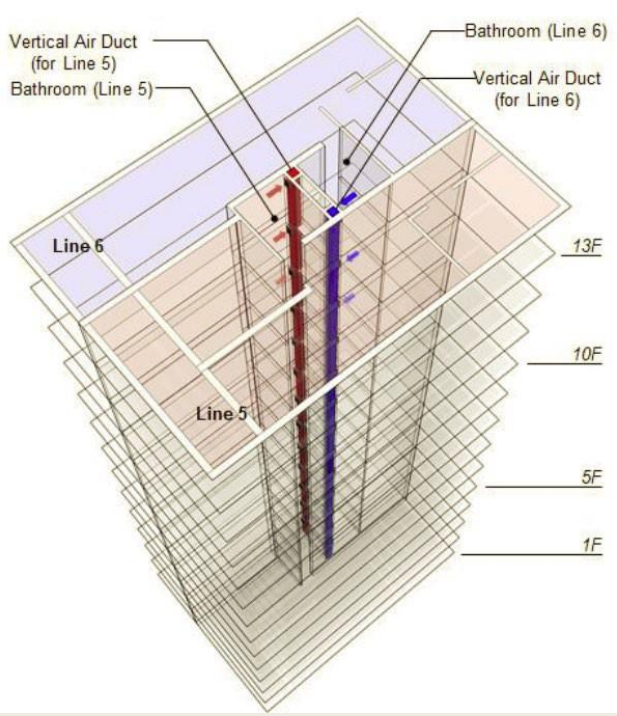
https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-building-readiness.pdf

Two recent investigations document plumbing and air shaft transmission



Kang, M., et. al. 2020 Probable evidence of faecal aerosol transmission of SARS-CoV-2 in a High-Rise Building. Ann Intern Med. doi:10.7326/M20-0928

