WHITE PAPER

BUILDING OPPORTUNITIES FOR THE NEW COVID-19 REALITY

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DISCLAIMER

This document is based on best available evidence and knowledge, but in many aspects' COVID-19 (SARS-CoV-2) information is so limited or non-existent that previous evidence from other airborne infectious diseases has been utilized for best practice recommendations. Autocase™ and IncentiFind™ excludes any liability for any direct, indirect, incidental damages or any other damages that would result from, or be connected with the use of the information presented in this document.

INTRODUCTION

This whitepaper is a summary of the building science literature collected to date by Autocase - an economics SaaS and advisory company for the real estate and infrastructure market - on the indoor air quality relationship between Heating, Ventilation and Air-Conditioning (HVAC) systems and the spread of airborne infectious diseases. It represents the latest information in this field and is aligned with recommended guidelines to reduce the spread of COVID-19 from the US Centers for Diseases Control and Prevention (CDC), the World Health Organization (WHO), and HVAC industry leaders. Due to the evolving nature of COVID-19, Autocase is committed to staying on top of the state of practice in this area and will continue to utilize best available peer-reviewed literature.

As businesses begin to open again since being in lockdown due to the COVID-19 crisis, health and safety protocols can be put in place to reduce the spread of COVID-19. This daunting task is made even more complex with the potential for airborne transmission of COVID-19 within the built environment. The building science literature discussed herein analyzes the usage of HVAC systems to reduce the risk of infection from airborne infectious diseases.

Building operators should consider interventions relating to:

- building/floor plan layouts,
- cleaning/sanitation,
- ventilation,
- filtration,
- humidity control, and
- temperature control.

Given the accelerating timeline of returning to work and increasing demand for understanding the value of measures to reduce the spread of COVID-19, economic analysis is a tool that can support stakeholders by providing insights into long-term trade-offs, occupant health outcomes, and community benefits (1). Autocase can assist users in valuing the financial, social, and environmental impacts of implementing HVAC system suggestions, and IncentiFind can assist users in finding financial incentives that will reduce the financial incremental costs of implementing these suggestions.

TRANSMISSION OF COVID-19

As the unravelling of lockdown protocols begins around the world and employees return to the office environment, building owners may need to consider altering the layout of their floor plans to encourage “social distancing” between employees to reduce the spread of COVID-19. The WHO has reported that the transmission of COVID-19 occurs along 2 major routes: droplet transmission (the release of infectious particles through actions such as sneezing, coughing, or talking) and surface (fomite) transmission, through direct contact (hand to hand) and indirect contact (hand to surface) (2).

It has been reported that COVID-19 also has the potential to be transmitted through another route: airborne transmission (2-7, 13, 14). Airborne transmission occurs when large droplets are released into the air (via coughing, sneezing, talking, shouting) and evaporate and desiccate into small particles, also known as droplet nuclei (8). These droplet nuclei can remain airborne for several hours (9) and, when infected, can spread COVID-19 to other individuals. See Figure 1 for a graphical representation of the transmission routes of COVID-19 (dark blue arrows represent known transmission routes; light blue, potential routes). Other diseases that share similarities to COVID-19, such as SARS or influenza, have been documented as being transmitted through the airborne route (10-12). As new research continues to investigate the dynamics of COVID-19, our understanding of how the disease is transmitted will become clearer.

