



**FLEXTECH
ENERGY EFFICIENT INDOOR AIR QUALITY STUDY
FINAL CONCLUSIONS REPORT**

**For
Guth DeConzo Consulting Engineers, P.C.**

**New York State Energy Research and
Development Authority
17 Columbia Circle
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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

	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
Outdoor airflow rate	<ul style="list-style-type: none"> • 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. 	<ul style="list-style-type: none"> • 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 cleaners¹. • For HVAC system that use Demand-controlled ventilation sequences we recommend disabling this feature for the duration of the crisis² 	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	<ul style="list-style-type: none"> • 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 coils⁴. • 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. 	<ul style="list-style-type: none"> • 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 coils⁴. • 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 units¹. 	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 <i>version 5.21.2020</i> and/or Commercial Guidance <i>version 4.20.2020</i>	NOW Core Recommendations <i>version 1.6.2021</i> , Building Readiness <i>version 4.27.2021</i> , and/or Commercial Guidance <i>version 3.22.2021</i>	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.	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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. 	<ul style="list-style-type: none"> Evaluate the operation of your energy recovery devices to determine that they are well-designed and well-maintained and fix them if there are issues⁵. 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	<ul style="list-style-type: none"> 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 humidity⁶ 	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](#).



Energy Efficient Indoor Air Quality Study
Conclusion Report

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I. Research Conducted:

Guth DeConzo Consulting Engineers, under contract with NYSERDA, was tasked with performing Indoor Air Quality (IAQ) Assessments for three institutional facilities: Albany Medical Center, North Colonie School District, and a Higher Education University.

The studies began with extensive research into ASHRAE's many position and guidance documents that were released in response to the Covid-19 pandemic. ASHRAE's Epidemic Taskforce released guidance documents with regards to re-opening of various types of commercial, educational, and healthcare buildings and the steps that should be taken from an HVAC perspective to promote the safest possible environment for occupants. Refer to bibliography section for specifics on the ASHRAE documents.

In conjunction with ASHRAE guidance documents, research was conducted, and information was obtained through various ASHRAE led webinars and papers by third party consultants, all of which are also noted in the bibliography section. The learnings from this research were used as the basis of recommendations for this study effort.

Independent research and case study experiments were also done on several IAQ technologies. Guth DeConzo conducted experiments with various UV, bi-polar, and HEPA units using particle counters, CO₂ monitors, ion counters, and other data logging equipment to test effectiveness of these technologies (experiments conducted were independent of this study). Although the results of these experiments were not used in the reports, this testing is instrumental to verify Guth DeConzo has a practical understanding of the operational effectiveness of these relatively emerging technologies.

Once a basis for the study was obtained through research, Guth DeConzo conducted site visits and field investigations at the various client sites to obtain critical information about the existing HVAC systems in place. Information on existing HVAC systems, how the clients use their current building management system (BMS), the occupant information, and tendencies and hours of operation were obtained and compiled. Using the gathered knowledge about IAQ and

infection control and knowing the clients' existing conditions, evaluations of various IAQ strategies was then conducted.

II. Study Methodology:

The methodology behind this study was to evaluate several measures that ASHRAE, at the time of this study, put forth as they pertain to increasing overall indoor air quality as well as evaluating their effects on energy efficiency. There were two 'packages' of measures described in this study. The base package includes measures which ASHRAE recommends to increase overall indoor air quality¹. The second package contains measures that once implemented, can increase the overall indoor air quality if properly utilized, while also increasing the energy efficiency of the facility.

Using open-source calculation tools and tools developed by ASHRAE, we are able to determine the levels of occupant safety that each package and each measure produces. Using equivalent air changes (eACH) as determined by the ASHRAE-developed Flushing Time Calculation (equivalent outdoor air calculator) Tool and the exposure time limit as calculated by the MIT Safety Guideline Tool as proxies for risk, we were able to evaluate the reduced risk that each measure provides to occupants in a given space. Within each evaluation tool, metrics such as airflow, MERV ratings, air cleaning device efficacy, contaminant concentration/generation, space size and occupancy, along with many others, were inputted as they change with each proposed measure. Using the above methodology to determine risk reduction, it was found that the measures in the Energy Efficiency Package were able to achieve equivalent or improved levels of safety, with respect to SARS-CoV-2, when compared to the ASHRAE Recommended Package.

For the energy calculations (absent Ultraviolet Germicidal Irradiation, UVGI), a bin analysis was utilized. The bin analysis (which is based on local weather data in 5°F increments) modeled the energy use change for both electric and thermal usage. Key variables for the models include:

¹ Recommendations were taken from ASHRAE Building Readiness – Healthcare (June 17, 2020), ASHRAE Building Readiness – Commercial (April 20, 2020) and ASHRAE Building Readiness – Reopening of Schools and Universities (May 5, 2020)

- Existing and proposed hours of operation
- Existing and proposed airflow (total air and outdoor air)
- Existing equipment efficiency (chiller and boilers)
- Existing and proposed electric demand
- Existing and proposed filter airside pressure drop

For the **ASHRAE Recommended Package**, we compared the increased thermal and electrical usage to that of the normal (pre-Covid) usage in order to obtain the energy impact. For the **Energy Efficiency Package**, we compared the thermal and electric usage associated with these measures to that of the **ASHRAE Recommended Package** to see what energy savings can be realized if an energy efficient measure is used over an ASHRAE recommended measure as well as achieve equivalent occupant safety. Typical engineering industry standards and assumed values were used in the calculation models (i.e. setback temperatures, reheat offset temperatures and setpoints, enthalpy values, return air temperatures, etc.).

Energy usage data was gathered from each client from previous, pre-Covid years (typically 1-2 years of utility usage). The data from each year was averaged to obtain a baseline energy usage that was then used to compare to the energy usage when deploying the various IAQ strategies. Electric and thermal rates were calculated using said averages and further used to evaluate the economic impact each IAQ strategy.

III. Overall Findings:

Refer to the tables on the following pages for details on the overall findings for each study:

Figure 1: Baseline Energy Data

WP#	Building	Pre-Covid Baseline							ASHRAE Measures Baseline										Energy Efficiency Measures Baseline							Notes					
		Energy Use			Total Supply Air CFM	CFM Outside Air	Air Changes OA	Energy Cost			Measures Included	Energy Use			CFM Outside Air	eACH	Energy Cost			Measures Included	Energy Use			CFM Outside Air	eACH		Energy Cost				
		kWh	kW	MMBtu				kWh	kW	MMBtu		kWh	kW	MMBtu			Implementation Cost	kWh	kW		MMBtu	Implementation Cost	kWh				kW	MMBtu	Implementation Cost		
WP-02	Albany Medical Center 43 New Scotland Avenue, MC-143 Albany, NY 12208	38,234,278	1,796	587,221	446,456	402,221	4	\$2,472,085	N/A	\$2,919,747	MERV 13, Purge, Humidification, Increased OA Ventilation (Max)	40,719,714	1,798	602,217	446,456	5	\$2,719,346	N/A	\$2,997,306	\$144,300	UVGI airside	40,775,742	1,809	602,217	446,456	5	\$2,772,750	N/A	\$3,191,749	\$305,757	ASHRAE baseline energy costs taken from the Energy Efficiency PSS baseline table
WP-03	North Colonie Central School District 91 Fiddlers Lane Latham, NY 12110	5,217,714	N/A	44,449	541,515	260,599	2	\$668,926	N/A	\$243,991	MERV 13, Purge, Humidification, Increased OA Ventilation (Max)	7,059,879.2	N/A	73,546	541,515	4	\$937,795	N/A	\$410,425	\$659,950	UVGI airside (AHUs, Unit Vents/PTACs/FCUs)	7,110,909	N/A	73,546	541,515	4	\$1,031,082	N/A	\$410,425	\$597,451	ASHRAE baseline energy costs taken from the Energy Efficiency PSS baseline table
WP-04	Higher Education University	12,160,507	3,213	140,196	361,119	100,607	2	\$1,283,861	N/A	\$1,176,013	MERV 13, Purge, Humidification, Increased OA Ventilation (Max)	14,252,783	3,222	160,236	301,395	8	\$1,514,440	N/A	\$1,436,748	\$749,800	UVGI airside (AHUs, FCUs)	14,360,850	3,232	160,236	301,395	7.92	\$1,579,694	N/A	\$1,436,748	\$580,596	ASHRAE baseline energy costs taken from the Energy Efficiency PSS baseline table