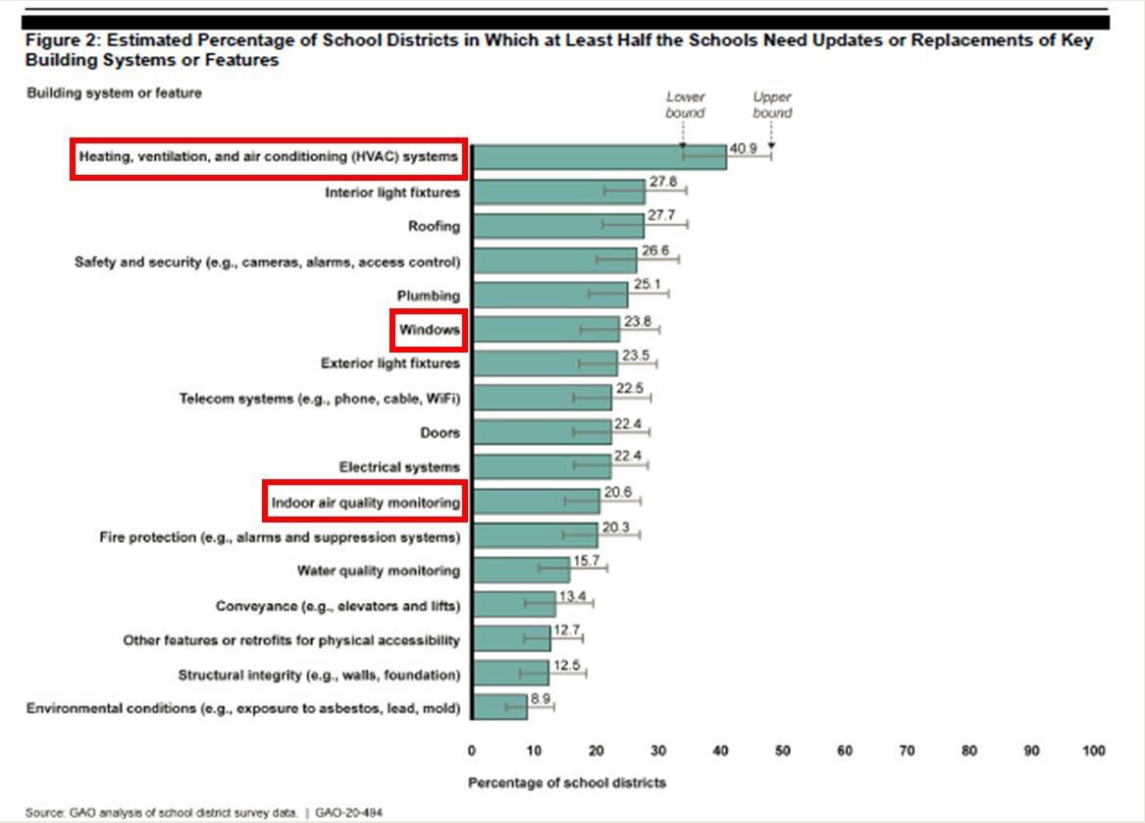




Hwang, S.E., Chang, J.H., Bumjo, O. and Heo, J., 2020. Possible Aerosol Transmission of COVID-19 Associated with an Outbreak in an Apartment in Seoul, South Korea, 2020. *International Journal of Infectious Diseases*.

5. System Commissioning

- *Verify that HVAC systems are functioning as designed.*
- Why it's important
  - *Many existing systems are poorly maintained*
  - *Performance of badly maintained systems is unpredictable*
  - *Retro-commissioning likely to make buildings safer and save energy*



https://www.gao.gov/assets/710/707374.pdf

Summary

