FLEXTECH
ENERGY EFFICIENT INDOOR AIR QUALITY STUDY

FINAL CONCLUSIONS REPORT

For

EMCOR Services Betlem

New York State Energy Research and Development Authority
17 Columbia Circle
Albany, New York 12203-6399

Date: November 1, 2021

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	• 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)

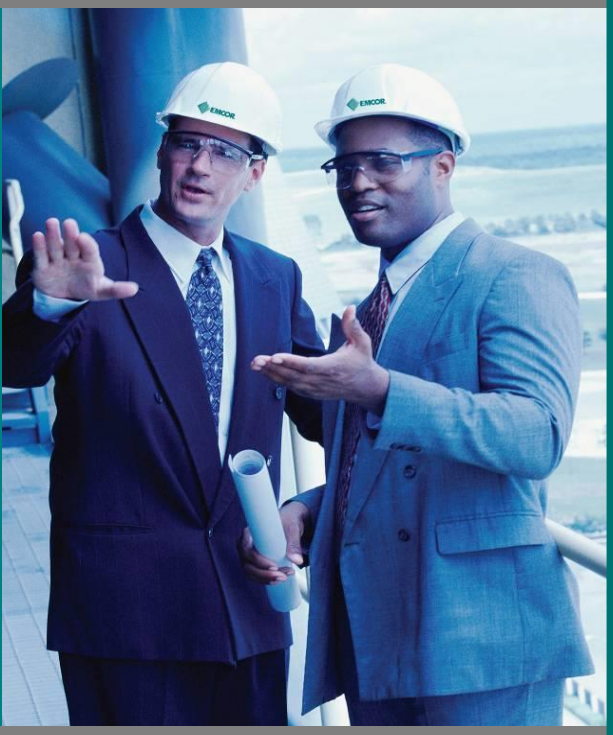
Energy Efficient measures include Ultraviolet Germicidal Irradiation (UVGI), air filtration strategies, and building operation optimization solutions that perform equally on the basis of COVID-19 risk of infection to the ASHRAE guidance package of measures

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.

EMCOR Services Betlem



NYSERDA FlexTech Indoor Air Quality Energy Studies

IAQ Study Conclusion Report

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May 25, 2021

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Preface

During the onset of the COVID-19 pandemic, many organizations and businesses which were considered non-essential were forced to shut down and/or move to remote activities. As case numbers stabilized in New York State, these businesses and organizations slowly reopened either to full occupancy with new restrictions, or reduced occupancy. As the reopening process began to unfold, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) began releasing guidelines and best practices for reopening facilities safely. These guidelines and recommendations included recommended changes to facility and HVAC controls, HVAC operating conditions, and equipment and materials to implement to help mitigate the spread of the SARS-CoV-2 virus.

While the ASHRAE recommendations were intended to maximize the fight against the spread of the SARS-CoV-2 virus within facilities, they were made with little regard to energy efficiency. To address this, the New York State Energy Research and Development Authority (NYSERDA) contracted consultants, including EMCOR Services Betlem (EMCOR), across the state via a FlexTech mini-bid to investigate energy efficient solutions. The five energy studies completed by EMCOR were intended to understand the energy impact of ASHRAE's primary re-opening guidelines and determine if different equipment and materials could act as suitable energy savings measures (ECMs) while as effectively, or more effectively fighting the SAR-CoV-2 virus.

EMCOR Services Betlem (EMCOR) prepared this report for NYSERDA as the final deliverable of the FlexTech Indoor Air Quality (IAQ) energy studies completed in upstate NY. EMCOR's Energy Engineers who worked on this project are Cody Jones, Jonathan Suhre, and Christopher Ward. The energy savings calculations within this report were reviewed for technical quality by Bill Coe as well as NYSERDA's third party technical reviewers.

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Disclaimer

The recommendations and findings in this report are for informational purposes only and are not intended to represent fully engineered designs that are satisfactory for construction. EMCOR recommends that each of the measures identified in this report be fully designed and reviewed by a competent professional prior to implementation to ensure compliance with all applicable federal, state, and local codes. EMCOR makes no representation that the use of any product, apparatus, process, method, or other information will not infringe privately-owned rights and will assume no responsibility for any loss, injury, or damage resulting from, or occurring in connection with, the use of information contained, described, disclosed, or referred to in this report. Additionally, EMCOR makes no claims as to the efficacy of any of the evaluated projects in inactivating or eliminating the SARS-CoV-2 virus, or to the acceptable level of occupancy or activity in the facility by implementing any of the evaluated projects.

