FLEXTECH
ENERGY EFFICIENT INDOOR AIR QUALITY STUDY

FINAL CONCLUSIONS REPORT

For

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Joint Statement from NYSERDA and ASHRAE on the Energy Efficient Indoor Air Quality Study Conclusion Reports

The Energy Efficient Indoor Air Quality Study Conclusion Reports summarize the findings from individual studies conducted under the FlexTech Energy Efficient Indoor Air Quality Pilot. NYSERDA presented this offering in May 2020 in response to a two-fold call from commercial market building owners and managers of New York to better understand:

1. the energy impact of the COVID-19 response guidance that was emerging in the market between March and May of 2020, and
2. how energy efficiency goals could be achieved in conjunction with reducing the risk of building occupants transmitting and contracting COVID-19 in the built environment.

When reading these reports and contemplating the conclusions drawn, it is important to consider the context of the time period in which these studies were conducted and the uniform parameters by which the consultants were bound. NYSERDA directed the consultants to use the building readiness guidance that was in the market when the studies commenced in June 2020. The ASHRAE Epidemic Task Force (ETF) guidance available to the market at the time consisted of the following document versions:

Building Readiness v.5-21-2020
Commercial v.4-20-2020
Schools & Universities v. 5-5-2020
Healthcare v. 6-17-2020
Filtration & Disinfection v. 5-27-2020
ERV Practical Guide v. 6-9-2020

While a benefit of this approach is to allow for a comparative analysis across all the studies under the initiative to explore overarching conclusions applicable to the broader market sector, a drawback emerged when ASHRAE guidance evolved significantly while the studies were underway. As a result, some of the guidance that formed the basis of the studies is no longer advocated as best practices by leading authorities in the market, including the ASHRAE ETF. Current ASHRAE ETF guidance is summarized in its Core Recommendations (1/6/2021). The concise guidance in the Core Recommendations is reflected in more recent versions of the guidance documents noted in the table above. To provide the reader a side-by-side account of the changes to the ASHRAE ETF's guidance, the table below compares guidance available to the market at the time the studies commenced to the current ASHRAE Core Recommendations and the resulting energy implications.

ASHRAE Epidemic Task Force Guidance

	<u>**THEN**</u> **Building Readiness Guidance *version 5.21.2020*** and/or **Commercial Guidance *version 4.20.2020***	<u>**NOW**</u> **Core Recommendations *version 1.6.2021*, Building Readiness *version 4.27.2021*,** and/or **Commercial Guidance *version 3.22.2021***	**Energy Impact Takeaways**
Outdoor airflow rate	• Increase system outdoor air ventilation as much as the system and or space conditions will allow to reduce the recirculation air back to the space during occupied hours • Open windows where appropriate during occupied hours. • For HVAC system that use Demand-controlled ventilation sequences we recommend disabling this feature for the duration of the crisis.	• Provide and maintain at least required minimum outdoor airflow rates for ventilation as specified by applicable codes and standards • Maintain equivalent clean air supply required for design occupancy whenever anyone is present in the space served by a system • Evaluate the use of additional outdoor air as a mitigation strategy compared to other items, such as filters or air cleaners[1]. • For HVAC system that use Demand-controlled ventilation sequences we recommend disabling this feature for the duration of the crisis[2]	It is more energy and cost efficient to operate systems with less outdoor air
Filtration	Update or replace existing HVAC air filtration to a minimum of MERV 13 (MERV 14 preferred) or the highest compatible with the filter rack	Achieve MERV 13 or better levels of performance for air recirculated by HVAC systems by using a combination of filters and air cleaners[3]	Depending on the performance of the current filtration system, higher MERV filter ratings might increase system pressure drop, leading to increased energy use and cost. Using carefully selected filters, or the appropriate combination of MERV filtration and air cleaners, could mitigate a negative energy impact.
Air Cleaners	• Where there can be a large assembly of people, consider air treatment, e.g. upper-room UVGI lamps. • Consider adding air treatment and cleaning devices such as UVGI in duct, plenums and air handling units and on the face of cooling coils[4]. • If an increase in filter MERV level cannot be accommodated using the existing air handling equipment fans and motors, consider using In Room portable HEPA filter units in high occupancy or high bioburden (such as the building entry) spaces.	• Only use air cleaners for which evidence of effectiveness and safety is clear. Per the CDC, consumers should match any specified claims against the consumer's intended use, request efficacy performance data that quantifies a protective benefit under conditions consistent with the intended application of the technology, and look for multiple sources including independent, third-party sources that conclude the same performance data. • Consider adding air treatment and cleaning devices such as UVGI in duct, plenums and air handling units and on the face of cooling coils[4]. • If the outdoor air, filter or air cleaner in the HVAC system is not achieving the desired exposure reduction, consider adding In Room portable HEPA filter units[1].	No impact in the context of these studies. Only air cleaners with a proven track record of safety and effectiveness were allowed in the NYSERDA studies. UVGI and HEPA filtration are considered safe technologies by ASHRAE if applied correctly and the appropriate safeguards are put into place.