Figure 2: Albany Medical Center Findings

WP#	Building Name and Address, Campus or Complex	Measure Description	Measure Category	Measure Sub-Category	Measure Application	Package	Feasible?	Barrier(s) to Feasibility	Evaluated?	Barrier(s) to Evaluation	Measure Status	Barrier(s) to Recommendation	Product/Manufacturer/Model Analyzed	Risk Reduction/ Safety Impact			Outdoor Air		Energy Use Impact				Energy Cost Impact ¹			Notes	
														eACH	Prob of Infection	Method of Analysis	CFM	kWh	kW	MMBtu	kWh (\$)	kW (\$)	MMBtu (\$)	Total (\$)	Maintenance Cost		First Cost
WP-02	Albany Medical Center 43 New Scotland Avenue, MC 143, Albany, NY 12208	MERV 13 Filter Replacement	Filtration	Increased MERV rating	Local In-Room	ASHRAE	Yes	N/A	Yes	N/A	RME	N/A	MERV 13 filters basis of design not defined in report.	N/A	N/A	N/A	N/A	6,284	2	0	\$478	N/A	\$0	\$478	\$3,445	\$0	
WP-02	Albany Medical Center 43 New Scotland Avenue, MC 143, Albany, NY 12208	Airflow Adjustment (Purge Cycle)	Ventilation	Institute 2 hr. Building Air Flush	Central System	ASHRAE	Yes	N/A	Yes	N/A	R	N/A	N/A	N/A	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	354,258	350,883	0	11,887	\$24,587	N/A	\$60,915	\$85,501	N/A	\$0	OA CFM represents minimum levels for SCC, MR, MS and ME buildings only. The total aggregate airflow for these buildings is 396,956
WP-02	Albany Medical Center 43 New Scotland Avenue, MC 143, Albany, NY 12208	Localized Humidification	Humidification	Increased RH	Central System	ASHRAE	Yes	N/A	Yes	N/A	NR	This measure is not recommended for complete implementation. The addition of central humidification is far too costly and while increased humidification can help IAQ, maintaining proper humidity levels while avoiding condensation and mold will prove difficult.	Add humidification units to space. - Report does not define basis of design.	N/A	N/A	N/A	N/A	2,119,028	0	0	\$218,053	N/A	\$0	\$218,053	N/A	\$55,500	
WP-02	Albany Medical Center 43 New Scotland Avenue, MC 143, Albany, NY 12208	BMS Modifications (3% Increase)	Ventilation	Increased OA%	Central System	ASHRAE	Yes	N/A	Yes	N/A	ME	Maximum allowable OA% increase selected instead. "Being that more cool air is being used for cooling thus less cooling energy is required for a large portion of the occupied time, an energy savings can be realized (specifically with the return air units in SCC)"	N/A	Calculated on a per building basis. See Appendix B of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	415,614	393	0	98	\$30	N/A	\$515	\$545	N/A	\$88,800	
WP-02	Albany Medical Center 43 New Scotland Avenue, MC 143, Albany, NY 12208	BMS Modifications (Maximum Allowable OA% Increase)	Ventilation	Increased OA%	Central System	ASHRAE	Yes	N/A	Yes	N/A	RME	N/A	N/A	Calculated on a per building basis. See Appendix B of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	446,456	9,241	0	3,109	\$16,644	N/A	\$699	\$17,343	N/A	\$88,800	
WP-02	Albany Medical Center 43 New Scotland Avenue, MC 143, Albany, NY 12208	Electrostatic Filter Replacement (alternate to MERV 13 Filter Replacement)	Filtration	Electrostatic Filtration	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	ME	MERV 13 without electrostatic charge recommended instead due to cost considerations	Report does not define Electrostatic Filtration basis of design equipment	N/A	N/A	N/A	N/A	-199,218	-36	0	-\$30,296	N/A	\$0	-\$30,296	\$16,701	\$579,116	
WP-02	Albany Medical Center 43 New Scotland Avenue, MC 143, Albany, NY 12208	UVGI Lighting (Upper Room, All Spaces)	UVGI	Upper Room UVGI	Local In-Room	Energy Efficiency	Yes	N/A	Yes	N/A	NR	The facility already utilizes upper room UVGI lighting in select spaces as well as mobile UV units that can be rolled into high risk rooms. Widespread UVGI lighting is a very expensive measure as well as a labor intensive effort.	300 ft ² per fixture, 1213 fixtures - basis of design not defined in report.	Calculated on a per building basis. See Appendix B of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	N/A	105,120	0	0	\$7,296	N/A	\$0	\$7,296	N/A	\$1,411,200	First costs include material and labor per Figure 29 in report
WP-02	Albany Medical Center 43 New Scotland Avenue, MC 143, Albany, NY 12208	UVGI Lighting (Upper Room) Critical Spaces Only	UVGI	Upper Room UVGI	Local In-Room	Energy Efficiency	Yes	N/A	Yes	N/A	NR	The facility already utilizes upper room UVGI lighting in select spaces as well as mobile UV units that can be rolled into high risk rooms. Widespread UVGI lighting is a very expensive measure as well as a labor intensive effort.	300 ft ² per fixture, 243 fixtures - basis of design not defined in report.	Calculated on a per building basis. See Appendix B of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	N/A	14,183	0	0	\$1,026	N/A	\$0	\$1,026	N/A	\$190,400	First costs include material and labor per Figure 29 in report
WP-02	Albany Medical Center 43 New Scotland Avenue, MC 143, Albany, NY 12208	UV Airside	UVGI	In-AHU UVGI	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	R	N/A	In-AHU -UVGI Fixtures - Report does not define basis of design.	N/A	N/A	N/A	N/A	56,028	12	0	\$4,253	N/A	\$0	\$4,253	N/A	\$161,457	
WP-02	Albany Medical Center 43 New Scotland Avenue, MC 143, Albany, NY 12208	IAQP - Ventilation Reduction in Parallel with UV-C (Air Purification)	Ventilation	Reduced OA%	Central System	Energy Efficiency	Yes	Needs further study including a hazard assessment.	Yes	Needs further study including a hazard assessment.	ME	Needs further study including a hazard assessment. Maximum OA increase recommended as alternative.	Install IAQ sensors - Report does not define basis of design equipment	Calculated on a per building basis. See Appendix C of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	1,675	319,394	0	-2,830	\$4,246	N/A	-\$15,149	-\$10,903	N/A	\$50,000	
WP-02	Albany Medical Center 43 New Scotland Avenue, MC 143, Albany, NY 12208	BiPolar Ionization	Other	BPI	Central System	Energy Efficiency	Yes	Not currently accepted technology by NYSERDA & ASHRAE	Yes	N/A	NR	Being that the implementation of any type of air ionization is not approved by ASHRAE or NYSERDA, this measure is not recommended. This measure is outside the scope of work of this study and was not reviewed by NYSERDA.	O2 Prime (AH, IR 36/18, OC-3TBAS, OC2-24, OC-48, OC-IC)	N/A	N/A	N/A	N/A	36,228	7	0	-\$208	N/A	\$0	-\$208	N/A	\$39,193	