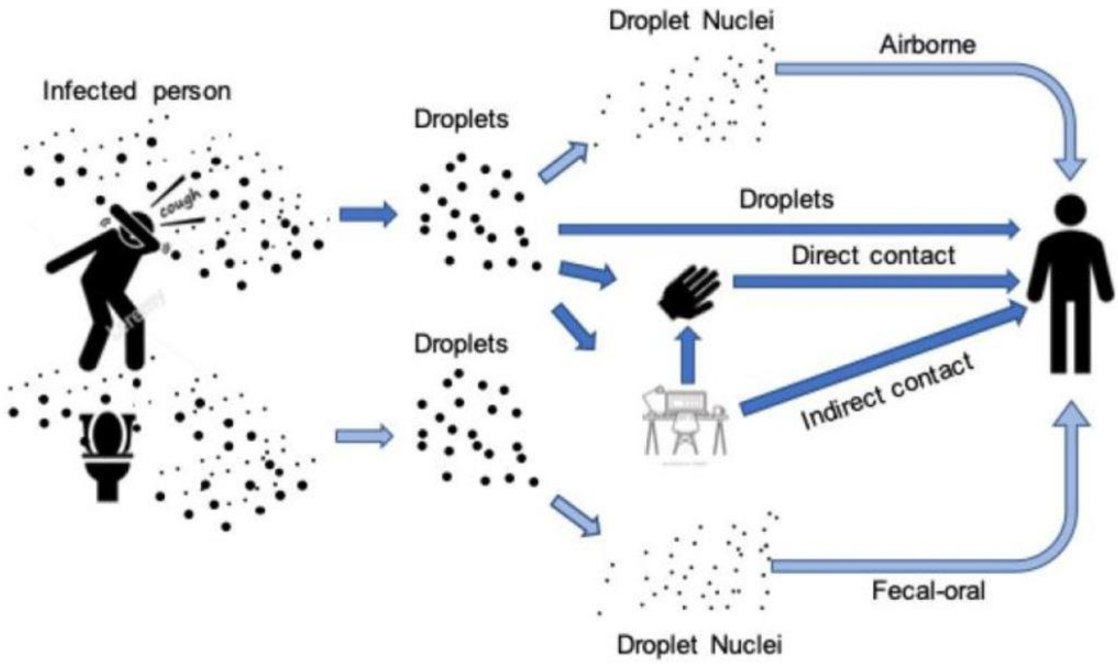

Figure 1. Transmission Routes of COVID-19
Source: REHVA COVID-19 guidance document, April 3, 2020

INTERACTION OF AIRBORNE TRANSMISSION OF COVID-19 AND THE BUILT ENVIRONMENT

The goal of HVAC is to provide its occupants with thermal comfort and acceptable indoor air quality (IAQ). Residential and commercial buildings can utilize their HVAC systems to reduce the airborne transmission of COVID-19. Research has shown that a poorly ventilated restaurant in Guangzhou, China led to the spread of COVID-19 among 3 families (13, 14). Though seated at distances away from each other, this preliminary research concluded that with the exhaust fans turned off (in others words, no mechanical ventilation), COVID-19 was able to spread from the index patient to the other families via the spread of infected airborne particles. The conclusion from this research is that aerosol transmission of SARS-CoV-2 from poor ventilation may explain the community spread of COVID-19. By improving the quality of the HVAC system, the airborne transmission of COVID-19 may be reduced.

HVAC industry leaders, such as ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) and REHVA (Federation of European Heating, Ventilation and Air-Conditioning Associations), recommend using HVAC to reduce the airborne transmission of COVID-19 and, have released guidance and position statements on best practices for HVAC usage within the built environment. ASHRAE's stance on the relationship between HVAC and COVID-19 is that "transmission of SARS-CoV-2 through the air is sufficiently likely that airborne exposure to the virus should be controlled" (15).

Changes to building operations, including the operation of HVAC systems, can reduce airborne exposures. For example, recommended interventions from ASHRAE and REHVA include:

- increasing ventilation (both mechanical and natural),
- improving air filters,
- disinfecting the HVAC system (i.e., UGVI), and
- altering the relative humidity (RH) within the building.
- The disabling of HVAC systems is not a recommended measure to reduce the transmission of the virus (8, 15)

Other industry leaders and research experts, such as HoK (16), A.G. Coombs (17), UC Davis Energy and Efficiency Institute (18), and Urban Land Institute (19), have corroborated the recommendations set forth by ASHRAE and REHVA. These recommendations support and align with policies recommended from the US CDC (20) and the WHO (21).

HOW CAN HVAC BE USED TO REDUCE THE SPREAD OF AIRBORNE DISEASES

This section discusses three major aspects of HVAC that can reduce the airborne transmission of airborne diseases: ventilation, filtration, and relative humidity. Research on the direct relationship between HVAC and COVID-19 remains preliminary and findings are receiving a fast-tracked version of the scientific process (i.e., peer review). Until the research is scientifically confirmed, recommendations and guidelines must be based on findings from the current consensus on the relationship between HVAC and other infectious diseases that can be spread via airborne transmission, such as SARS, MERS, tuberculosis, measles, or influenza. Reviews of literature on aspects of the relationship between HVAC and COVID-19/other airborne diseases that are not included here (i.e. disinfectants and HVAC, natural ventilation) may be included in future versions of this whitepaper as interest grows.