[1] ASHRAE ETF Core Recommendations, v.1.6.21, item 2.4
[2] ASHRAE ETF Core Recommendations, v.1.6.21, item 4.2
[3] ASHRAE ETF Building Readiness Guidance v.4.27.21, Equivalent Outdoor Air section
[4] ASHRAE ETF Commercial Guidance v.4.20.20

	THEN **Building Readiness Guidance** ***version 5.21.2020*** and/or **Commercial Guidance** ***version 4.20.2020***	**NOW** **Core Recommendations** ***version 1.6.2021*,** **Building Readiness** ***version 4.27.2021,*** and/or **Commercial Guidance** ***version 3.22.2021***	**Energy Impact Takeaways**
Building Flush	Flushing sequence or mode may be implemented to operate the HVAC system with maximum outside airflows for two hours before and after occupied times.	When necessary to flush spaces between occupied periods, operate systems for a time required to achieve three air changes of equivalent clean air supply. Use the Equivalent Outdoor Air Calculator to determine the flush time required to achieve 3 equivalent changes of space volume based on the outdoor air levels, filtration levels, and/or efficacy of air cleaners in use OR use a 2-hour flush period.	• Depending on the system configuration, achieving three air changes of equivalent clean air supply could be less energy intensive than conducting a two-hour flush. • Performing only one flush between building occupancy will be more energy efficient than conducting a flush both pre- and post-occupancy of the building.
Air Distribution	Check that air handling systems are providing adequate airflow, there are no blockages in the duct system (for example – closed fire/smoke dampers) and air from the air handling system is reaching each occupied space.	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	Both sets of guidance could have an increased impact on energy use if deficiencies in airflows levels require corrective action.
Contaminated Air Re-entry	• Well-designed and well-maintained air-to-air energy recovery systems should remain operating in residences, commercial buildings and medical facilities during the COVID-19 pandemic. • Heat wheels may continue operation if the unit serves only one space.	• Evaluate the operation of your energy recovery devices to determine that they are well-designed and well-maintained and fix them if there are issues[5]. • Limit re-entry of contaminated air that may re-enter the building from energy recovery devices, outdoor air, and other sources, such as relief air from patient rooms to acceptable levels	No substantial change in guidance
Setpoints	• Maintain dry bulb temperatures within the comfort ranges indicated in ANSI/ASHRAE Standard 55-2017 • Consider adjusting the space comfort setpoints to increase the system's ability to use more outside air. • Maintain relative humidity between 40%-60% • Prioritize increasing outside air over humidity[6]	Maintain temperature and humidity design set points	The current guidance will likely result in less energy use compared to the prior guidance.
System Performance	Verify that equipment and systems are properly functioning	Verify that HVAC systems are functioning as designed	No substantial change in guidance

[5] Practical Guidance for Epidemic Operation of Energy Recovery Ventilation Systems
[6] ASHRAE ETF Commercial Guidance v.4.20.20

It is also important to understand the basis of the package groupings in these reports.

Pre-COVID energy use establishes the typical energy use baseline prior to any impacts resulting from COVID-19

ASHRAE guidance measures include the HVAC-related guidance from the ASHRAE Epidemic Task Force documents that are feasible in the subject building(s)

Energy Efficient measures include Ultraviolet Germicidal Irradiation (UVGI), air filtration strategies, and building operation optimization solutions that perform equally on the basis of COVID-19 risk of infection to the ASHRAE guidance package of measures

ASHRAE has recommended UVGI since the inception of the Epidemic Task Force as a potential mitigation strategy. NYSERDA chose to use UVGI in the Energy Efficiency package because of its potential to reduce the energy impact of risk mitigation.

One final note is that major mechanical capital improvements were intended for exclusion from analysis under these studies.

For more information, the NYSERDA-issued mini-bid for the Energy Efficient Indoor Air Quality studies can be found here and the current ASHRAE ETF Core Recommendations can be found here.

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Final Report

NYSERDA Energy Efficient Indoor Air Quality Analysis
June 21st, 2021

Contents

Executive Summary

Syska was engaged by NYSERDA to evaluate the engineering feasibility, energy usage and operational cost impact of making indoor air quality (IAQ) improvements to existing buildings and spaces. A total of two studies were conducted, Study 1 was for a typical commercial office tenant in Manhattan and Study 2 focused on a large commercial office facility located in Westchester County, New York. The study focused on assessing COVID-mitigating improvements to building systems and operations that also incorporate energy efficiency without sacrificing safety or indoor air quality.

Study Methodology and Assumptions

The overall approach to the IAQ studies was as follows:

1. Collect and analyze up to two years of historic building energy consumption to establish the baseline performance, EUI, and end use analysis of the systems affected by the proposed measures

2. Perform site surveys, including but not limited to collection of currently installed equipment, nameplate data and available clearances, survey currently installed ductwork and current level of filtration and noting space available for additional IAQ systems. Review the existing HVAC control systems pertaining to levels of outside air and recirculated air. Survey the space and note any special considerations that may make any of the potential IAQ measures especially effective or impractical. Interview building operations staff regarding the performance and scheduling of building systems.

3. Review survey results and identify IAQ measures to be implemented and studied, including but not limited to, the installation of UVGI systems and additional filtration for the HVAC systems.