- Initial guidance c. May 2020 was conservative, un-prioritized, semi-quantitative
- Feedback and review identified importance of addressing economics and energy
- Quantitative risk models provided a way to define acceptable airborne controls
- Current guidance is more flexible, less conservative, but still focused on risk reduction
- Mask use perceived more important now than ever
- Highest priority for ASHRAE is recommendations for equivalent clean air supply rates

Questions?

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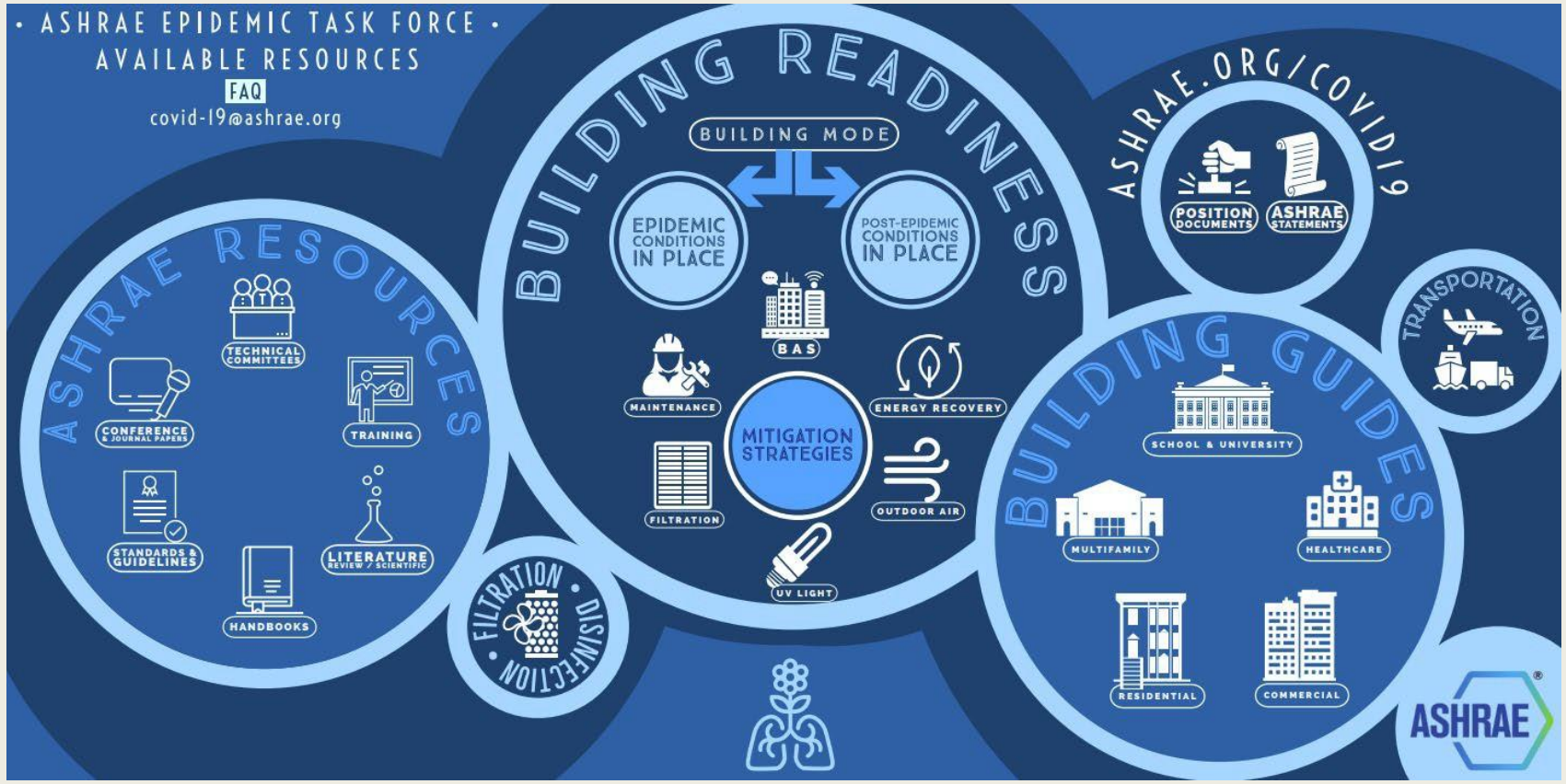
wbahnfleth@psu.edu