1.0 Study Approach

Research Conducted

ASHRAE guidelines vary based on which facility type is being analyzed. The studies performed by EMCOR include commercial facilities such as the museum and planetarium at Rochester Museum and Science Center (RMSC) and Webster Ice Arena as well as schools & universities such as Genesee Community Charter School (GCCS) and Finger Lakes Community College (FLCC). To determine the appropriate guidelines for each of the facility types, the ASHRAE Epidemic Task Force reopening guides for both types of facilities were reviewed. Following the identification of the appropriate measures, an energy analysis was completed to determine the impact these measures would have on their respective buildings.

Implementation of upper and system-level UVGI is intended to be an alternative to fully implementing the ASHRAE recommendations as they may result in substantial increases in facility energy use. The methodology used to determine the energy savings capabilities of UVGI systems was derived from the publication, *Guidelines for the Application of Upper-Room Ultraviolet Germicidal Irradiation for Prevention Transmission of Airborne Contagion*. This methodology allows for the effectiveness of upper-air UVGI systems in controlling pathogen spread to be compared to typical HVAC control methods through dilution ventilation. The publication provides a formula to determine equivalent air changes per hour (EAC) based on the specific virus that is being designed for, the irradiance of the UVGI system, and the exposure time of the pathogen to the UV light. The formula is as follows:

$$EAC = -\ln\frac{N_s}{N_o} = KIt$$

The authors define EAC as the number of air changes provided by mechanical ventilation in a well-mixed room that would be required to reduce the number of viable airborne bacteria to the same degree as the UV irradiation alone. The formula takes the average UVGI dose (*It* = Irradiance x Exposure Time) and multiplies it by a *K* value which represents the inactivation rate and is pathogen-specific (First, 1999). For the purposes of the ECM calculations, air circulating in each case is perfectly mixed. Also, *K* for SARS-CoV-2 was assumed to be the same as the alpha coronavirus HCoV-229E *K* value of 0.0041 $cm^2/\mu W\text{-sec}$.

To determine if the traits of coronaviruses that have extensively studied apply to SARS-CoV-2, further research was done. According to the publication, *Far-UVC light (222 nm) efficiently and safely inactivates airborne human coronavirus*, "all human coronaviruses have similar genomic sizes" so "far-UVC light would be expected to show similar inactivation efficiency against other human coronaviruses including SARS-CoV-2" (Buananno, 2020). Therefore, it was assumed that the EAC methodology developed for this study also applied to SARS-CoV-2.

For FLCC, Webster Ice, the RMSC Planetarium, and GCCS additional research was done to determine the impacts of installing the specific upper-level UVGI units. The product that was selected as the basis of design for this ECM is called VidaShield and is sold by a company called Medical Illumination. They provide a white paper on the VidaShield website on the performance of the VidaShield system, written by Dr. Wladyslaw J. Kowalski. The white paper details information on disinfection rates for various pathogens that were used in the EAC equation that was previously developed. Due to the enclosed irradiation

chamber with reflective interior, it was discovered that the VidaShield can provide a continuous UV dosage to 50 CFM of airflow per unit. Based on the parameters of the EAC equation above, the eACH (equivalent air changes per hour) can be greater than the actual ACH seen within the space the UVGI is applied. The Vidashield can provide 80 eACH to the continuous volume of air circulated through the unit. In this analysis, EMCOR generally selected the quantity of VidaShield units to achieve a minimum of 1 ACH per room. Looking back at the publication, *Guidelines for the Application of Upper-Room Ultraviolet Germicidal Irradiation for Prevention Transmission of Airborne Contagion*, an EAC of 20 eACH or higher for a properly designed upper air UVGI system is not uncommon and shows the effectiveness of upper-air UVGI in inactivating pathogens when compared to standard dilution ventilation methods on their own.