VENTILATION

Ventilation refers to the distribution and removal of air from space by mechanical or natural means (22). Mechanical ventilation in a building is best measured through the air flow or ventilation rate, which represents the amount of air introduced into the building, and airflow patterns. A multidisciplinary study conducted an extensive literature review of the association between ventilation and the airborne transmission of infectious diseases, including measles, tuberculosis, influenza, and SARS (23). This review determined that strong evidence exists to demonstrate the association between infectious disease and ventilation (both for rates and airflow patterns); however, they were unable to recommend minimum ventilation requirements in offices, homes, hospitals, and schools. This has been corroborated by more recent research that further highlighted the association between ventilation and the airborne transmission of infectious agents (24). Research has also found that increasing ventilation rates reduces the risk of infection from long-range airborne diseases (25, 26). The concern with increasing ventilation rates is that it can lead to increases in the relative humidity of a building (27), with extreme RH resulting in thermal discomfort and negative health impacts. Changes to the ventilation of buildings must occur with these concerns of other impacts in mind.

In conclusion, increasing ventilation rates and improving airflow patterns for buildings are a viable aspect of HVAC to use in reducing the spread of airborne diseases. Exceedingly high ventilation rates, based on building- and location-specific factors, may lead to other negative health impacts.

FILTRATION

Filtration refers to the use of air filters to remove particulate matter (PM) from the outdoor and recirculated air in a building before circulating it through the HVAC system. A majority of air filters are rated using the minimum efficiency reporting value (MERV), where the higher the rating, the larger the percentage of PM captured by the air filter on each pass. Research has shown that in a hypothetical office setting, higher rated MERV filters (i.e., MERV 13-16) were found to achieve the greatest risk reduction of influenza (28), tuberculosis and rhinovirus (29) infection. Guidelines set out by ASHRAE recommend that buildings upgrade their air filters to a minimum rating of MERV 13 (30). MERV 13 filters can remove microbes and particles that range from 0.3 to 10.0 µm (26), while COVID-19 has been observed in aerosolized particles at sizes that range from 0.25 to 0.5 µm (31). Thus, the highest rated MERV filters may be able to reduce the risk of infection from COVID-19, though there is no guarantee that the filter will capture all particles (26). Higher rated MERV filters also carry consequences for higher filter turnover rates, if the environment is not used to its presence, and increased purchasing costs, though the cost for a MERV 13 is roughly comparable to a MERV 11 but with greater reductions in infection with the former (28).

In conclusion, higher efficiency filters are a viable aspect of HVAC to use in reducing the spread of airborne diseases. Higher efficiency filters are better suited to removing the smallest particles, but are not guaranteed to capture all particles. They may also lead to higher operational costs in the short-term.

RELATIVE HUMIDITY

Relative humidity "is the amount of moisture air can hold compared to the maximum amount of moisture the air can hold at a specific temperature" (27). ASHRAE standards, and common consensus among building science research (32), recommend that buildings maintain an RH range of 40-60%. At a temperature consistent with the built environment (low-to-mid 20℃), this range of RH leads to reductions in the survival rate of airborne diseases, such as influenza and TGEV (33-35). However, research has also shown that other coronaviruses, such as SARS or MERS, do not experience reductions in durability at the recommended RH range at these temperatures (36-38), but these studies were conducted in environments that may not correlate with the dynamics of the built environment. This diverging literature has led to different sentiments from industry leaders on humidity control and COVID-19, with REHVA stating that humidification should not be used to reduce the spread of COVID-19 (8) and ASHRAE recommending its usage, but dependent upon the building specific situation (30). Research has also shown that setting RH above 60% is also effective in reducing the survival rate of airborne diseases (26, 36, 37), however this will result in thermal discomfort and other negative health impacts within the built environment.