ashrae.org/covid19

Q & A

Submit Questions
www.slido.com event code **#DOE**

U.S. DEPARTMENT OF ENERGY

Additional Resources

- COVID-19 Resource Center
  - https://betterbuildingssolutioncenter.energy.gov/covid19
- HVAC Resource Map
  - https://hvacresourcemap.net
- ASHRAE COVID-19 Resources
  - ashrae.org/covid19

Next Webinar in the COVID-19 Webinar Series

The Energy Impacts of COVID-19 HVAC Mitigation Strategies

Monday, Feb 22, 2021 | 1:00 – 2:00 PM ET

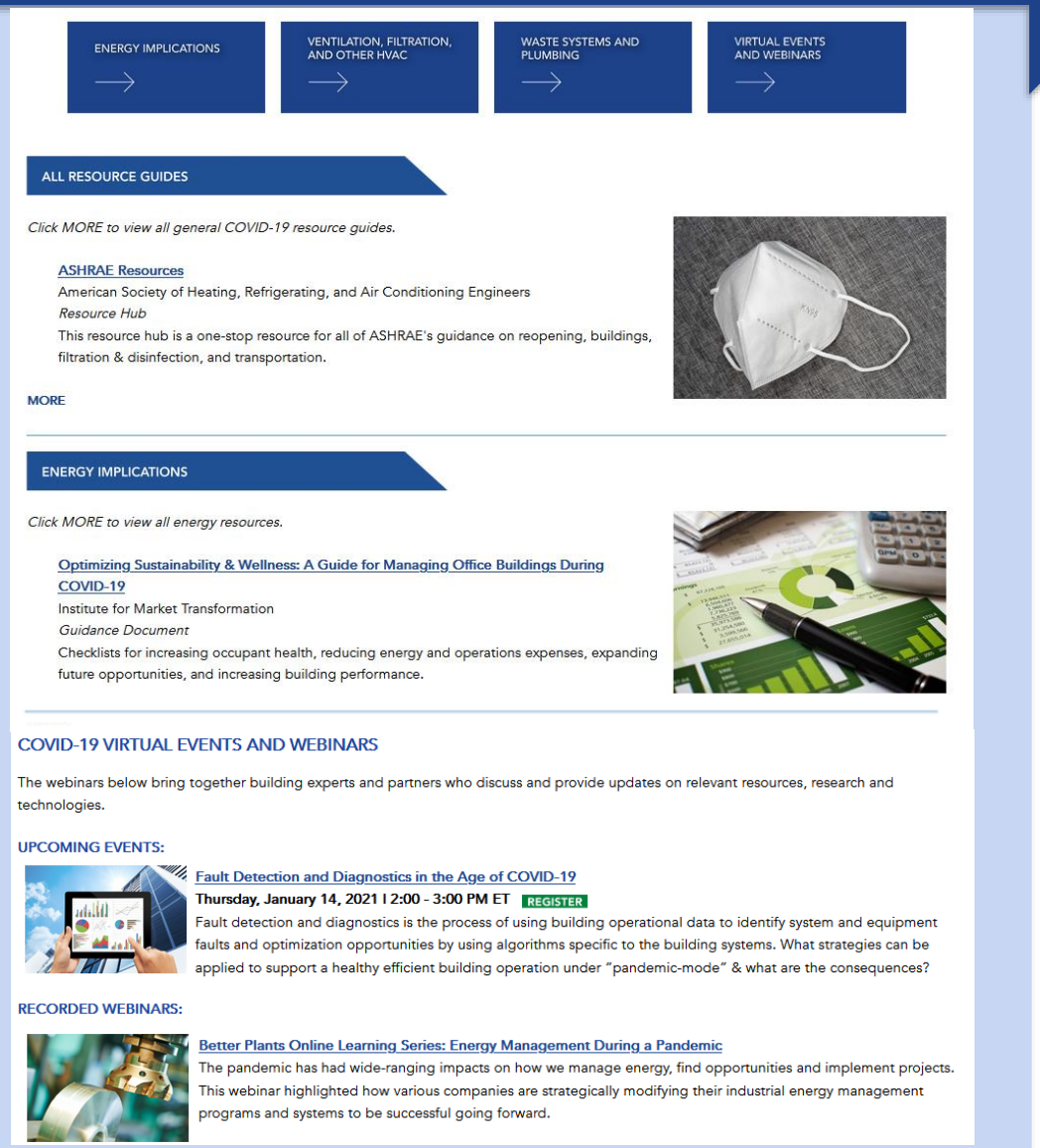
REGISTER TODAY

Chris CaraDonna
NREL

Kim Trenbath
NREL

What is the energy impact of major HVAC system operation guidance to reduce transmission of COVID-19 inside buildings across the U.S. commercial building stock? Speakers will discuss the energy implications of (1) 100% outdoor air ventilation rates, (2) installing MERV-13 filters or better, (3) disabling demand control ventilation, and (4) HVAC flushing mode operation. Analysis of these measures using ComStock provides a national view of the energy implications for various commercial building types in all U.S. climate zones.

COVID-19 Resource Center



ENERGY IMPLICATIONS

VENTILATION, FILTRATION, AND OTHER HVAC

WASTE SYSTEMS AND PLUMBING

VIRTUAL EVENTS AND WEBINARS

ALL RESOURCE GUIDES

Click MORE to view all general COVID-19 resource guides.

ASHRAE Resources
American Society of Heating, Refrigerating, and Air Conditioning Engineers
Resource Hub
This resource hub is a one-stop resource for all of ASHRAE's guidance on reopening, buildings, filtration & disinfection, and transportation.

MORE

ENERGY IMPLICATIONS

Click MORE to view all energy resources.

Optimizing Sustainability & Wellness: A Guide for Managing Office Buildings During COVID-19
Institute for Market Transformation
Guidance Document
Checklists for increasing occupant health, reducing energy and operations expenses, expanding future opportunities, and increasing building performance.

COVID-19 VIRTUAL EVENTS AND WEBINARS

The webinars below bring together building experts and partners who discuss and provide updates on relevant resources, research and technologies.

UPCOMING EVENTS:

Fault Detection and Diagnostics in the Age of COVID-19
Thursday, January 14, 2021 I 2:00 - 3:00 PM ET REGISTER
Fault detection and diagnostics is the process of using building operational data to identify system and equipment faults and optimization opportunities by using algorithms specific to the building systems. What strategies can be applied to support a healthy efficient building operation under "pandemic-mode" & what are the consequences?

RECORDED WEBINARS:

Better Plants Online Learning Series: Energy Management During a Pandemic
The pandemic has had wide-ranging impacts on how we manage energy, find opportunities and implement projects. This webinar highlighted how various companies are strategically modifying their industrial energy management programs and systems to be successful going forward.

Explore COVID-19 Resources today.

- **Learn from the experts** with resources from ASHRAE, EPA, DOE, and more…
- **View resources** grouped by technology type
- **Watch webinars** & register for upcoming virtual learning opportunities

Learn more at: https://betterbuildingssolutioncenter.energy.gov/covid19

Additional Questions?

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