Installing, Operating, And Servicing A/C Systems With COVID-19 In Mind
United Nations Environment Programme/Ozone Action Side Event to MOP 32

ENGINEERING CONTROLS FOR AIRBORNE INFECTION RISK

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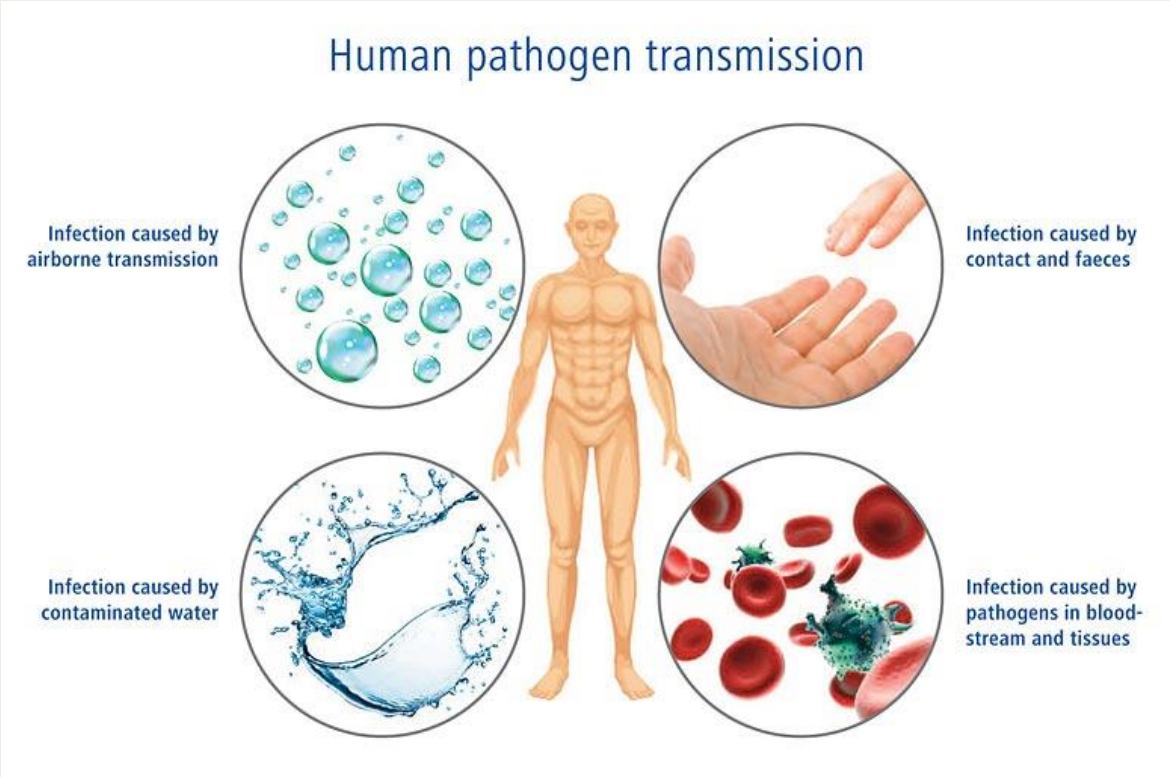
ARCHITECTURAL ENGINEERING

Infectious Disease Transmission Modes

- Airborne
  - *Droplet*
  - *Aerosol*
- Fomite – intermediate surface
- Direct contact
- Vehicle borne (water, food, blood)
- Vector (insect, animal)