4. Perform feasibility, IAQ/safety, energy, and economic analysis of all potential IAQ measures identified in the previous step, by way of spreadsheet calculations and/or energy modeling. The energy study will had three step approach:
    a. Develop a baseline utilizing pre-COVID lockdown energy use, assuming 100% occupancy
    b. Develop an initial scenario following the ASHRAE COVID-mitigation recommendations for commercial spaces, assuming 100% occupancy
    c. Develop an energy model and/or calculations identifying options for energy efficient IAQ improvements in addition to the ASHRAE recommendations scenario.

During the study, research was conducted on the following items:

- Appropriate ventilation rate and air change rates to minimize airborne viral infection risk (see Bibliography below for more information)
- In-room portable and permanent air cleaning equipment and technologies (see Bibliography below for more information)
- Commercial-grade indoor air quality meters and healthy levels of indoor air containment parameters (see RESET-related info in Bibliography below for more information)
- The typical static pressure drop across different levels of HVAC filtration (MERV 8, 13, 16, HEPA)
- A review and comparison of various academic studies to determine the appropriate level of UV-C dosage required to inactivate SARS-CoV-2 (see Bibliography below for more information)

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The following tools and resources were utilized in both studies:

- IES VE Energy Modeling and Simulation Software for energy modeling of various building operations scenarios and energy impacts of ventilation rates and static pressure increases due to increase filtration efficiencies:
  - https://www.iesve.com/software
- NIST (National Institute of Standards and Technology) online simulation tool to compare the virus mitigation effectiveness of various filters and outside air rates:
  - https://pages.nist.gov/CONTAM-apps/webapps/FaTIMA/
- The DHS (US Department of Homeland Security) calculators to estimate the time it takes SARS-CoV-2 to decay in the air and on surfaces based on UV, Temperature and RH:
  - https://www.dhs.gov/science-and-technology/sars-airborne-calculator
  - https://www.dhs.gov/science-and-technology/sars-calculator
- Branch Pattern's "Facility Infection Risk Estimator" to compare the virus mitigation effectiveness of various filters and outside air rates:
  - https://branchpattern.com/research/facility-infection-risk-estimator-v2-0/
- ASHRAE Fundamentals 2017 for non-modeling energy and HVAC related calculations
- ASHRAE Building Readiness Guidance (**dated 4/20/20**): https://www.ashrae.org/technical-resources/building-readiness
- ASHRAE Building Reopening COVID-19 Guidance (**dated 4/20/20**): https://www.ashrae.org/file%20library/technical%20resources/covid-19/guidance-for-re-opening-buildings.pdf
- Harvard School of Public Health Reopening Guidance for reference of appropriate effective air-changes per hour (ACH) rates for COVID-19 risk reduction in spaces
  - https://crosscut.com/sites/default/files/files/harvard-healthy-buildings-program-covid19-risk-reduction-in-schools-nov-2020-2.pdf
- ASHRAE Standard 170-2013 (Ventilation of Health Care Facilities) for reference of appropriate effective ACH rates for airborne infection risk reduction, including the minimum outdoor air ACH rates and the total effective ACH rates
- ASHRAE Standard 62.1-2019 (Ventilation for Acceptable Indoor Air Quality) for reference of baseline appropriate ventilation airflow rates based on various occupancy types for commercial spaces, as well as for zone air distribution effectiveness factors.

Below is a summary of the existing energy and system assumptions for both studies.

Study 1 – Manhattan Commercial Office Tenant			
Number of Floors	6	Peak Occupants (pre-COVID)	800
Project Gross Floor Area	186,000 Square Feet	Typical Operating Hours	8am through 8pm
Location	Midtown Manhattan	Current Occupancy %	2%
Heating System(s)	The tenant's floors are heated by a perimeter fin-tube radiator system outfitted with new control valves supplied by the landlord. Hot water is supplied by the landlord's boilers and routed through risers located at the perimeter columns.		
Cooling System(s)	The tenant's floors are cooled via VAV boxes supplied with base building chilled air from two main air risers located at the buildings core. Cooling air is supplied to these floors from two variable volume AHUs. These AHUs with VFDs each provide approximately 67,000 CFM and are the main source of cooling for half the building. Chilled water is produced by 3 Chillers located in the basement totalling approximately 2,700 Tons. This chilled water is split between the AHUs that serve the lower levels and upper floor AHUs. Secondary units are installed in areas to be used during dense occupancy. These units are only run during these times and are typically off. Supplemental units currently have MERV 8 filters installed.		
Ventilation System(s)	Ventilation air is introduced via the main AHUs providing supply air to the tenant floors. The actual amount of outside air varies depending on outside conditions, but the landlord estimates the OA rate to be approximately 4,500 CFM per floor.		
Domestic Hot Water System(s)	DHW is provided by the landlord to the main core restrooms. Additional DHW for the pantries and additional tenant restrooms is provided by the tenant under-counter instantaneous water heaters and above ceiling storage type water heaters.		
Building Management System / HVAC Controls	All landlord and tenant equipment is connected to the base building BMS which is a Reliable Controls system and maintained by the landlord's automated controls contractor. Each tenant has visibility to the BMS for their HVAC terminal unit setpoints, leak detectors, CRAC/AC unit failures, etc		

	Jan-Dec 2019 Utility Consumption
Annual Electricity Consumption (kwh)	1,447,686.35
Annual Gas Consumption (therms)	137
Annual Steam Consumption (kbtu)	4,377,210
Total Energy Consumption (kbtu)	9,330,415.33
Site EUI (for project area)	49.57
Source EUI (for project area)	101.02