In conclusion, there is a divide in the research on the recommended range/value of RH to combat the spread of airborne diseases. The extremes of RH (i.e., low RH of ~20% or a high RH of ~80%) should not be used as they lead to other negative health impacts.

VALUING INVESTMENTS INTO RECOMMENDED HVAC STRATEGIES

Strategies proposed by the CDC (39), the American Institute of Architects (AIA) (40), and ASHRAE (41) encourage the usage of HVAC to prevent the airborne transmission of COVID-19 and are based on the preceding research. Implementing these recommendations into the built environment will require discussions and agreements among building owners, managers, floor planners, and construction workers. Each building type requires a unique implementation of proposed recommendations, due to a variety of location-specific factors including city- and state-policy, climate, temperature, wind speed, energy efficiency policies and more. When optimizing the HVAC system to a specific building type, all inputs and local incentives must be considered.

The financial impacts of implementing such strategies are easily measured, but what cannot be ignored among this global pandemic is the social and environmental impacts that will occur from these recommendations. Triple Bottom Line Cost Benefit Analysis (TBL-CBA) is an ideal framework to understand the overall net benefit of these HVAC recommendations and provide a quantitative measure of qualitative considerations into the decision-making process.

Cost Benefit Analysis (CBA) involves identifying, quantifying, monetizing and summing in dollars to the extent possible the value of incremental costs and benefits over the life of a project. The importance of CBA for decision makers is that its results provide a quantitative measure of a project's worthiness – the value of which can be measured from the perspective of the facility owner and the public at large. Furthermore, it uses location-specific data to give facility owners and design professionals the flexibility and capability to provide a rigorous analysis of HVAC recommendations that are suitable for your location. Autocase's TBL-CBA framework can be used to value the incremental costs and benefits that occur from the COVID-19 specific recommendations and guidelines for HVAC systems.

CBA is frequently used in healthcare contexts to understand the quantitative outcomes of investments, policies, and regulations, by placing monetary values on health outcomes. For example, quality-adjusted life years (QALYs) are a means of quantifying the health effect of a medical intervention or a prevention program and are utilized in CBA to place monetary values on lives saved or illnesses reduced. Beyond its usage in healthcare contexts, CBA is a common approach to better understand investment and policy outcomes to inform the decision making process.

Though many of these interventions and suggestions are relatively inexpensive, the economic impacts of COVID-19 have reduced the financial capabilities of companies. IncentiFind has identified opportunities for building investments related to COVID-19 response interventions to be offset by [financial] incentives. Their database of real estate incentives boasts over 12,000 incentives available to commercial property owners. Of those incentives 36% are custom energy efficiency incentives. Custom energy efficiency incentive programs are applicable to a variety of HVAC upgrades, applications, equipment, and measures that a property owner may leverage in response to COVID-19 interventions. Of the (over) 12,000 incentives, 15% are specific to HVAC system upgrades or installations. Funds from custom or HVAC incentives are designed to reward installations that go above basic building code. The more energy efficient the HVAC equipment is, the more funding a property owner can claim.

Here are a few examples of property owners claiming substantial savings from custom and/or HVAC incentives.

A large retrofit of a Houston office (class B) in January 2020, applied to a custom incentive program and, captured $190,000 in cash reimbursements for their HVAC upgrade and LED lighting upgrade. Leveraging the funds available through Centerpoint's Standard Offer Program allowed the tenant to cover 30% of total improvement costs.

In Los Angeles County California in March 2020, a multifamily building underwent a retrofit and applied to two incentives and, captured $162,000 in cash reimbursements for their HVAC and LED lighting upgrade. Leveraging the funds available through Los Angeles Department of Water and Power's Custom Performance Program and Commercial Lighting Program incentive allowed the operator to cover 41% of improvement costs.

In Baltimore June 2020, a hotel upgraded their building while occupancy was low (due to COVID-19) and applied for three incentives and, captured $156,000 in cash reimbursements for their HVAC, controls, and LED lighting upgrade. Leveraging the funds available through Baltimore Gas & Electric's HVAC Systems, Custom Measures and Projects, and Instant Lighting Incentive Program allowed the property owner to cover 24% of improvement costs.