…HVAC mainly impacts aerosol transmission



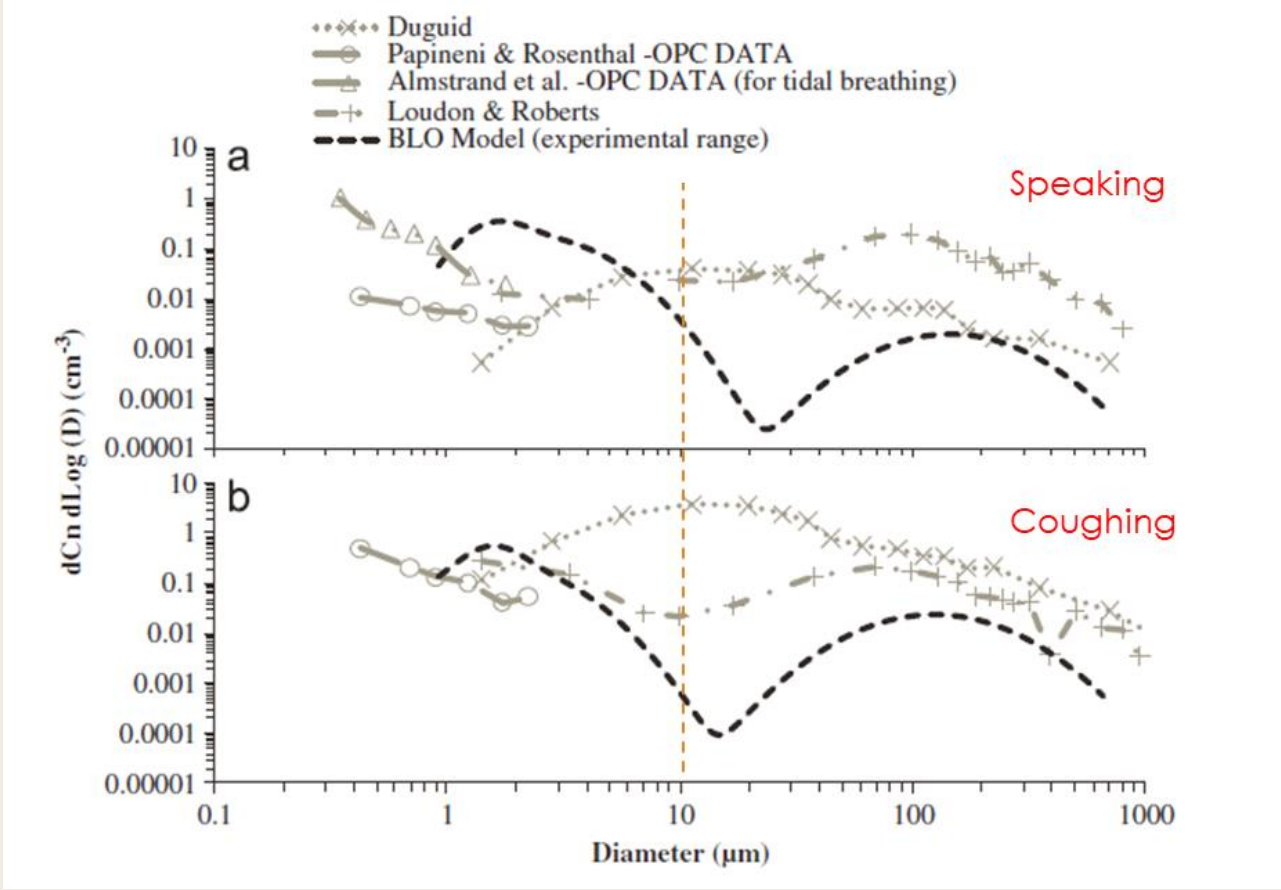
bode-science-center.com

Sources of Infectious Aerosols

- Humans – breathing, talking, singing, coughing, sneezing
- Plumbing – toilet flushing, splashing in sinks
- Medical procedures – dentistry, endotracheal intubation, others

Respiratory Droplet Characteristics

- Droplets contain proteins and salts, dry to 20-40% of initial size
- Pathogens are incorporated in particles
- Half or more of infectious load is in particles < ~5 μm
- Small particles can stay airborne for long periods of time



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

US CDC and WHO recognize possible indoor airborne transmission of Covid-19

(10/5/2020)