Study 2 – Westchester Commercial Office Facility

Number of Floors	3 & Parking Garage	Peak Occupants (pre-COVID)	2,828
Project Gross Floor Area	867,305 Square Feet	Typical Operating Hours	5am – 6pm Mon-Fri
Location	Westchester	Current Occupancy %	10
Heating System(s)	The site is heated by (3) 300 HP boilers which provide steam and hot water to heating and reheat coils in the central air handling units and VAV/FPBs throughout the office spaces. The perimeter is heated with supplemental constant volume fans and steam coils.		
Cooling System(s)	The site is cooled via water-cooled chiller plant, with (3) 800-ton cooling towers and a total 2,100 tons of chiller capacity. The chiller plant provides chilled water to the cooling coils of all air handing units. The perimeter is cooled as needed with supplemental constant volume fans and chilled water coils.		
Ventilation System(s)	Supply and ventilation air to the occupied areas is provided by large central air handlers, some variable volume some constant volume.		
Domestic Hot Water System(s)	DHW is generated via heat exchangers on the steam supply from the space heating boilers which is stored in a domestic hot water tank which then supply the plumbing fixtures.		
Building Management System / HVAC Controls	The ventilating and air handling units are controlled via a central BMS which monitors status of all fans and coils as well as other setpoints, including OA damper open %, fan power, supply pressure and supply and return air temperatures.		

	Jan-Dec 2019 Utility Consumption
Annual Electricity Consumption (kWh)	17,164,607
Annual Gas Consumption (therms)	340,337
Total Energy Consumption (kBtu)	92,589,673
Site EUI (kBtu/SF/yr)	106.8
Source EUI (kBtu/SF/yr)	231.6

Recommended Measures

Below is a summary of the recommended measures and their impacts vs their respective baselines from both studies. Measures that were part of the ASHRAE baseline COVID-19 risk mitigation recommendations are in **bold**.

Study #	Measure Description	Energy Use Impact			Energy Cost Impact			First Cost	Notes
		kWh	kW	MMBtu	kWh ($)	MMBtu ($)	Total ($)		
1	**2b - Portable humidification to maintain relative humidity levels between 40-60%**	4,351 (0.02/SF)	N/A	N/A	$653	$0	$653 (<$0.01/SF)	$1,117 ($0.01/SF)	
1	12 - Install UVGI systems at zone-level cooling coils	131 (<0.01/SF)	0	0	$20	$0	$20 (<$0.01/SF)	$3,520 ($0.02/SF)	
1	**13 - Replace air filters on zone-level systems with MERV 13 rated filters (as high as existing systems can accommodate) within tenant controlled spaces**	0	0	0	$0	$0	$0	$450 (<$0.01/SF)	
1	14 - Install permanent, ceiling mounted, room-level air scrubbers equipped with fan, HEPA filters and/or UVGI system in high traffic office spaces or spaces with poor air quality. All installed above units controlled via occupancy sensors.	-3,652 (-0.02/SF)	-2	N/A	-$548	$0	-$548 (<- $0.01/SF)	$117,230 ($0.63/SF)	
2	1a - Maintain a minimum of 30% outside air in the supply airflow in all AHUs serving occupied zones during occupied hours	-415,467 (-0.48/SF)	0	-12,287 (-0.01/SF)	-$49,856	-$143,761	-$193,617 (-$0.22/SF)	$0	

2	2 - Maintain relative humidity between 40-60% in all occupied spaces. Implement room-level plug in humidifiers for occupied multioccupant zones (conference rooms, break rooms, small amenity areas	1,039 (<0.01/SF)	2	0	$124	$0	$124 (<$0.01/SF)	$9,161 ($0.01/SF)	
2	3 - Install MERV 16 filters on all main AHUs serving regularly occupied zones	205,475 (0.24/SF)	58	0	$22,559	$0	$22,559 ($0.03/SF)	$53,985 ($0.06/SF)	**Mutually exclusive with measure #7
2	5 - Install UVGI systems at central AHU cooling coils	60,822 (0.07/SF)	7	0	$7,229	$0	$7,229 ($0.01/SF)	$45,736 ($0.05/SF)	
2	9 - Install portable, room-level, air filters in conference rooms, pantries and other high-traffic office spaces	14,530 (0.02/SF)	6	0	$1,744	$0	$1,744 (<$0.01/SF)	$111,814 ($0.13/SF)	
2	13 - Maintain MERV 15 filters on fan powered boxes serving occupied spaces	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No impact to facility energy usage or utility cost, FPB fans cannot increase their HP
2	21 - Disable DCV systems where existing to supply the maximum amount of design OA to high occupancy spaces.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Recommended disabling to run systems at the design OA rate for high occupancy.
2	24 - Install permanent IAQ sensors (CO2, PM2.5, Temp, RH, TVOC) and monitor IAQ metrics and verify ventilation and filtration systems are functioning properly	0	0	0	$0	$0	$0	$23,709 ($0.03/SF)	No impact to facility energy usage or utility cost, only capital cost for IAQ sensor installation.