Figure 3: North Colonie School District Findings

WP#	Building Name and Address, Campus or Complex	Measure Description	Measure Category	Measure Sub-Category	Measure Application	Package	Feasible?	Barrier(s) to Feasibility	Evaluated?	Barrier(s) to Evaluation	Measure Status	Barrier(s) to Recommendation	Product/Manufacturer/Model Analyzed	Risk Reduction/ Safety Impact			Outdoor Air			Energy Use Impact			Energy Cost Impact ¹			Notes	
														eACH	Prob of Infection	Method of Analysis	CFM	kWh	kW	MMBtu	kWh (\$)	kW (\$)	MMBtu (\$)	Total (\$)	Maintenance Cost		First Cost
WP-03	North Colonie Central School District 91 Fiddlers Lane, Latham, NY 12110	MERV 13 Filter Replacement	Filtration	Increased MERV rating	Central System	ASHRAE	Yes	N/A	Yes	N/A	RME	N/A	Canfil AP-13	N/A	N/A	N/A	N/A	50,357	8	0	\$18,199	N/A	\$0	\$18,199	-\$10,898	\$0	
WP-03	North Colonie Central School District 91 Fiddlers Lane, Latham, NY 12110	Airflow Adjustment (Purge Cycle)	Ventilation	Institute 2 hr. Building Air Flush	Central System	ASHRAE	Yes	N/A	Yes	N/A	R	N/A	N/A	Calculated on a per building basis. See Appendix B of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	260,599	548,683	0	16,301	\$79,559	N/A	\$93,240	\$172,799	\$0	\$0	
WP-03	North Colonie Central School District 91 Fiddlers Lane, Latham, NY 12110	Localized Humidification	Humidification	Increased RH	Central System	ASHRAE	Yes	N/A	Yes	N/A	NR	This measure is not recommended for complete implementation. The addition of central humidification is far too costly and, while increased humidification can help IAQ, maintaining proper humidity levels while avoiding condensation and mold will prove diff	Aircare H12(CN) Series Console Evaporative Humidifier	N/A	N/A	N/A	N/A	1,243,125	0	0	\$182,009	N/A	\$0	\$182,009	\$0	\$208,750	
WP-03	North Colonie Central School District 91 Fiddlers Lane, Latham, NY 12110	BMS Modifications (3% Increase)	Ventilation	Increased OA%	Central System	ASHRAE	Yes	N/A	Yes	N/A	ME	N/A	N/A	Calculated on a per building basis. See Appendix B of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	253,003	0	0	353	\$0	N/A	\$2,020	\$2,020	\$0	\$451,200	
WP-03	North Colonie Central School District 91 Fiddlers Lane, Latham, NY 12110	BMS Modifications (Maximum Allowable OA% Increase)	Ventilation	Increased OA%	Central System	ASHRAE	Yes	N/A	Yes	N/A	RME	N/A	N/A	Calculated on a per building basis. See Appendix B of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	541,579	0	0	12,796	\$0	N/A	\$73,194	\$73,194	\$0	\$451,200	
WP-03	North Colonie Central School District 91 Fiddlers Lane, Latham, NY 12110	Electrostatic Filter Replacement (alternate to MERV 13 Filter Replacement)	Filtration	Electrostatic Filtration	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	ME	This measure is expensive to implement (material cost) and would require a case by case inspection and possible modification of ductwork or AHU	Report does not define electrostatic filter basis of design	N/A	N/A	N/A	N/A	-60,073	-20	0	-\$15,024	N/A	\$0	-\$15,024	\$6,314	\$330,390	
WP-03	North Colonie Central School District 91 Fiddlers Lane, Latham, NY 12110	UVGI Lighting (Upper Room, All Spaces)	UVGI	Upper Room UVGI	Local In-Room	Energy Efficiency	Yes	N/A	Yes	N/A	NR	Complete implementation of UVGI lighting (upper room) is far too costly for the district	UVR - Xplus UV-C Nema 4X Fixture, American UltraViolet TB & CM 15	Calculated on a per building basis. See Appendix B of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	N/A	173,680	0	0	\$25,184	N/A	\$0	\$25,184	\$0	\$2,971,000	
WP-03	North Colonie Central School District 91 Fiddlers Lane, Latham, NY 12110	UVGI Lighting (Upper Room) Critical Spaces Only	UVGI	Upper Room UVGI	Local In-Room	Energy Efficiency	Yes	N/A	Yes	N/A	NR	Implementation of upper room UVGI lighting in critical spaces only is a very costly measure	UVR - Xplus UV-C Nema 4X Fixture, American UltraViolet TB & CM 15	Calculated on a per building basis. See Appendix B of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	N/A	25,840	0	0	\$3,747	N/A	\$0	\$3,747	\$0	\$440,600	
WP-03	North Colonie Central School District 91 Fiddlers Lane, Latham, NY 12110	UV Airside (AHUs Only)	UVGI	In-AHU UVGI	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	R	N/A	N/A	Calculated on a per building basis. See Appendix B of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	N/A	37,110	12	0	\$5,381	N/A	\$0	\$5,381	\$0	\$227,731	
WP-03	North Colonie Central School District 91 Fiddlers Lane, Latham, NY 12110	UV Airside (Unit/UV Airside (Unit Vents/PTACs/FUCUs Only)	UVGI	In-FBU UVGI	Local In-Room	Energy Efficiency	Yes	N/A	Yes	N/A	R	N/A	N/A	N/A	N/A	N/A	N/A	13,920	5	0	\$2,018	N/A	\$0	\$2,018	\$0	\$369,720	
WP-03	North Colonie Central School District 91 Fiddlers Lane, Latham, NY 12110	IAQP - Ventilation Reduction in Parallel with UV-C (Air Purification)	Ventilation	Reduced OA%	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	ME	It is not in the district's best interest to NOT begin to reduce OA during these pandemic times. Highest amount of OA is the most beneficial to IAQ.	UVR - SLX Single Lamp High Output Fixture	Calculated on a per building basis. See Appendix B of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	86,080	0	0	-26,510	\$0	N/A	-\$151,636	-\$151,636	\$0	\$80,000	
WP-03	North Colonie Central School District 91 Fiddlers Lane, Latham, NY 12110	BiPolar Ionization	Other	BPI	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	NR	Being that the implementation of any type of air ionization is not approved by ASHRAE or NYSERDA, this measure is not recommended. This measure is outside the scope of work of this study and was not reviewed by NYSERDA.	O2Prime-AH, O2Prime-OC-3TBAS, O2Prime-OC3-24, O2Prime-OC-48, O2Prime-IC	N/A	N/A	N/A	348,422	9	0	\$4,210	N/A	\$0	\$4,210	\$0	\$55,563		