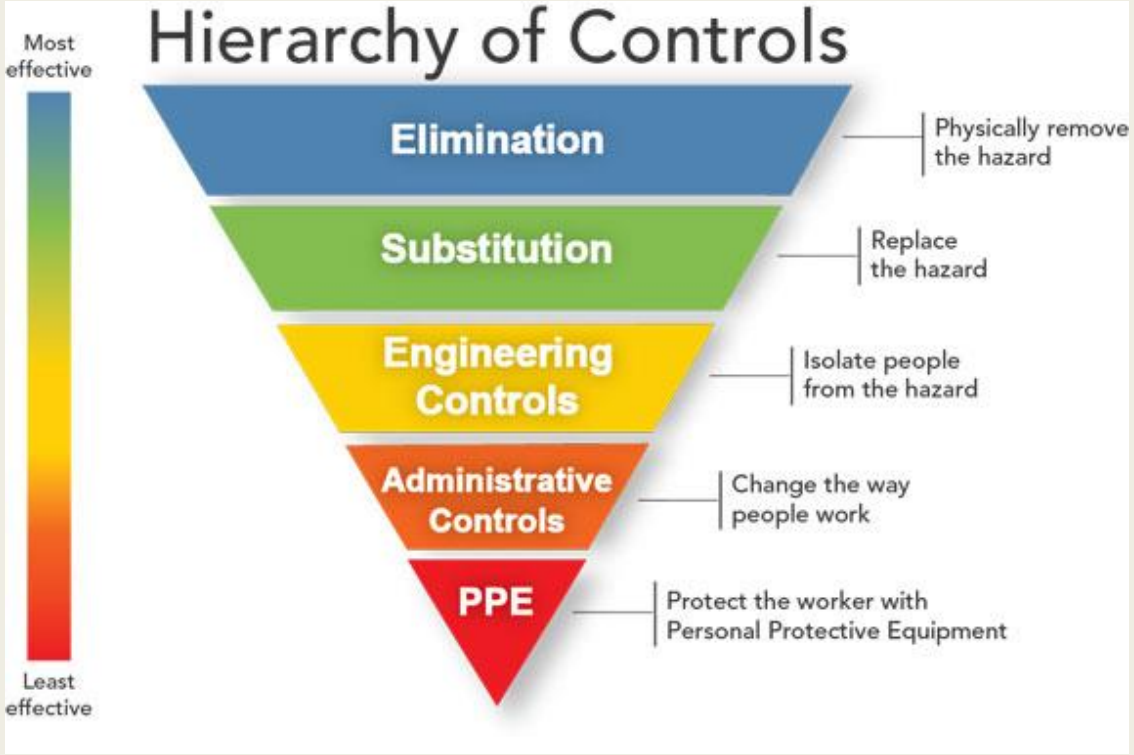
- *COVID-19 most commonly spreads during close contact*
  (cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/how-covid-spreads.html)
- *COVID-19 spreads less commonly through contact with contaminated surfaces*
  (cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/how-covid-spreads.html)
- *Airborne transmission of SARS-CoV-2 can occur under special circumstances*
  (cdc.gov/coronavirus/2019-ncov/more/scientific-brief-sars-cov-2.html)
  - *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."

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

Risk management:
HVAC is one layer of an effective mitigation strategy

- Source elimination
  - *Testing, contact tracing*
- Substitution – NA
- **Engineering controls**
  - ***HVAC interventions to control aerosols***
- Administrative controls
  - *Rules and procedures*
- Personal protective equipment
  - *N95 mask – mainly protects wearer*
  - *Surgical/cloth masks protect others (mainly)*



Engineering Controls

- Ventilation
- Air distribution
- Filtration
- Inactivation
  - *Air cleaners*
  - *Humidity and temperature control*

Ventilation with Outdoor Air

- Dilutes contaminants, increases exposure time required for exposure to an infectious dose
- Effective, but energy intensive, even with energy recovery
- Minimum required (e.g., ASHRAE 62.1) is a good baseline – must supplement with other controls
- 7-10 L/s-pers ≈ 15-20 cfm/pers