2	25 - Limit maximum building occupancy to 50% of typical peak occupancy (adjust ventilation airflows per reduced occupancy)	-264,516 (-$0.30/SF)	0	-237 (<-0.01/SF)	-$31,742	-$2,777	-$34,519 (-$0.04/SF)	N/A	No impact to facility energy usage or utility cost, minimum OA was maintained under "business as usual" operation.
2	26 - Operate HVAC systems at outside air rates set to minimum with MERV 16 filters equipped, long enough achieve 3 complete air changes (29 minutes), prior to occupied hours and after occupied hours.	-1,889 (<-0.01/SF)	0	-2,092 (<-0.01/SF)	-$227	-$24,472	-$24,698 (-$0.03/SF)	N/A	#Mututally exclusive to Measure 27

Non-Recommended Measures

Below is a summary of the non-recommended measures and their impacts vs their respective baselines from both studies. Measures that were part of the ASHRAE baseline COVID-19 risk mitigation recommendations are in **bold**.

Study #	Measure Description	Energy Use Impact			Energy Cost Impact			First Cost	Notes
		kWh	kW	MMBtu	kWh ($)	MMBtu ($)	Total ($)		
1	1 - Increase outside air supply as close to 100% as possible during occupied hours while maintaining comfortable conditions in occupied spaces	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended
1	2a - Central Humidification to maintain relative humidity levels between 40-60%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended
1	3 - Install air filter on main AHUs with a rating of MERV 13 or higher	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended
1	4 - Shut off energy wheels in ERV systems serving 2+ spaces if they do not meet ASHRAE guidance for minimal cross-contamination between exhaust and ventilation air streams (exhaust and OA supply fans should both e on the outdoor-side of the energy wheel so outdoor air is pushed through and exhaust air is pulled through the wheel)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended
1	5 - Install UVGI systems at central AHU cooling coils	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended

1	6 - Install UVGI systems in central supply ductwork	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended
1	7 - Install HEPA-rated filters on main AHUs	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended
1	8 - Install heat recovery ventilation systems (fixed plate) for existing AHUs providing ventilation air	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended
1	9a- Install portable, room-level, HEPA air filters in all occupied zones, including open office. Total of 118 units.	30,312 (0.16/SF)	6.1	N/A	$4,547	$0	$4,547 ($0.02/SF)	$14,700 ($0.08/SF)	Mutually exclusive to a recommended measure
1	**9b - Install portable, room-level, HEPA air filters in conference rooms, pantries, and other high-traffic office spaces. Total of 68 units.**	17,468 (0.09/SF)	3.5	N/A	$2,620	$0	$2,620 ($0.01/SF)	$63,893 ($0.34/SF)	Mutually exclusive to a recommended measure
1	**10 - Install local exhaust to negatively pressurize conference rooms, pantries, and other high-traffic office spaces**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended
1	**11 - Install local upper-room UVGI or other air treatment systems for large public assembly spaces**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended
1	14- Install permanent, ceiling mounted, room-level air scrubbers equipped with fan, HEPA filters and/or UVGI system in all occupied zones. A total of 83 units, operated in open office spaces via schedule and conference/meeting rooms via occupancy sensors.	56,224 (0.30/SF)	11.4	N/A	$8,434	$0	$8,434 ($0.05/SF)	$175,220 ($0.94/SF)	Not Recommended

1	15 - Install supplemental outside air ventilation units, equipped with filtration and/or heat recovery systems at a room-level in spaces with inadequate ventilation or poor air quality	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended
1	16 - Operate HVAC systems with outside air supply at 100% capacity for at least 2 hours before and after typical occupied hours	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended
1	17 - Run toilet exhaust fans 24/7, do not open operable windows in bathrooms	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended
1	18 - Run garage exhaust systems 2 hours prior and after occupied times	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended
1	19 - Run building exhaust systems 2 hrs. prior and after occupied times	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended
1	20 - Divert outside air from unoccupied floors to occupied floors	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended
2	1b - Increase outside air supply as close to 100% as possible during occupied hours while maintaining comfortable conditions in occupied spaces.	723,445 (0.84/SF)	0	12,525 (0.1/SF)	$86,813	$146,538	$233,351 ($0.17/SF)	$0	Mutually exclusive to a recommended measure

2	4 - Shut off energy wheels in ERV systems serving 2+ spaces if they do not meet ASHRAE guidance for minimal cross-contamination between exhaust and ventilation air streams (exhaust and OA supply fans should both e on the outdoor-side of the energy wheel so outdoor air is pushed through and exhaust air is pulled through the wheel)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended
2	6 - Install UVGI system in central supply ductwork	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Recommended
2	7a - Install MERV-13 -rated filters on main AHUs	17,487 (0.02/SF)	5	0	$2,098	$0	$2,098 (<$0.01/SF)	$21,838 ($0.03/SF)	Mutually exclusive to a recommended measure
2	7b - HEPA filters for all main AHUs	362,860 (0.42/SF)	103	0	$43,624	$0	$43,624 ($0.05/SF)	$164,145 ($0.19/SF)	*Mutually exclusive with Measure #3 & 7a
2	8 - Install heat recovery ventilation systems (fixed plate) systems for existing AHUs providing ventilation air	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended
2	10 - Install local exhaust to negatively pressurize conference rooms, pantries and other high-traffic office spaces	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended
2	11 - Install local upper-room UVGI or other air treatment systems for large public assembly spaces	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended

2	12 - Install UVGI systems at zone-level cooling coils	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended
2	14 - Install permanent, ceiling mounted, room-level air scrubbers equipped with fan, MERV/HEPA filters and/or UVGI system in high-traffic office spaces or spaces with poor air quality	93,884 (0.11/SF)	40	0	$11,266	$0	$11,266 ($0.01/SF)	$270,715 ($0.31/SF)	Mutually exclusive to a recommended measure
2	15 - Install supplemental outside air ventilation units, equipped with filtration and/or heat recovery systems at a room-level in spaces with inadequate ventilation or poor air quality	N/A	N/A	N/A	N/A	N/A	N/A	N/A	"Not Recommended – Additional ventilation capability is not required.
2	16 - Operate HVAC systems, with outside air supply set to 100% of capacity, for at least 2 hours before and after typical occupied hours	38,583 (0.04/SF)	0	11,329 (<0.01/SF)	$4,360	$132,546	$136,906 ($0.16/SF)	N/A	Mutually exclusive to a recommended measure
2	17 - Run toilet exhaust fans 24/7, do not open operable windows in bathrooms	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Measure currently implemented
2	18 - Run garage exhaust systems 2 hours prior and after occupied times	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Measure currently implemented
2	19 - Run building exhaust systems 2 hours prior and after occupied times	11,432 (0.01/SF)	0	0	$1,372	$0	$1,372 (<0.01/SF)	N/A	"Based on air change, heating, cooling

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2	20 - Divert outside air supply from unoccupied floors to occupied floors	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Feasible - Not Recommended
2	22 - Open windows where possible during occupied hours while maintaining comfortable conditions in occupied spaces.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	There are no operable windows in any of the occupied areas
2	23 - Maintain DHW storage temperatures at 140F minimum and DHW supply temperatures at 120F.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Measure currently implemented
2	27 - Operate HVAC systems at outside air rates set to maximum (80%) with MERV 13 filters equipped, long enough achieve 3 complete air changes (29 minutes), prior to occupied hours and after occupied hours	22,942 (0.03/SF)	0	12,525 (0.01/SF)	$2,753	$33,471	$36,224 ($0.04/SF)	N/A	Only applicable if Measure 7a is implemented in lieu of Measure 3 #Mututally exclusive to Measure 26

Study Conclusions and Comparison

Overall, the approach and methodologies utilized in the study were the same for both the commercial tenant and the larger commercial office building. The main conclusion when comparing the studies is that if it's possible to modify the ventilation and filtration media at system and building level equipment, that is a more impactful and cost-effective method (when taking capital and operational costs into account) of improving the indoor air quality and effective Air Changes per Hour (eACH) throughout a commercial space at 100% occupancy, rather than deploying air cleaning or ventilation measures at a room-by-room level.

For spaces that do no intend to be occupied at 100% occupancy or commercial tenants that do not have control over large base building air handlers and ventilation systems, local filtration options such as those recommended in Study #1 become the primary method and most energy efficient method of increasing eACH in the space.

Below are the key similarities and differences between the commercial office building and commercial tenant floor study, organized by topic:

Study Approach

- Similarities:
  - Overall steps taken, baselining and energy calculations methodologies are the same between both studies
  - Target eACH levels for superior indoor air quality and increased safety (6+)
- Differences:
  - Energy modeling only utilized for whole-building measures and analysis, not used in tenant study
  - IAQ testing only performed for whole building study

Recommended Measures

- Similarities:
  - UVGI systems to be installed at cooling coils to reduce contaminant building up on coils and filters
  - Improve rating of installed air filters from existing to a minimum of MERV 13
- Differences:
  - Given the ability to improve IAQ holistically for the whole building study, portable air cleaners where recommended only needed to boost ACH in high occupancy rooms, whereas larger and more permanent ceiling-mounted air-cleaners were recommended at the tenant level given lack of control of any system-level improvements.
  - MERV 15/16 was recommended at a system level for the whole building study to allow for reduction OA without a reduction in safety, but at the tenant level only MERV 13 was recommended due to additional cleaners with HEPA filters installed throughout occupied zones.

Non-Recommend Measures

- Similarities:
  - Achieving increased eACH through very high levels of outside air ventilation (80%+) was not recommended.
  - Installing HEPA or MERV 17+ filters for main air handlers or fan coils/fan-powered boxes was not recommended
- Differences:
  - A much larger portion of considered IAQ measures were not feasible for the tenant study due to limited control over building HVAC and ventilation systems

Energy Impacts

- Similarities:
  - Ramping additional IAQ-boosting systems (additional ventilation, air cleaners, etc.) down during periods of low occupancy is a key strategy to minimizing the energy increase
  - Increasing filtration is a relatively more energy efficient method of increasing eACH compared to increasing ventilation (i.e. more outside air in the supply air stream)
- Differences:
  - The increase in energy per relative increase in safety is smaller for a tenant project scope as compared to the whole building project, due to the tenant project utilizing only filtration as an ACH-boosting strategy and installing air filter equipment that is de-coupled from their central HVAC systems.
    - A 1% energy usage increase to achieve 6+ eACH for the tenant project vs a 3% energy usage increase to achieve 6+ eACH for the whole building project)

Safety Impacts

- Similarities:
  - 6+ effective air changes was found to be achievable in the existing commercial spaces without major capital upgrades and with currently available technologies
  - The largest reduction in infection risk and average concentration of contaminant particles is achieved by a combination of increased ventilation and filtration at the system level and additional filtration at the room level.
- Differences:
  - The amount of calculation scenarios to capture the various possible combinations of system filtration, local filtration and ventilation supply air and provide a complete picture of safety impacts was significantly larger when assessing a whole building.