CASE STUDY

FORT BLISS REPLACEMENT HOSPITAL

Fort Bliss Replacement Hospital in El Paso, Texas used TBL-CBA to analyse two design alternatives for reducing hospital acquired infections (HAIs) from airborne and surface contaminants.

The first design alternative was using HEPA (High Energy Particulate Arresting) filtration systems at all air handling units in patient-care areas to reduce HAIs from airborne contaminants. Fort Bliss' design for HEPA filters distributed the system throughout the hospital, focusing on patient care units, the Emergency Department, chemotherapy infusion areas, hematology-oncology areas, operating suites, and ICU's. This was expected to result in mean total investment costs of $190,000.

The second design was using hydrogen peroxide vapor (HPV) cleaning to reduce HAIs from surface contaminants. Compared to conventional cleaning, HPV was found to result in significant reductions in Methicillin-resistant Staphylococcus aureus (MRSA) contamination (42). This design would install a fixed HPV distribution system, via ducts and valves, in the ceiling of all 200 patient care units. This was expected to result in mean total investment costs of $1.275 million.

Working as part of an interdisciplinary project team, the study leveraged the best available peer-reviewed, empirical data and projected the impacts on an annual basis over a long term study period (40 years). The Net Present Value (NPV) - the sum of the present value of future cash flows less the present value of the project's costs - represents the discounted value of these future cash flows in current dollars; a positive value denotes net benefits exceeding costs. In this case, both design alternatives would lead to positive TBL-NPVs and increases in QALYs, with the HPV cleaning generating the greatest results of roughly $258 million and 993 QALYs gained from mortality reductions (see Table 1 and 2 for more details).

TBL-CBA showed that both design alternatives resulted in positive TBL-NPVs and non-monetary gains via increases in QALYs from morbidity and mortality reductions. Furthermore, other social and environmental impacts were also captured using the TBL-CBA process. These results helped the project team and owner understand the trade-offs and outcomes from these options to make more informed design decisions.

Table 1. Triple Bottom Line Net Present Value of HEPA Filtration and HPV Cleaning for Fort Bliss Replacement Hospital

(44 Years and Using 4.8% Discount Rate)			
	Impact	HEPA Filtration	Hydrogen Peroxide Vapor Cleaning
Financial	Capital Costs	-$190,000	-$1,275,000
	O&M	-$484,610	-$164,116
	Replacement Costs	-$71,003	-$95,927
	Residual Value	$11,874,621	$42,069,949
	Electric Bill Cost	-$1,686	-$3,877
Social	Mortality Savings	$67,624,038	$211,512,052
	Morbidity Savings	$229,156	$716,770
	Treatment Cost Savings	$916,426	$2,866,376
	Labour Efficiency Savings	-	$2,542,158
Env.	Carbon Emmisions	-$490	-$920
	Air Pollution	-$950	-$1,824
Financial NPV		$11,127,322	$40,531,029
Social NPV		$68,769,620	$217,637,356
Environmental NPV		-$1,440	-$2,744
Triple Bottom Line NPV		$79,895,502	$258,165,641

Table 2. Non-Monetary Results of HEPA Filtration and HPV Cleaning for Fort Bliss Replacement Hospital

(44 Years and Using 4.8% Discount Rate)		
	HEPA Filtration	Hydrogen Peroxide Vapor Cleaning
Total QALYs gained due to morbidity reductions over 40 years	1	3
Total QALYs gained due to mortality reductions over 40 years	317	993

CONCLUSION

As lockdowns around the globe begin to be rolled back, the implementation of health and safety protocols against COVID-19 in the built environment is of paramount importance for countries, building owners, and health officials. HVAC systems may assist the built environment in reducing the airborne transmission of COVID-19, through:

- increased ventilation,
- higher rated/efficient air filters, and
- maintaining the temperature and relative humidity of the building/room within an optimal range.

Implementation of these and other recommendations are dependent upon location and building-specific features. These features are designed to reduce the spread of COVID-19, not remove it entirely. Under constrained capital budgets and uncertainty with interventions, economics can offer additional insights into the quantitative outcomes of a broad-array of investments, including infection control, allowing for more informed decisions in risk reduction, project prioritization, design guidelines development, and stakeholder engagement.

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