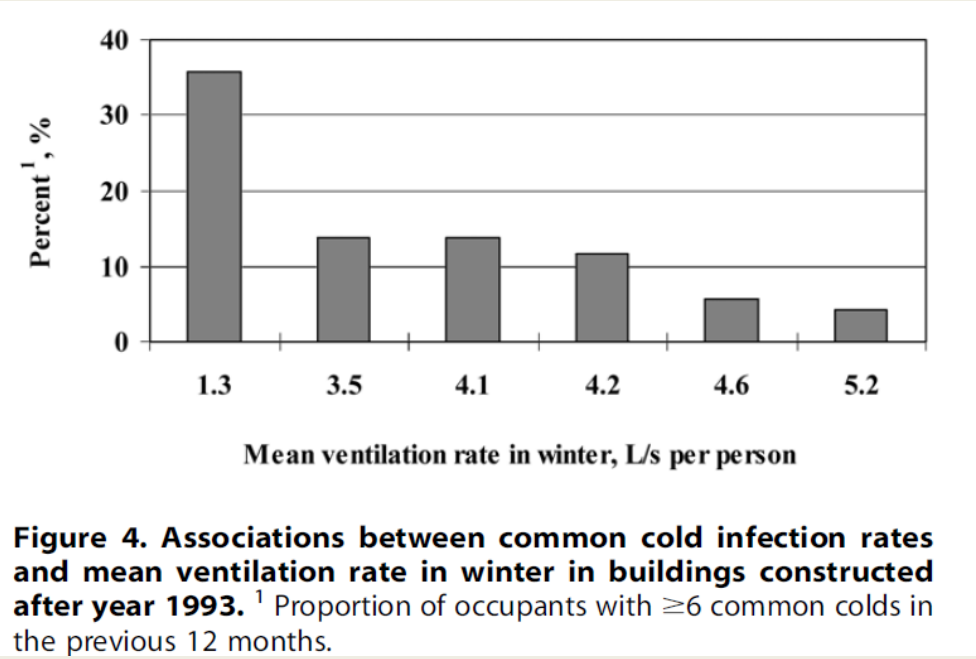
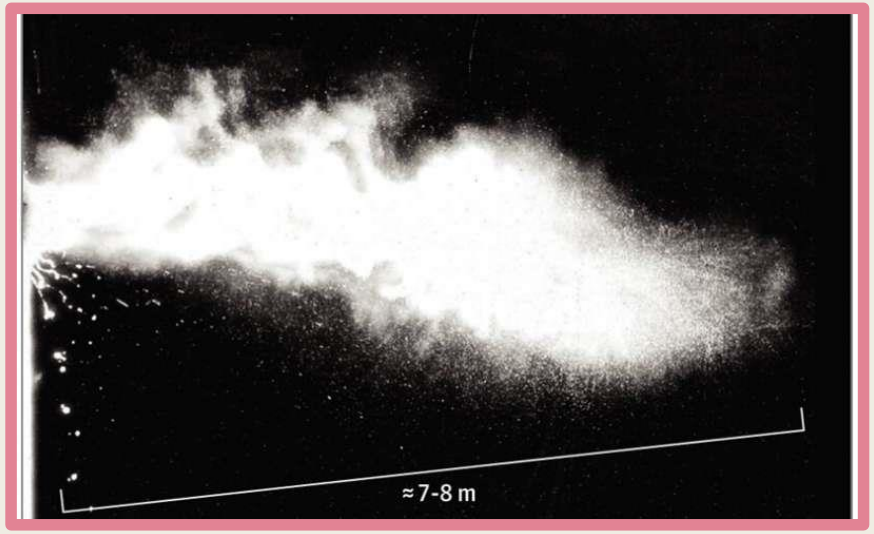


Figure 4. Associations between common cold infection rates and mean ventilation rate in winter in buildings constructed after year 1993. [1] Proportion of occupants with ≥6 common colds in the previous 12 months.

Sun, et al. (2011)
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3217956/

Air Distribution

- Strong drafts may extend distance travelled by large droplets - avoid
- Lower velocity mixing may be preferable to displacement
- Local exhaust/personal ventilation may be useful in some situations



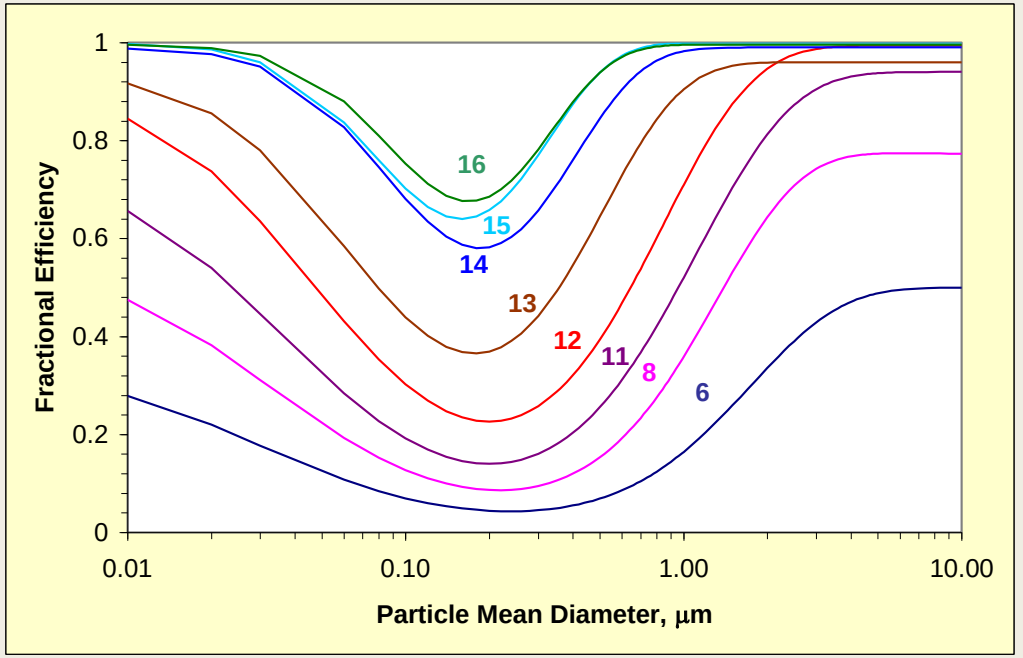
Bourouiba, L. JAMA. 2020;323(18):1837-1838.