Figure 4: Higher Education University Findings

WP#	Building Name and Address, Campus or Complex	Measure Description	Measure Category	Measure Sub-Category	Measure Application	Package	Feasible?	Barrier(s) to Feasibility	Evaluated?	Barrier(s) to Evaluation	Measure Status	Barrier(s) to Recommendation	Product/Manufacturer/Model Analyzed	Risk Reduction/ Safety Impact			Outdoor Air		Energy Use Impact			Energy Cost Impact ¹			Notes		
														eACH	Prob of Infection	Method of Analysis	CFM	kWh	kW	MMBtu	kWh (\$)	kW (\$)	MMBtu (\$)	Total (\$)		Maintenance Cost	First Cost
WP-04	Higher Education University	MERV 13 Filter Replacement	Filtration	Increased MERV rating	Central System	ASHRAE	Yes	N/A	Yes	N/A	RME	N/A	N/A	Calculated on a per building basis. See Appendix E of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	N/A	33,259	9	0	\$16,918	N/A	\$0	\$16,918	\$13,445	\$0	
WP-04	Higher Education University	Airflow Adjustments (Purge Cycle)	Ventilation	Institute 2 hr. Building Air Flush	Central System	ASHRAE	Yes	N/A	Yes	N/A	R	N/A	N/A	Calculated on a per building basis. See Appendix E of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	99,179	311,763	0	8,444	\$10,719	N/A	\$75,403	\$86,122	\$0	\$0	
WP-04	Higher Education University	Localized Humidification	Humidification	Increased RH	Central System	ASHRAE	Yes	N/A	Yes	N/A	NR	This measure is not recommended for complete implementation. The addition of central humidification is far too costly and, while increased humidification can help IAQ, maintaining proper humidity levels while avoiding condensation and mold will prove diff	Localized Humidifiers basis of design are not defined in report	N/A	N/A	N/A	N/A	1,681,280	0	0	\$188,898	N/A	\$0	\$188,898	\$0	\$541,000	
WP-04	Higher Education University	BMS Modifications (3% Increase)	Ventilation	Increased OA%	Central System	ASHRAE	Yes	N/A	Yes	N/A	ME	Maximum allowable OA% increase selected instead.	N/A	Calculated on a per building basis. See Appendix E of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	110,901	3,299	0	203	\$363	N/A	\$1,808	\$2,171	\$0	\$208,800	
WP-04	Higher Education University	BMS Modifications (Maximum Allowable OA% Increase)	Ventilation	Increased OA%	Central System	ASHRAE	Yes	N/A	Yes	N/A	RME	N/A	N/A	Calculated on a per building basis. See Appendix E of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	301,395	65,974	0	11,596	\$7,257	N/A	\$103,555	\$110,813	\$0	\$208,800	
WP-04	Higher Education University	Electrostatic Filter Replacement (alternate to MERV 13 Filter)	Filtration	Electrostatic Filtration	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	ME	Require more physical space within an AHU and may require some additional modification to allow installation. More expensive.	Electrostatic filtration basis of design is not defined in report	Calculated on a per building basis. See Appendix E of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	N/A	-103,035	-23	0	-\$23,193	N/A	\$0	-\$23,193	\$11,343	\$381,019	
WP-04	Higher Education University	UVGI Lighting (Upper Room) Critical Spaces Only	UVGI	Upper Room UVGI	Local In-Room	Energy Efficiency	Yes	N/A	Yes	N/A	NR	Complete implementation of UVGI lighting (upper room) is far too costly for the district.	Upper room Basis of design is not defined in report	Calculated on a per building basis. See Appendix E of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	N/A	314,526	0	0	\$34,598	N/A	\$0	\$34,598	\$0	\$4,234,000	
WP-04	Higher Education University	UV Airside (AHUs)	UVGI	In-AHU UVGI	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	R	N/A	UV Airside basis of design not defined in report	Calculated on a per building basis. See Appendix E of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	N/A	49,016	4	0	\$6,506	N/A	\$0	\$6,506	\$0	\$90,796	
WP-04	Higher Education University	UV Airside (FCUs)	UVGI	In-AHU UVGI	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	R	N/A	UV Airside basis of design not defined in report	Calculated on a per building basis. See Appendix E of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	N/A	59,052	6	0	\$6,496	N/A	\$0	\$6,496	\$0	\$489,800	
WP-04	Higher Education University	IAQP - Ventilation Reduction in Parallel with UV-C (Air Purification)	Ventilation	Reduced OA%	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	NR	It is not in the district's best interest to NOT begin to reduce OA during these pandemic times. Highest amount of OA is the most beneficial to IAQ	UV-C Airside basis of design not defined in report	Calculated on a per building basis. See Appendix E of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	20,550	-85,084	0	-12,000	-\$9,359	N/A	-\$107,164	-\$116,523	\$0	\$80,000	
WP-04	Higher Education University	MERV 8 Filters (if paired with UV-C Airside)	Filtration	Recuded MERV rating	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	ME	MERV 13 filters are recommended as they cost less than the combined cost of MERV 8 AND UV lighting	N/A	Calculated on a per building basis. See Appendix E of report.	N/A	ASHRAE Equivalent OA Calculator / SMP IAQP Calculation Tool	N/A	-42,040	-9	0	-\$16,564	N/A	\$0	-\$16,564	\$1,990		
WP-04	Higher Education University	Bi-Polar Ionization	Other	BPI	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	NR	Being that the implementation of any type of air ionization is not approved by ASHRAE or NYSERDA, this measure is not recommended. This measure is outside the scope of work of this study and was not reviewed by NYSERDA.	O2Prime-AH O2Prime-IR 36/18 O2Prime-OC-3TBAS O2Prime-OC2-24 O2Prime-OC-48 O2Prime-OC-IC	N/A	N/A	N/A	N/A	170,662	75	0	\$18,773	N/A	\$0	\$18,773	\$0	\$310,804	

IV. Study Comparisons

The same measures were evaluated for all studies conducted. As part of the **ASHRAE Recommended Package**, the following measures were evaluated (as a function of the pre-Covid baseline):

- **MERV 13 Filter Replacements** – Replace existing filters with higher efficiency filters to capture greater amounts of potential contaminants
- **Airflow Adjustment (Purge Cycle)** – Alter the air handling equipment run hours to allow for pre-/post-occupancy purge cycles. Running equipment at 100% outdoor air before and after occupants are present in the building to allow for flushing of the stagnant air out of the building and introduction of outdoor air into the spaces.
- **Humidification** – The addition of humidification systems to increase the relative humidity in the various spaces in an attempt to achieve the ideal relative humidity range of 40% - 60%.
- **BMS Modifications (3% Outdoor Air Increase and Maximum Outdoor Air Increase)** – Modifications to the BMS can allow for the facility to introduce greater amounts of fresh, outdoor air.

The second package, the **Energy Efficiency Package**, includes measures that, when compared to the **ASHRAE Recommended Package**, produce energy savings while also increasing or maintaining the same level of IAQ. Although the UV Airside measure produces an energy penalty, it is needed in this package as, if the ventilation reduction measure was to be implemented, UV lighting or another form of air disinfecting is required. Refer to the table below to see how the overall eACH changed for each study when going from pre-Covid baseline, to the ASHRAE Package, and then to the Energy Efficiency Package:

Package	North Colonie SD eACH	Albany Medical eACH	Higher Ed. eACH
Pre-Covid	2	4	2
ASHRAE Recommended	4	8	8
Energy Efficiency	4	5	7.9

The following measures were evaluated as part of the **Energy Efficiency Package**:

- **Electrostatic Filter Replacement** – Replace existing filters with high efficiency electrostatic filters. These filters utilize electrostatic charges to polarize filter material and incoming particles in order to capture more particles as they pass through the filter.
- **UV-C Airside** - Installation ultraviolet lamps within the HVAC equipment as a means to disinfect incoming return air before being re-introduced in the space.
- **Reduced Ventilation using the Indoor Air Quality Procedure (IAQP) Method** in conjunction with UV-C implementation – The IAQP Method utilizes contaminant concentration in the space to calculate the required amount of outdoor air (OA) needed to properly ventilate said space. With an air cleaning device present, the amount of OA required to properly ventilate a space can be reduced, thus saving energy on heating/cooling loads.
- **UVGI Upper Room Lighting** – Installation upper room UVGI lighting directly in the space in order to disinfect circulating air in the room. This type of UV installation relies on airflow in the space in order to properly disinfect the air.

Due to the same measures being evaluated and their recommendation status being consistent across all studies, below is a breakdown of the measures according to their recommendation status. Being that the general premise behind each measure is applicable to all types of HVAC systems across all sectors, the recommendation statuses were consistent across all studies. Although different unit types and building spaces require different sized UV lamps, or different amounts of required ventilation air, or different sized filters depending on their size and/or use, the fundamental idea within each measure with regards to improving IAQ remains the same, it is just a matter of cost and energy savings/penalties. The key commonalities and differences within each measure across the varying building types, system types/configurations and sector types are also described on the following pages.