Approach

In addition to site visits and facility drawing reviews, EMCOR analyzed each facilities building management system (BMS) to extract logged data for varying time periods depending on system capabilities. The RMSC Museum and GCCS both had limited BMS access which resulted in the utilization of design data in energy savings calculations. This data was then utilized after a thorough review of the ASHRAE reopening guidelines for commercial and school/university facilities that was used to compile a list of measures and potential ECMs, further referred to as "ASHRAE Safe Operation Baseline." From this documentation the following list of ASHRAE recommendations were analyzed as part of this study:

- Implement a (2) hour pre and post-occupancy flush period (all)
- Increase outdoor air levels to maximum levels
- Run bathroom exhaust fans 24/7 (excludes the RMSC Museum and Webster Ice)
- Open VAVs to 100% when their respective AHU is 100% economizing (FLCC and RMSC Planetarium)
- Maintain space relative humidity at 40%-60% (excludes RMSC Museum)
- Install MERV 13 filters (excludes RMSC Museum)
- Install portable HEPA air cleaners in common areas
- Disable demand control ventilation (Webster Ice)
- UVGI applications in RTUs and AHUs

The ECMs identified for these studies consisted of the utilization of UVGI to improve the system's ability to mitigate the effects of the SARS-CoV-2 pathogen. The UVGI increases the ability of the system to "clean" the air supplied to the space and thus allows for the ASHRAE measures to be rolled back. The energy impacts of each measure were determined utilizing custom spreadsheet calculations for each ECM and ASHRAE Safe Operation Baseline Measure. These were based on equipment nameplate and design information, trend data downloaded from the BMS, utility information, and comments and reports from facility personnel. Weather-dependent applications were evaluated utilizing TMY3 weather data for Rochester, NY.

The baseline case for each system was established using the operational data taken prior to any changes resulting from the onset of the COVID-19 pandemic. From there, the projected utility usage associated with each ASHRAE measure was estimated by determining the impact of each measure on the baseline usage. This included the increased conditioning requirements as well as fan energy required to meet these recommendations. Evaluating these measures utilizing code-minimum requirements was not performed as part of this study. This was due to the substantial capital investments required for facilities that do not currently meet code minimum for outdoor air. Several assumptions were utilized within the calculations

including those pertaining to equipment operational data that could not be determined from design or nameplate data, impacts of dirty filters on the implementation of MERV 13 filters, UVGI equipment operation and impacts on the SARS-CoV-2 pathogen, heating and cooling setpoints and return temperatures, and economizer operation.

All ASHRAE safe operation recommendations result in an increase in facility energy use. By implementing UVGI, there is a chance that some of the ASHRAE measures can be rolled back in their implementation due to added benefit in fighting the virus brought about by UVGI. To determine this potential for energy use reduction, EMCOR developed an effective air changes per hour (EAC) to utilize for the ECMs included in this study. It should be noted that detailed designs of UVGI systems were beyond the scope of this study and EMCOR makes no claims on the efficacy of the systems in eliminating the SARS-CoV-2 virus. EMCOR recommends that all customers consult a UVGI professional for a detailed space-by-space design before purchasing and installing an upper-air UVGI system.

The calculated energy impact for both ASHRAE measures and ECMs was converted to cost impact using historical utility blended rates. Cost estimates were developed for each project to evaluate financial metrics such as simple payback, and pricing was developed using a combination of quoted equipment and RS Means pricing and labor rates. Estimates did not carry contingencies and it is recommended to carry contingencies when budgeting for implementation.

2.0 Overall Findings

Please refer to Appendix A for overall and measure-level findings.

3.0 Study Comparisons

EMCOR investigated a variety of ASHRAE Safe Operation recommendations including implementation of a flush cycle, utilization of 100% outdoor air during occupied hours, installation of MERV 13 filters, running the exhaust fans 24/7, maintaining humidity at 40%-60% during the winter, setting VAVs to max settings when economizing, and implementation of HEPA air cleaners. Many of these measures resulted in an increase in utility usage associated with the increase in fan power as well as space conditioning requirements. The only instances of minimal utility impacts and/or savings were in locations where the ASHRAE recommendations resulted in a reduction in fan operation or air handling units were already running near capacity.

Despite their increase in utility usage, many of these measures have minimal implementation costs as they are simply control changes. This provides a cost-effective methodology to directly increase indoor air quality and occupant safety with minimal investment by increasing outdoor air levels. The measures that were not recommended, such as maintaining humidity at 40%-60% and implementation of HEPA air cleaners at the planetarium, required substantial capital investment. Facilities should therefore only consider these measures if they already monitor and control humidity, resulting in minimal implementation costs, or do not currently meet code requirements for ventilation.