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

Filtration

- High efficiency filters can remove respiratory aerosols efficiently
- For indoor sources, must have recirculation in space or through central system
- Effective if clean air delivery rate (efficiency × flow rate) is high enough
- Typical HVAC filters aren't effective for respiratory aerosol removal – MERV 13/ePM1 50% recommended for recirculated air
- Standalone HEPA filters can supplement HVAC

ASHRAE Standard 52.2
Minimum Efficiency Reporting Value



Representative MERV rated filter performance (Kowalski and Bahnfleth 2002)

Inactivation – Air cleaners

- Germicidal ultraviolet light
  - *UVC damages DNA/RNA or envelope of pathogen*
  - *Well developed technology approved by US CDC for tuberculosis control*
  - *Multiple ways to use*

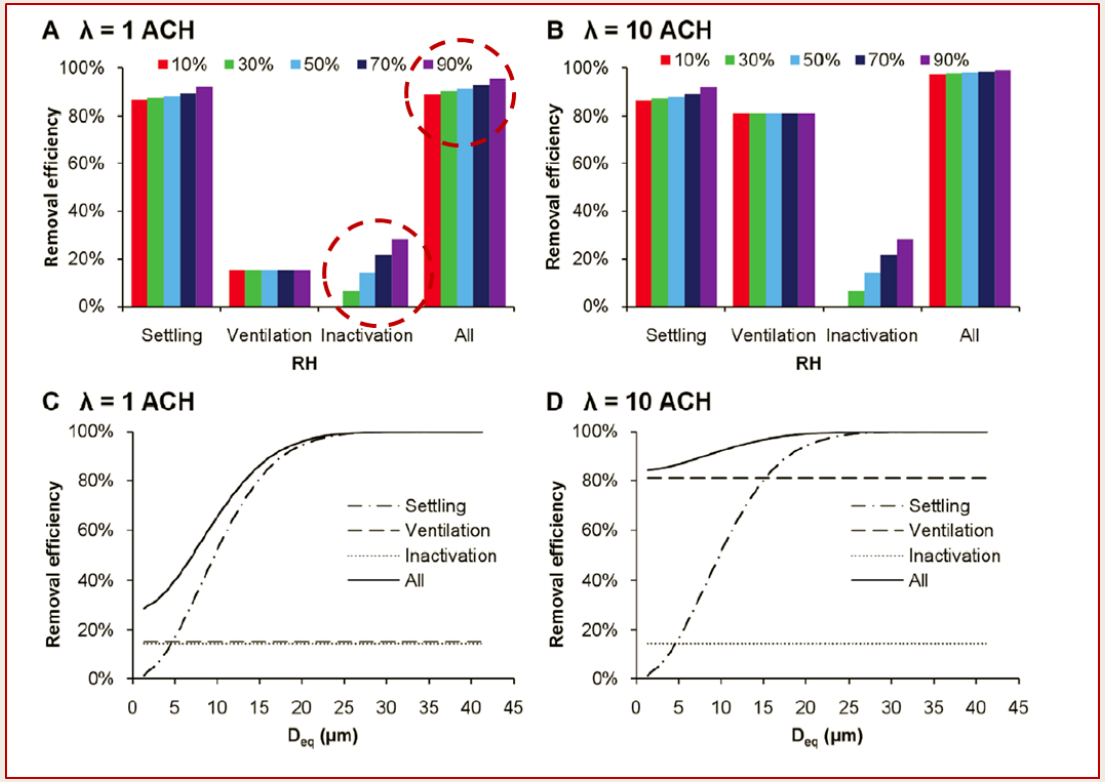
Upper Room

Airstream

- Other, less proven technologies that put reactive species in air
  - *Ionizers*
  - *Dry hydrogen peroxide*
  - *Photocatalytic oxidation*
- Be sure air cleaners are:
  - *Safe*
  - *Effective for proposed application*

Inactivation Temperature and Humidity

- Activity of viruses varies with temperature and relative humidity
- Affect susceptibility to infection
- Maintaining a minimum humidity has benefits, but difficult to implement in many buildings
- Order of magnitude lower effect than ventilation and filtration



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

Summary

- Engineering controls reduce airborne infection risk by reducing exposure through dilution/exhaust, capture, and inactivation
- Minimum ventilation and filtration requirements for non-healthcare facilities generally do not provide acceptable infection risk
- To achieve best outcome, combine required minimum ventilation with other controls, especially high efficiency filtration of recirculated air, to achieve control targets
- Air cleaners are an important class of controls, but available technologies have a wide range of evidence for efficacy and safety

Thank You!