Below is a high-level summary of the recommended measures across both packages and all studies:

- **MERV 13 Filter Replacement:** This measure, for all unit types, will produce an electric energy penalty that is dependent upon the difference in pressure drop from the existing filter and the MERV 13 filter, the airflow of the unit and the hours of operation. Increasing filter rating will aid in improving IAQ in any system, in any sector. Increasing your filter rating increases the achievable equivalent air change rate (eACH) in the space.
- **Airflow Adjustment (Purge Cycle):** This measure produces both an electric and thermal energy penalty. The total energy penalty shall be dependent upon airflow of the units evaluated and the hours of operation. Refer to the Airflow Adjustment section in the following pages for more information regarding how airflow and hours of operation affect the energy penalty. For all applications, this measure introduces more dilution air prior to occupancy of the building in order to flush the stagnant air with the purpose of improving the IAQ.
- **BMS Modifications – Max OA:** This measure produces thermal energy penalties as bringing in larger amounts of outdoor air increases the thermal load. However, introducing greater amounts of clean outdoor air will certainly increase the indoor air quality of space. Note that special consideration must be given while increasing setpoints to maximum OA as comfort conditions within the space may be altered.
- **UV-C Airside:** There are no energy savings that result from this measure. Adding UV-C lamps to air handling equipment induces a slight energy penalty due to the added kWh of the UV-C. As noted in more detail in the following sections, UV-C lamps have the potential to disinfect airstreams that pass over them and therefore improving the IAQ of the space that is served.

Recommended Measures – Descriptions/Comparisons:

MERV 13 Filter Replacement:

Description:

Replacing current air handling equipment filters with a minimum MERV 13 filter will prove beneficial to IAQ while not incurring a huge economic penalty. As seen in the studies, filters are a commodity which are approximately \$12.50 more expensive than the assumed existing MERV 8 filters. Installation can be done by facility staff with relative ease and a pressure drop increase

of approximately 0.16” will only induce a minor energy penalty. Installing higher rated MERV filters such as MERV 13 will improve overall IAQ as higher rated MERV filters are more efficient at capturing small particles. As mentioned in the studies, the typical SARS-CoV-2 particle is typically 0.125 microns but travels on larger aerosolized particles and therefore a higher rated filter would improve the IAQ as it has the potential to capture more small particles. Using higher rated filters produce greater equivalent air changes (eACH) according to ASHRAE’s Equivalent Air Change Calculator and higher eACH means more equivalent outdoor air which means greater dilution of the space air (i.e. reduced risk). In the case of the facilities included in this study, the associated increase in fan pressure drop is such that the fans can still overcome that added pressure without any modification. Note however that in some cases, the added pressure drop may be too substantial for the existing fan and fan modification or replacement may be needed. Since these filters are a normal maintenance item, the filters can be installed by facility maintenance staff with relative ease. This measure should be considered the bare minimum to increase infection control ability.

Comparison (by space type/system type):

- MERV 13 filters can only be installed in spaces or areas served by mechanical ventilation
- Energy savings and cost associated with installation of these filters depends on airflow, size of unit, number of filters, installation etc.
 - Larger airflow units will have larger relative energy penalties due to the larger fan motors
 - Loosely installed filters can affect the energy impact due to gaps and leaks around the frame. Large gaps will decrease the pressure drop across the filter.
- MERV 13 filters have a reduced room infection control impact when utilized on air handling units with 100% OA
- MERV 13 filter upgrades are most beneficial to air handling units that utilize return air
- Filter performance is best when installed correctly (i.e. units with intact sealing and framing around filter box will produce greatest filtration benefits)

Energy Impact:

- Average energy impact: 40% increase in electric usage. Note that this increase is dependent upon what the original filtration level was. Newer MERV 13 filters have a pressure drop that is not much more than that of the old MERV 8 filters. Typically, the higher the MERV rating goes, the greater the pressure drop.
 - For purposes of calculating the increase in electric usage for this measure, typical dirty filter pressure drops for the existing filters and for MERV 13 filters along with airflows were used to calculate break horsepower. Electric demand was then determined and multiplied by the unit's hours of operation to get the electric usage of the unit while operating with MERV 8 vs MERV 13.
- Note that the impact will vary on individual basis based on airflow of the unit, the prior filtration level, available filter space and face velocity of airflow in AHU. Larger airflows will produce greater energy penalties
- It was found that at Albany Medical Center, as typical with many healthcare facilities, there were already at minimum, MERV 13 filters installed in many air handling units. The impact this measure has on healthcare facilities is presumably less than in a school as most healthcare facilities already have high MERV rated filters installed throughout

Safety Impact:

The introduction of a higher MERV rated filter (MERV 13) will benefit in indoor air quality. A space served by a higher MERV rated filter as compared to its baseline filter, will be provided with cleaner air, thus increasing the indoor air quality of the space. Transitioning to higher efficiency filters, such as going from a MERV 8 filter to a MERV 13 filter, aids in capturing the conglomerated aerosols that the typical SARS-CoV-2 particle travels on, at more effective rates. The size of a SARS-CoV-2 particle on its own is approximately 0.125 microns, however, these small particles typically travel via the aerosols produced by human speech. These aerosols are typically in the size range of 0.3 microns to 1.0 microns. A typical MERV 8 filter captures less than 20% of 0.3-1.0-micron particles while a MERV 13 filter can capture up to approximately 75% of particles at that same size.

Areas served by 100% OA or ERV units do not benefit as much from MERV 13 filters from an air cleaning and safety as return air units do. Being that these types of units already us 100% OA,

assuming this OA is cleaner than return air, the MERV 13 filters will be filtering the already clean OA. Whereas in return air units, the higher rated filters should be required as they are necessary to effectively filter the dirty return air.

Airflow Adjustment (Purge Cycle):

Description:

At the time this report was written, ASHRAE recommended increasing air handling equipment run hours 2 hours pre- and post- occupancy (or equivalent of 3 air changes per hour, ACH) in the attempt to ‘purge’ the space of stagnant air and bring in fresh, outside air prior to occupancy. More amounts of fresh air to dilute space return air allows for a better air quality in the space. There is an energy penalty associated with increasing the amount of time units run. However, this measure can be implemented with relative ease through changes in the building management system (BMS) sequence of operation or through manual start up, if required.

Comparison (by space type/system type):

- Systems utilizing BMS connectivity can be adjusted to allow for purge cycle through a sequence of operation modification
- Manual adjustments can be made to units not connected to a BMS (as in the Higher Education University)
- Energy impacts will vary depending on size of unit (airflow and horsepower) and occupancy schedule
- Specialized laboratories or operation rooms, as in Albany Medical Center, oftentimes have specific defined schedules. Rooms such as these may not fit the criteria for a purge cycle as the defined schedule is necessary for a variety of reasons.

Energy Impact:

- Average Energy Impact: 51% increase in electric usage and 131% increase natural gas usage
- Energy impact will vary depending on size (HP)/airflow of units. Larger units will have larger energy penalties
 - Albany Medical Center Average AHU Size: (15 HP) / 10,700 CFM

- North Colonie School District Average AHU Size: (5 HP) / 4,500 CFM
- Higher Education University Average AHU Size: (10 HP) / 8,725 CFM
- The hours in which the units operate under the purge cycle conditions also affect the energy impact (i.e. early mornings or late nights will have lower OA temperatures). With greater amounts of cold OA being brought into the air handling units, the heating coils will need to expend more energy in order to heat that additional OA up to the desired supply air temperature setpoint.
- This measure does not have an impact on units that are under a 24/7 operation schedule (such as the majority of Albany Medical Center Medical Research Building)

Safety Impacts:

There are minimal safety concerns with regards to this measure. Occupant comfort however must be considered when utilizing a purge cycle. Facilities must ensure that the increased amounts of air can be properly conditioned, as to maintain occupant comfort.

Ultraviolet (UV) Airside:

Description:

The implementation of UV Airside lighting decreases the risk associated with occupying spaces. The disinfection properties and the light's ability to inactivate airborne pathogens and viruses, although inducing an energy penalty, is the reason this measure is recommended. From an indoor air quality and risk reduction point of view, UV-C lighting is recommended for implementation across all studies.