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Overarching Takeaways

Below are the key takeaways and best practices that can be applied to the commercial marketplace at large for building occupants, owners and operators looking to improve indoor air quality and reduce airborne viral infection risk:

Conclusion	Applicable Sector/ Project Type	Applicable System Type
6+ effective air changes is a useful organizing holistic target to achieve improved air quality and significantly reduce airborne viral transmission risk	Any Non-Healthcare Project	Any (HVAC with DOAS may require supplemental air cleaners to achieve 6+ eACH)
Based on net capital + operational costs, it is more cost-effective to improve air quality through increased filtration and ventilation at the building system level rather than at the zone or room level for an existing space.	Any	Any
UVGI is most effective as a surface decontamination solution rather than an air stream decontamination solution.	Any	Any
UVGI systems will only provide significant energy savings in a retrofit scenario with aging and poorly maintain cooling/heating coils or filters.	Any	Any
For increases in MERV filtration ratings to have maximum effect, the filtration must be applied to mixed air supply stream (both the return and outside air), not only the outside air stream.	Any	Any mechanical ventilation
The relative increase in safety per increase in energy usage and cost is optimal at the MERV 13-15 range, and this ration decreases greatly when implementing MERV ratings that cannot be achieved with a pleated filter (e.g. MERV 16+)	Any	Any mechanical ventilation
For systems with 80%+ OA in the supply air stream, there is only a marginal safety benefit to increasing the filtration rating on the mixed air beyond MERV 8 *(except for spaces where a high viral dosage in the return air is possible)*	Any (except areas with high air pollution)	Any mechanical ventilation
Installing additional controls or IAQ sensors (CO2) to reduce levels of ventilation air or turn of supplemental filtration systems during times of low occupancy or in unoccupied areas can achieve high energy savings but may increase viral transmission risk in those spaces.	Any	Any mechanical ventilation
When upgrading or replacing a filter with a specific MERV ratings, ensure that the system air speed at the location of the filter does not exceed the maximum rated air speed of the filter. (Max speed value located on filter cutsheet, typically 300-500 Feet Per Minute)	Any	Any mechanical ventilation
It is more energy efficient to run systems at maximum ventilation capacity until they achieve 3 complete air changes rather than running them in a “flush-out mode” for 2 hours.	Commercial Buildings	Any
Permanent, ceiling-mounted, air cleaners are more energy efficient and likely more effective at improving IAQ in spaces than portable air cleaning units, as long as occupancy-based controls are utilized and proper airflow to occupants is achieved.	Commercial Tenant	Any

Bibliography and References

Below is a summary of the resources that were consulted and discovered as part of this study:

- As introduced and endorsed by ASHRAE in the September 9th Webinar titled "Reopening Commercial Buildings: Evaluating Your HVAC System's Readiness to Mitigate the Spread of SARS-CoV-2, the following free online tools allow for additional calculations regarding the airborne spread and survivability time of SARS-CoV-2 under varying airflow, outside air, MERV filtration, temperature and relative humidity conditions:
  - NIST (National Institute of Standards and Technology) has developed an online simulation tool to compare the virus mitigation effectiveness of various filters and outside air rates:
    - https://pages.nist.gov/CONTAM-apps/webapps/FaTIMA/
  - The DHS (US Department of Homeland Security) has developed calculators to estimate the time it takes SARS-CoV-2 to decay in the air and on surfaces based on UV, Temperature and RH:
    - https://www.dhs.gov/science-and-technology/sars-airborne-calculator
    - https://www.dhs.gov/science-and-technology/sars-calculator
  - Branch Patterns has developed an online tool entitled "Facility Infection Risk Estimator" to compare the virus mitigation effectiveness of various filters and outside air rates:
    - https://branchpattern.com/research/facility-infection-risk-estimator-v2-0/
- IES UV-C Recommendations: https://media.ies.org/docs/standards/IES-CR-2-20-V1-6d.pdf
- ASHRAE Building Readiness Guidance (**dated 4/20/20**): https://www.ashrae.org/technical-resources/building-readiness
- ASHRAE Building Reopening COVID-19 Guidance (**dated 4/20/20**): https://www.ashrae.org/file%20library/technical%20resources/covid-19/guidance-for-re-opening-buildings.pdf
- ASHRAE Standard 170-2013 (Ventilation of Health Care Facilities) for reference of appropriate effective ACH rates for airborne infection risk reduction, including the minimum outdoor air ACH rates and the total effective ACH rates
- ASHRAE Standard 62.1-2019 (Ventilation for Acceptable Indoor Air Quality) for reference of baseline appropriate ventilation airflow rates based on various occupancy types for commercial spaces, as well as for zone air distribution effectiveness factors.
- Studies consulted on the effects of various dosages of UV-C on SARS-CoV-2:
  - https://pubmed.ncbi.nlm.nih.gov/32842655/
  - https://www.medrxiv.org/content/10.1101/2020.06.05.20123463v2
  - https://www.biorxiv.org/content/10.1101/2020.06.06.138149v1.full
  - https://www.nature.com/articles/s41598-020-67211-2
  - https://www.sciencedirect.com/science/article/pii/S0196655320307562
- HARVARD School of Public Health Reopening Guidance: https://crosscut.com/sites/default/files/files/harvard-healthy-buildings-program-covid19-risk-reduction-in-schools-nov-2020-2.pdf
- CDC Study, which includes evaluation of portable vs fixed air cleaners: https://www.cdc.gov/mmwr/preview/mmwrhtml/rr5417a1.htm