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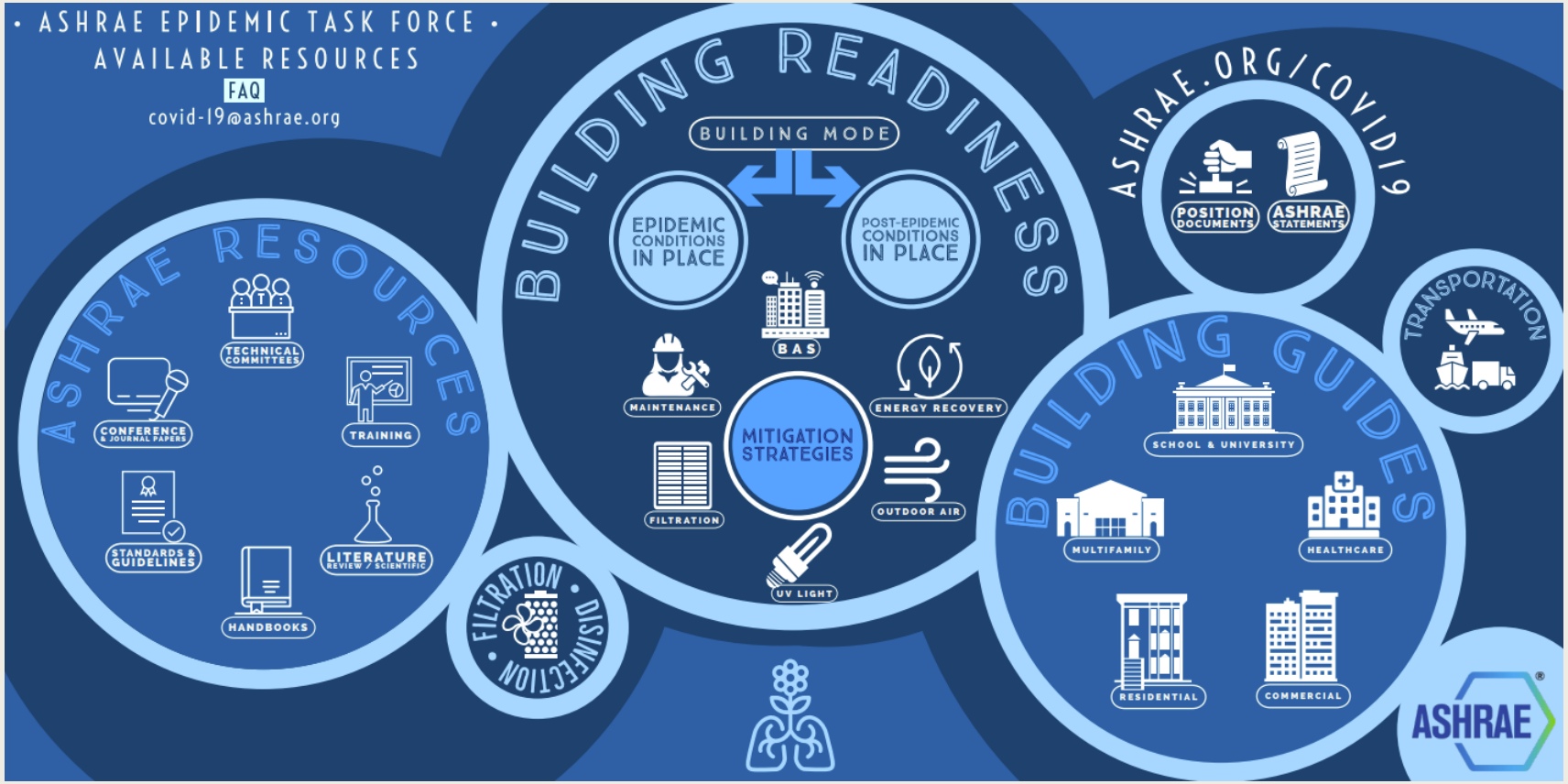

ashrae.org/covid19