Comparison (by space type/system type):

- There are airside UV-C devices for a variety of system types. Note that for this measure, only airside UV devices were evaluated. Upper room UV devices were evaluated as a separate measure. Refer to the 'Not Recommended' Measures section below for more information on upper room UVGI. For airside UV, there are UV-C devices for:
 - Air Handling Unit (AHU) in-unit UV-C fixture: This type can be installed inside of an AHU or rooftop unit (RTU) to provide air disinfection as well as coil cleaning properties if located in direct line of sight of the coils. This is the desired

installation type if applicable because the air inside of an AHU is moving considerably slower than in ductwork (~500 feet per minute in AHU vs. ~1,000 feet per minute in ductwork). The slower the air is moving across the lamp, the greater the exposure time of the air to the UV light, which increases the disinfection efficacy of the light.

- Note that air disinfection applications and coil cleaning applications require different dosages of light. To effectively disinfect moving air across the lamp, one would require a higher dosage of UV light as opposed to simply cleaning and treating a coil inside of an AHU.
- Unit Ventilator in-unit fixture: This type of device can be installed inside of a unit ventilator, FCU or PTAC. It functions similarly to the AHU in-unit type whereas it provides cleaning to the air passing over the lamps as well as cleaning to filters or coils that are directly exposed to the UV-C light.
- In-duct UV-C fixture: This type of device is installed in the supply or return duct of an HVAC system. Note that installing the device in the return duct decreases the rate of fouling of the coil. Cleaner, disinfected return air now flows over the coil thus reducing the amount of potential for fouling.
 - The effectiveness of the in-duct UV-C fixture relies heavily upon exposure time that the lamps have on the passing air. Air velocity is much greater in ducts than in AHUs due to the reduced cross-sectional area of a duct. To increase the exposure time of the lamps in ducts, several lamps may be installed in series within a duct.
- Stand-Alone Portable UV-C Units: These units work well for areas or spaces that have no mechanical ventilation (i.e. no AHUs, RTUs or associated ductwork). These units utilize UV-C lighting in conjunction with a fan and HEPA filter to provide air purification to a designed square footage. Various sizes of these portable units are available on the market for a variety of sized spaces.
- UV-C lighting devices have a reduced benefit, from an IAQ perspective, for 100% OA units. Whereas return air units benefit the most from UV-C lighting, being that the return air is being purified before entering back into the space.

- Prices and costs associated with this measure depend on type of UV-C devices needed, and size of AHU and/or size of space.
 - Larger AHUs will require larger and/or a higher quantity of UV-C devices which will increase the material and labor cost.
 - UV-C devices suitable for large, high volume AHUs carry a higher wattage and therefore induce a greater energy penalty.
 - Unit ventilator/FCU UV-C devices are typically a standard size and wattage.
However, large open spaces usually contain numerous FCUs.
- Note that for this measure, in-duct and standalone UV devices were not evaluated. Effectiveness of UV lamps relies upon the exposure time. Where air is moving fast (around 1,000 feet per minute) across the lamps such as in ductwork, the disinfection properties on the UV-C light are diminished. For this reason, we assumed and evaluated UV-C lamp installation in the most effective location with regards to exposure time, that is, inside of the AHUs or FCUs. Inside the units the air is moving relatively slower than in the ductwork, assumed ~500 feet per minute. Standalone UV units were also not evaluated as part of this measure because for the majority of the applicable situations, the in-unit device was the preferable alternative and therefore was the only solution evaluated.

Energy Impact:

- Average Energy Impact: 22% increase in electric usage when compared to ASHRAE Recommended Measures baseline
- Size and number of the units will affect the energy impact as larger units or larger rooms will require larger/more UV-C lamps or devices
- This measure is not as applicable in healthcare facilities where 100% OA are often used for the majority of spaces. Using UV light to sanitize OA is almost a redundant process, although disinfecting OA can be done if wanted. UV lighting and its associated energy impact should be reserved for return air units

Safety Impacts:

There is a risk associated with UV-C lighting. Although the UV-C wavelength (approximately 254 nanometers) is the least dangerous of all UV sources, this type of light is still harmful to humans. Caution should be taken when installing these devices and proper notation and warning labels should be put on the equipment where these are installed. As previously stated in this section, UV-C light has the ability to disinfect an airstream that passes over it and that the amount of time the air is exposed to the light impacts its disinfection efficacy. A dirty airstream containing SARS-CoV-2 infectious aerosols has the potential to be irradiated once it has passed through the light emitted by a UV-C lamp.

BMS Modifications (Max. OA):

Description:

An evaluation of a 3% increase in outdoor air across all handling equipment was done as a conservative estimate of increased OA that would provide increased IAQ while not greatly impacting economics negatively. Another evaluation was done, this time analyzing the effects of increasing the OA to the units' maximum potential (according to coil capacities). It was found that altering the BMS to allow for units to bring in their maximum amount of OA would allow for the greatest potential of good IAQ (more dilution air being brought into the spaces) while also not introducing a significant increase in an energy penalty. For context, the resulting increase in energy from the pre-Covid baseline for each study is:

- Albany Medical Center: 0.5% increase
- North Colonie School District: 29% increase
- Higher Education University: 8% increase

Although the jump from increasing the OA by 3% to increasing the OA to the maximum allowable OA (approximately 100% depending upon AHU capacities) did increase the associated energy penalty, this measure also presents a significant risk reduction, refer to the Safety Impacts section for this measure.

Comparison (by space type/system type):

- Maximum amount of OA that a unit can handle is determined by the coil capacity. This will vary depending on size of unit and conditions under which the unit was designed.

Each AHU's cooling/heating coil has a certain capacity for which they can effectively condition incoming outdoor air. Existing equipment may have been sized under different operating conditions such as warmer or colder outdoor air which would affect the coil capacity. Typically, units that serve densely occupied spaces will have larger capacities to ensure occupant comfort.

- Spaces with no mechanical ventilation are not able to have the amount of OA increased (absent from opening windows)
 - Some of the older buildings at the Higher Education University contained spaces where no mechanical ventilation was present.
- 100% OA units and energy recovery units already utilize the maximum amount of OA and therefore cannot be modified to accept more. These unit types are optimal from an IAQ perspective
 - Albany Medical Center, because it is a healthcare facility, utilizes 100% OA systems for many spaces included in this study. For this reason, there were only a few cases in which increase OA to the maximum allowable was even possible, and therefore this measure does not induce a large energy penalty with respect to the total annual cost (approximately 0.3% penalty of the total annual cost)
 - Shaker Middle School, part of the North Colonie School district, utilizes a large number of energy recovery units to provide conditioned air to its spaces. Increasing OA to 100% is not applicable for these types of unit and therefore this measure plays less of a factor for Shaker Middle School specifically.
- In hospitals, such as Albany Medical Center, there are certain laboratories and/or operating rooms which have specific, designed airflow patterns and capacities (typically 100% OA units serve these type of spaces)
- Damper positions and sequences can be altered with relative ease in buildings or facilities utilizing a central BMS.

Energy Impacts:

- Average Energy Impact: 103% increase in natural gas energy usage
- Maximum allowable OA is determined by coil capacity

- Majority of AHUs across the studies could handle 100% OA (with a few exceptions being designed to handle only 75% OA). The maximum allowable OA% was determined based on the heating coil capacity of the units. Note that all systems are different and these maximum OA values may not be typical of all systems for all seasons (i.e. 100% OA may be typical during shoulder seasons but not during the middle of winter when OA is typically much colder)
- Energy impact will vary depending on total airflow and the allowable maximum OA %. Units with greater total airflow and 100% maximum OA will have greater energy penalties than smaller units only accepting a maximum of 75% OA

Safety Impact:

There are significant safety impacts associated with increasing the outside air in spaces. Introducing greater amount of OA can increase the eACH and therefore produce better occupant safety. However, occupant comfort must be considered. With greater amounts of OA being introduced into spaces, heating and cooling loads will vary and occupant health and comfort issues need to be addressed if they arise. There is also a potential for mold issues inside during summer operation when OA is typically warmer and more humid. During the winter months, with greater amounts of OA being brought in and conditioned, the relative humidity levels will potentially fall to outside of the ASHRAE recommended range of 40% - 60%. As previously stated, this relative humidity range is the range at which the human immune system is most effective.