To limit the energy usage cost of the ASHRAE Safe Operation measures, EMCOR investigated the impact of ultraviolet germicidal radiation via installation within air handling equipment (system level) and ceiling-mounted upper-level units. Research into the “air-cleaning” efficacy of the UVGI units yielded that the technology has the capacity to deactivate similar coronaviruses leading to an “effective air change”. This allows for the outdoor air levels within the ASHRAE measures to be rolled back resulting in a reduction in utility usage. This then results in various recommendations of UVGI ECMs throughout the facilities included in this project. Should savings resulting from the reduced space conditioning requirements be greater than the utility cost to operate the system, the measure was recommended. However, there are several measures within the (4) work plans that this is not the case and are thus not recommended.

Commonalities and Differences Between Studies

As each study was completed, it became clear that there was a predominant theme in the results of the analyses performed of UVGI systems as energy conservation measures. This common theme was that UVGI technologies would tend to increase annual operating costs versus the ASHRAE Safe Operation measures, even when UVGI provided an energy savings over said measures. This is due to the annual maintenance requirements of UVGI systems, which includes lamp replacements and the labor to complete them once annually. Due to the high material costs of the annual maintenance packages for these systems, the energy cost savings was, in most cases, outweighed by the maintenance cost incurred. This is an unfortunate reality of this technology that makes recommending it difficult to justify in most cases. With that said, two specific ECMs did result in a net annual cost savings: GCCS ECM-1 and RMSC Museum ECM-2b. For GCCS, the savings resulted from the utilization of in-duct UVGI that is installed directly within the supply ducts of the Sterling unit as it doesn’t have a cooling coil. This difference in technology was determined by the manufacturer, UV Resources, to have a significantly higher dosage than units installed on the cooling coil. This results in significantly higher effective air changes per hour leading to significant energy savings due to the reduction in required outdoor air. ECM-2b for RMSC Museum resulted in a net

annual savings due to the significant decrease in outdoor air with UVGI installed to meet a minimum eACH of 3 or greater and allowed to roll back the flush period time.

The other primary commonality between the studies was that UVGI tended to be an energy savings measure versus the ASHRAE Safe Operation measures. There were only two instances where this was not the case and energy use were projected to increase with UVGI: RMSC Museum ECM-2c and FLCC ECM-2/5. In the case of FLCC, this appeared to be due to the UVGI systems were sized for the peak airflow of each AHU, but many AHUs at FLCC were already operating below design airflow levels due to the systems being oversized. Without any "turn-down" capabilities in the UVGI system, the energy impact of running UVGI outweighed the savings of reducing outdoor airflow through those AHUs. In the case of RMSC Museum ECM 2c, the UVGI is proposed to be installed within a system that has no outdoor air ventilation. The energy increases due to the operating costs of the UVGI system.

Regarding the ASHRAE Safe Operation measures, the most energy intensive ASHRAE recommendations were, predictably, the recommendations that increased outdoor airflows. This proved to be true across all five studies and illustrates just how energy intensive it is to condition outdoor air. A close second to the outdoor air measures were the portable HEPA air cleaner measures, which not only had a significant annual energy impact, but also incurred a substantial upfront installation cost. Conversely, the ASHRAE recommendations that typically had the smallest energy impact were the running of bathroom exhaust systems 24/7 and the implementation of MERV 13 filters. The results for the MERV 13 filter recommendations are potentially the most encouraging because improved filtration has been shown to have a substantial effect on indoor air quality and with the low energy cost impact, there is unlikely to be a noticeable operating cost impact from implementing this recommendation. The initial pressure drop of many MERV 13 filters turned out to be only modestly higher than comparable MERV 8 filters in these scenarios, making them a worthwhile recommendation.

4.0 Overarching Takeaways

The NYSERDA IAQ Study gave EMCOR and their customers insight on the reported effectiveness and energy/cost impact of improving indoor air quality. Based on the studies the following are takeaways that were observed.