- For spaces or buildings looking to install IAQ sensors, the directories of RESET-accredited IAQ monitors can serve as a useful starting point for commercial-grade sensors that are more robust than consumer-grade technology but not as costly as industrial-grade IAQ monitoring equipment. Manufacturers must submit their IAQ sensors for 3rd party testing and achieve certain thresholds for performance, accuracy, and data loss in order to be accredited and listed on RESET's website. See the links below for the IAQ sensor directories and RESET sensor standard:
    - Indoor, room-level sensors: https://www.reset.build/monitors/type/indoor
    - In-duct, system-level sensors: https://www.reset.build/monitors/type/induct
    - RESET IAQ Sensor Accreditation Standard: https://www.reset.build/download/RESET_Standard_v2_2_6_Monitor%20Standard%20180921.pdf

  About RESET: *The RESET Standard is the world's first sensor-based and performance-driven data standard and certification program for the built environment. The RESET Standard creates a structure for data quality, continuous monitoring, and benchmarking. The standard harnesses the power of technology in order to assess the performance of buildings and interior spaces during their operational phase.*

- Table provided by the ASHRAE epidemic taskforce with a reference efficiency for filtering out droplets that can potential contain SARS-CoV-2 virus particles per MERV Rating

MERV Rating (Based on 52.2-2017)	Filter Droplet Nuclei Efficiency
4	16.80%
5	26.55%
6	32.45%
7	41.13%
8	55.57%
9	62.00%
10	64.65%
11	72.86%
12	83.39%
13	89.93%
14	94.94%
15	96.18%
16	97.40%

- Below are the products and manufacturers that were used as the basis for the engineering feasibility and energy evaluation for the various IAQ improvement measures and technologies considered for each study. For most technologies listed below, multiple manufacturers and products exist that are comparable in performance, the ones noted below are only one example of what is currently available on the market. Syska makes no claim on the effectiveness of one product over another.

Ceiling-hung MERV/UVGI in-room air scrubber • **Manufacturer:** EnVerid • **Model No./ Name:** Ceiling Mounted Air Filtration System • **Reference**: https://enverid.com/wp-content/uploads/2020/08/enVerid-Air-Purifier-2020-08-16_AP_v2.pdf	AHU cooling coil and in-duct UVGI • **Manufacturer:** Steril-Aire • **Model No./ Name:** DE Series (large AHU Coil), SEN Series (Smaller AHU coil and in-duct applications) • **Reference (DE)**: https://www.steril-aire.com/download/3505/ • **Reference (SEN):** https://www.steril-aire.com/download/3727/
Portable room-level HEPA/Carbon Filter air purifier • **Manufacturer:** Oransi • **Model No./ Name:** EJ120 • **Reference**: https://www.oransi.com/p/oransi-ej-air-purifier	In-room HEPA recirculating/depressurizing air purifier • **Manufacturer:** B-Air • **Model No./ Name:** RA-650 • **Reference**: https://b-air.com/product/b-air-ra-650-hepa-scrubber/
Room-level heat recovery ventilation unit • **Manufacturer:** Blauberg • **Model No./ Name:** Freshbox 200 • **Reference**: https://blauberg-na.com/wp-content/uploads/2018/12/BL_US_Freshbox_200_ERV_WiFi_leaflet_2018_10_EN.pdf	Room-level portable humidifier • **Manufacturer:** Aircare • **Model No./ Name:** Pedestal EP9800 **Reference**: https://aircareproducts.com/site/assets/files/1159/epseries_manual-2020_web-1.pdf
MERV 8-15 Filters • **Manufacturer:** Air Handler • **Model No./ Name:** 24x24 Pleated Ai Filters • **Reference**: ○ MERV 8: https://www.grainger.com/product/AIR-HANDLER-General-Use-Pleated-Air-Filter-6B923 ○ MERV 13: https://www.grainger.com/product/AIR-HANDLER-LEED-Green-Pleated-Air-Filter-11C889 ○ MERV 15: https://hdsupplysolutions.com/p/mini-pleat-merv-15-high-performance-air-filter-24-x-24-x-2-box-of-6-p277242 ○ MERV 16: https://www.grainger.com/product/AIR-HANDLER-V-Bank-Air-Filter-33E935 ○ MERV 18/HEPA: https://www.grainger.com/product/AIR-HANDLER-HEPA-Air-Filter-19RR61	