Not Recommended Measures – Descriptions:

Local Humidification:

Description:

A relative humidity range of 40% - 60% is shown to increase the human body's effectiveness at fighting off viruses, bacteria, and other pathogens. Many viruses struggle to propagate at humidity levels of between 40% - 60%. While these are optimal levels of humidity to strive for, adding central humidification would typically be classified as a capital upgrade and therefore was not evaluated. Local humidification, while cheaper to implement and easier to customize on

a room-by-room basis, still presents a fairly large energy impact. This measure falls in the middle of the road in terms of first costs and energy penalties when compared to the rest of the measures evaluated. On average, there is a \$0.83/square foot energy penalty associated with this measure while it costs, on average, \$0.47/square foot. Along with the energy penalty and first costs, achieving that ideal relative humidity level will prove very difficult in the winter months and is not a feasible goal. Humidification in a space with a loose building envelope or older building with poor R-value walls can produce some safety concerns; buildings or rooms with a loose envelope can pose condensation and potential mold issues.

Comparison (by space type/system type):

- Central humidification, although not evaluated under the scope of this study, is only feasible where mechanical ventilation is present. Associated price depends on size and complexity of HVAC system
- Portable, stand-alone humidifiers can be used as a cheaper solution to humidification issues on a case-by-case solution to under humidified spaces. Note that portable humidification is not applicable for large spaces such as auditoriums or performance theatres
- Spaces or buildings with poor/loose envelopes have a greater potential for excess condensation, which can lead to mold issues
- Hospital laboratories or operating rooms, such as those in Albany Medical Center, should be given special attention if humidification is sought. Specific design conditions must be kept constant in rooms such as these and any variation from the design setpoints can cause issues.
- School gymnasiums or workout rooms typically have sufficient natural humidification

Energy Impacts:

- Average Energy Impact: 11% increase in energy usage when compared to the total baseline energy usage (water and electric)
- Amount of humidification, and therefore associated energy impact, varies depending upon size of space, size and type of system, number of stand-alone units and types of activities taking place in the space

Safety Impacts:

As previously stated, there is a risk associated with adding humidification in that excess condensation can lead to mold issues. Specifically, in older buildings with loose envelopes and poor overall R-values of walls (as found in the Higher Education University), there is a concern in the winter months that the condensation produced from the temperature difference of the indoor and outdoor environment will collect and potentially lead to mold growth. Although values of 40% - 60% relative humidity don't typically lead to mold growth, it is important to note that over-humidification can potentially lead to issues. Mold growth can be harmful to occupants exposed to it.

Upper Room UVGI Lighting:

Description:

This measure, although proven beneficial to overall indoor air quality, is too expensive and difficult and would be considered a capital upgrade. On average this measure costs about \$3.02/square foot of space, which is a considerable first cost, much higher than other measures.

See list below for other measures' average cost/square foot:

- Filter Replacement: \$0.00/sq. ft. – Filters are considered a commodity
- Airflow Adjustments (Purge Cycle): \$0.00/sq. ft. – This measure is done via BMS modifications, which are done by facility staff
- Humidification: \$0.28/sq. ft.
- BMS Modifications (3% OA Increase): \$0.34/sq. ft.
- BMS Modifications (Max. OA Increase): \$0.34/sq. ft.
- Electrostatic Filtration: \$0.67/sq. ft.
- UV Airside: \$0.52/sq. ft.
- IAQP Ventilation Reduction: \$0.11/sq. ft.

In this study, it was assumed implementation of UVGI lighting would require installation of entirely new fixtures based on the size of the space. New upper room UVGI lighting fixtures can be installed in parallel with the existing lighting and the number of UVGI fixtures is determined by the size of the space. This can be done in high-risk spaces (as discussed below) to improve IAQ while not incurring a huge cost associated with adding upper-room UVGI to entire

buildings. Note that UVGI cannot supplant regular, visible lighting and sufficient light levels are required. UVGI lamps shall be installed high enough in the space and be directed away from occupants to minimize risk of contact. There is a safety concern associated with installing any sort of UV lighting. Although the wavelength of UV-C lighting is considered the safest, exposure to UV-C lighting can be harmful to humans. Within the studies, breakdowns of costs and savings on a per-space basis were included in appendices for a more granular analysis.

Comparison (by space type/system type):

- This measure relies on airflow patterns in the space. Spaces with mechanical ventilation, more specifically spaces with proper airflow patterns, will benefit more from upper room UVGI lighting. Proper airflow ensures the space air is being circulated and disinfected in the upper room by the lights
- Spaces with no mechanical ventilation would not benefit as much from the UVGI lamps as it cannot be guaranteed that the air in the space is being circulated up into the lamp's disinfection radius
- Hospitals and specific clean rooms, as found at Albany Medical Center, utilize this type of lighting currently
- Albany Medical Center uses a mobile UVGI lighting unit that can be wheeled into any space for added disinfection
- High risk spaces such as nurse's offices, bathrooms and locker rooms are areas in which upper room UVGI lighting would be most applicable.

Energy Impacts:

- Average Energy Impact: 1% and less than 1% increase in electric usage when compared to the total baseline usage (for both entire facility implementation and high-risk space implementation respectively)
- Energy impact is dependent upon type and size of space, and therefore number of UVGI fixtures needed (assumed 1 fixture can effectively serve 300 square feet of space)
- High Risk Spaces are Defined as:
 - North Colonie School District: Nurse's office, main office, cafeteria, locker rooms, bathrooms

- Albany Medical Center: Operating rooms, locker rooms, bathrooms, labs
- Higher Education University: Specific classrooms such as studios, labs, and yoga centers, student health facilities, locker rooms, dining halls

Safety Impacts:

Similar to the airside UV-C lighting, there is a safety risk associated with upper room UVGI lighting. The wavelength that UVGI lighting operates at is harmful to human beings. Caution must be taken when installation and consideration must be given when decided where to mount these fixtures. In all space types, these fixtures should be mounted above the typical occupant eye level, so as the light shines upward and away from the occupants. Typically, this type of UVGI lighting is best suited for healthcare facilities in which undiagnosed, airborne diseases are relatively common or high-burden areas with lots of potential for transmission such as bathrooms and locker rooms. As with the UV-C Airside measure, air passing through the irradiation zone of an upper room UVGI fixture, if it does contain pathogenic or viral aerosols such as SARS-CoV-2, has the potential to be disinfected by the UV light.

Electrostatic Filters:

Description:

Electrostatic filters use a small voltage of electricity to charge the filter material and incoming particles in order to attract and capture more dust and particulate. These filters provide a MERV 14 rating with less of a pressure drop than that of a traditional MERV 13 filter. Although the lower pressure drop can prove energy savings as compared to MERV 13, the first cost associated with electrostatic filters is a considerable amount. These filters require more physical space than a traditional filter therefore they are more difficult to install (additional duct or unit modification may also be necessary to fit such filters).

Comparison (by space type/system type):

- These types of filter banks are only applicable for AHUs and RTUs
- It was found that approximately 2' of space was required in the unit's filter section to properly allow for installation. Smaller units with little access would be difficult to implement this filter type in

- Reduced impact for 100% OA units
- Would be most beneficial for high-risk spaces such as nurse's offices, operating rooms, locker rooms, etc.

Energy Impacts:

- Average Energy Impact: 49% decrease in electric usage when compared to the ASHRAE Recommended Measures as the baseline
- Energy impact associated relies on total airflow and size of unit. Units with larger airflow will produce greater relative savings when compared to MERV 13. Larger units have larger fan motors which, when an electrostatic filter is installed, will not have to work as hard to move the air across the filter, which results in larger savings

Safety Impacts:

These filter types can achieve the equivalent of a MERV 14 rating. Using these filters would provide greater air cleaning than a typical MERV 13 filter as these filters have a performance rating up to 84% at 0.3 – 1.0 micron particles as opposed to a maximum performance rating of 75% at 0.3 – 1.0 microns for MERV 13. Installing higher efficiency filters increases the eACH as a result of filtration effectiveness and therefore the overall eACH of a particular space/unit; this was conclusive across all studies. Due to increased eACH, using the MIT tool as a method for risk reduction calculation, as eACH increased the Covid-19 risk associated with occupying a space decreased. That is, more equivalent air changes resulted in longer exposure time (time an occupant can safely spend in a space if a positive Covid-19 individual is present) and higher maximum occupancy according to the MIT tool. Typically, these filters can last up to 3 years or more performing as designed. However, performance does decrease over time and after 3 years of continuous use, it is recommended they be changed out and replaced.

IAQP Ventilation Reduction:

Description:

The Indoor Air Quality Procedure, or the IAQP, is a ventilation calculation procedure that utilizes contaminant concentration when calculating the required ventilation air for a particular space. This measure is not recommended and can only be implemented when UV-C lighting (or

another form of air purification such as an in-room combination HEPA/UV device) is present in the space. This measure is not recommended because, from an IAQ perspective, although this procedure calculates the minimum required ventilation air, it is the most beneficial and safest option for occupants to have as much ventilation (dilution) air as possible in a space. Although the eACH associated with this measure is only slightly less than the eACH associated with the maximum OA measure across all studies, it is still beneficial to have the maximum amount of OA from a safety standpoint. The air purification device which scrubs the air of particulate matter and pathogens, allows for that cleaned, return air to be used as a substitute for outdoor air. For these analyses, an MIT open-source calculation tool and a Sustainability Management Partners (SMP) software tool were used to calculate the minimum required OA in each individual case. The MIT tool in conjunction with the SMP tool use the lowest possible ACH as a proxy for risk when compared to contaminant generation in each space. Using this ideology, we were able to determine the lowest possible ventilation rate that was still deemed as safe according to these spreadsheets. There is also an equivalent outdoor air calculation that be conducted using ASHRAE's Equivalent Outdoor Air Calculator, that calculates the total, equivalent outdoor air needed in space to obtain a desired air change rate. The air cleaned from the filter and the air cleaned from the UV-C light both produce an amount of air that is equivalent to a certain CFM of outdoor air. These values can be summed together to obtain an equivalent OA value. With this cleaned air being used as a substitute for outdoor air, the amount of actual outdoor air needed to obtain a desired air change rate can be reduced, thus providing energy savings. Recirculated air is returning to the air handling unit at a temperature much closer to the supply air setpoint than outdoor air, which reduces heating and cooling loads on the air handling unit's coils.

Comparison (by space type/system type):

- Space type, diffuser layout, design conditions and occupancy all effect the required IAQ standards that must be satisfied. For example, a classroom of a given occupancy will have a different ventilation requirement than a laboratory of the same size and occupancy. Different space types have different occupancy density values which in turn vary the amount of OA needed, spaces with properly designed diffuser layouts have better ventilation effectiveness factors, which also contribute to changes in required OA.

- ASHRAE Table 6.2.2.1 has set values of required ventilation air for a variety of different space types.
- Ventilation OA reduction is only feasible for mechanically ventilated spaces
- Ventilation OA reduction is not possible for 100% OA units or energy recovery units as, by design, these type of units are meant to use 100% OA under all circumstances.
- Occupant activity within the space will also affect the amount of OA needed. Spaces with greater activity will require more OA such as gymnasiums where occupants are exercising, or music classrooms where occupants may be singing or playing instruments
- Existing OA% and how much of a reduction is allowed will impact the energy savings potential

Energy Impact:

- Average Energy Impact: 44% energy savings when compared to the ASHRAE Recommended Measures as the baseline
- Energy impact will vary depending on size/airflow of unit. Larger units will have greater energy savings potential
 - Albany Medical Center Average AHU Size: 9 HP / 6,900 CFM
 - North Colonie School District Average AHU Size: 4 HP / 4,925 CFM
 - Higher Education University Average AHU Size: 8 HP / 7,600 CFM
- Facilities with high numbers of 100% OA or energy recovery units (such as Albany Medical Center and North Colonie Middle School) would have a reduced energy impact from this measure as these types of units do not allow for a reduction of OA
- This measure is not feasible for facilities lacking any mechanical ventilation

Safety Impact:

The safety impact across the three studies is consistent. With decreasing the amount of ventilation air being introduced into spaces, regardless of space type, there is an increased risk viral transmission. Using the MIT risk calculation tool, it was seen that, although the reduction of ventilation air in conjunction with an air purification strategy, is allowed using contaminant concentration and generation reducing the ventilation air in a particular space also decreases the maximum exposure time. This maximum exposure time, as calculated by the MIT tool, is the

time for which it would take everyone in the space to be considered a ‘contact’ with regards to contact tracing, if one infected person entered the room. The dilution effect that comes with large amounts of ventilation air help aid in the reduction of risk associated with occupying a space during a pandemic.

V. Overall Conclusions & Takeaways:

Information gathered throughout the studies show that there are several overarching takeaways associated with infection control and achieving good IAQ. The following is a list of general guidance with regards to the evaluated IAQ mitigation strategies:

- For any air handling system, the replacement of existing filters with MERV 13 filters (at a minimum) is recommended
- A 2-hour pre-/post- occupancy purge cycle (or equivalent of 3 ACH) is recommended as a simple method to introducing greater amounts of dilution air prior to occupancy. Flushing the stagnant air out of a space ensures fresh air is present for occupants before entering. Occupant comfort needs to be considered as colder OA is being brought in before and/or after occupancy
- If a reduction in ventilation from the facility's existing or increased ventilation rates is desired post-pandemic, as this measure is not recommended during the pandemic, UV-C lighting or another type of air purification must be installed in order to achieve equivalent air changes (calculated using the IAQP Method and ASHRAE Equivalent Outdoor Air Calculator)
- Humidification technologies are difficult to effectively implement and rather costly. There is a potential for excess condensation which can lead to mold growth issues. Achieving the desired relative humidity ratio will also prove difficult in the cold winter months
- Widespread implementation of upper room UVGI lighting is far too expensive of a measure. Room by room installation of UVGI lighting should only be considered if proper airflow patterns can be achieved and the safety factor has been considered. Proper airflow patterns include proper mixing and a 'sweeping' directional airflow flowing across the room without any sort of 'short circuit'. Properly spaced supply diffusers and return grilles (i.e. not right next to one another) ensure air flows throughout the space.
- There can be a significant penalty with increasing the OA% to the maximum allowable amount (based on coil capacities). However, increasing the amount of OA in a space creates a better IAQ environment with more dilution air. Costs and IAQ benefits must be

weighed and considered (MIT Tool can be used to evaluate risk). Occupant comfort needs to be considered as more OA is being brought into the spaces

- Electrostatic filters can be considered on a case-by-case basis in high-risk spaces where units' dimensions allow for easy installation. These filters provide MERV 14 rating with less pressure drop but have significant first costs associated
- The main similarities/differences in the three facilities included in this study are as follows:
 - One facility was part of the healthcare sector, one facility was a higher education university, and the final facility was a K-12 school district
 - The healthcare facility, Albany Medical Center, by virtue of its sector and overall age, had more modern and healthcare specific HVAC equipment (i.e. higher MERV filters and humidification systems) than the two other facilities.
 - The higher education university had much older infrastructure and HVAC systems than the other two facilities.
 - The K-12 school district, North Colonie School District, and the Higher Education University, being that there were multiple buildings of varying vintages in each study, had a variety of HVAC systems and complexities whereas the healthcare facility was relatively contained to two buildings of similar HVAC complexities.
 - The healthcare facility study included a lab/research building and therefore its HVAC system contained mostly 100% outdoor air units.

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