- Increasing filtration is number one priority when improving indoor air quality. Filters throughout a HVAC system captures unwanted airborne particles. It is suggested that air distribution systems use MERV 13 filters, if able. MERV 13 filters are more effective than the standard MERV 8 or MERV 10 filters in capturing airborne particles 0.3-1 microns in size. Due to the relatively low cost, changing filters to MERV 13 or greater is the highest priority when improving indoor air quality.
- UVGI can be used to improve the indoor air quality in under ventilated areas. Under ventilated areas/systems are an issue when trying to improve indoor air quality. Increasing outdoor air may not be possible and a new makeup air system, or additional capacity will have to be implemented, creating a capital investment. UVGI can clean the air to provide an equivalent air change within the dedicated space. UVGI is typically a cheaper alternative than installing a new outdoor air system to provide increase ventilation.
- When looking to implement UVGI, zoned air handler systems, such as VAV systems should consider using in-unit UVGI systems within the air handler. This is a central point for all their dedicated zones and allows for a single UVGI system to be installed to take care of multiple areas. This in combination with additional upper-air UVGI in larger occupied areas, such as an open office space, lecture hall, or auditorium, allows for large coverage throughout a ventilation system with a smaller amount of UVGI systems.
- Consider UVGI maintenance costs when evaluating viability of the system. UVGI systems require an annual lamp replacement. Most UV lamps start to lose effectiveness after about a year of operation (8,000-10,000 hours of operation), therefore it is recommended that the lamps are replaced each year. Depending on the system and configuration, maintenance costs may diminish the net cost impact of decreasing outdoor air flow with installing UVGI.

5.0 Works Cited

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Appendix A: Project Summary List

EMCOR Baseline Data

WP#	Building	Pre-Covid Baseline									
		Energy Use Impact			Total Suppy Air CFM	CFM Outside Air	Air Changes OA	Energy Cost Impact			
		kWh	kW	MMBtu				kWh	kW	MMBtu	
WP-01	Museum - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14607	1,653,998.00	N/A	1,896.50	27195	4533	0.5	$ 159,797.00	N/A	$ 10,245.00	
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14607	370,080.00	128	1,923.50	20800	6255	1.67	$ 43,942.87	N/A	$ 10,834.72	
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	5,495,928.00	N/A	15,157.00	199772	140,466 peak 85,384 avg	1.68	$ 501,364.00	N/A	$ 59,746.00	
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY 14607	376,320.00	146.4	2,572.00	25933	1103	0.3	$ 44,827.96	N/A	$ 13,538.58	
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	986,619.00	N/A	5,881.00	20425	7,544 peak 5,998 avg	0.5	$ 91,711.00	N/A	$ 27,793.00	

WP#	Building	ASHRAE Measures Baseline									
		Energy Use Impact				CFM Outside Air	eACH	Energy Cost Impact			
		Measures Included	kWh	kW	MMBtu			kWh	kW	MMBtu	Implementation Cost
WP-01	Museum - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14607	2 hr. purge, Max OA, Portable HEPA	1,731,010.00	N/A	2,773.90	18660	2.76	$ 167,388.67	N/A	$ 14,979.06	$ 25,000.00
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14607	2 hr. purge, Max OA, MERV 13, Exhaust 24/7, Max VAV OA	442,950.00	-8.6	2,176.80	13401.19	3.7	$ 52,595.41	N/A	$ 12,261.40	$ 129,509.22
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	2 hr. purge, Max OA, Bathroom exhaust 24/7, Max VAV OA, Humidification, MERV 13, Portable HEPA	6,030,934.00	N/A	32,400.90	191,997 peak 178,209 avg	3.5	$ 550,169.00	N/A	$ 127,719.00	$ 856,090.00
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY 14607	2 hr. purge, Max OA, Bathroom exhaust 24/7, MERV 13	464,871.00	-13	2,171.60	7312	1.8	$ 55,376.32	N/A	$ 24,968.65	$ 242,809.00
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	2 hr. purge, Max OA, Disable DCV, Humidification, MERV 13, Portable HEPA	1,062,242.00	N/A	7,046.00	20,425 peak 17,840 avg	1.46	$ 98,788.51	N/A	$ 33,327.58	$ 65,190.00

WP#	Building	Energy Efficiency Measures Baseline										
		Energy Use Impact				CFM Outside Air	eACH	Energy Cost Impact				Notes
		Measures Included	kWh	kW	MMBtu			kWh	kW	MMBtu	Implementation Cost	
WP-01	Museum - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14607	UVGI	1,726,233.00	0	2,310.80	11180	2.72	$ 166,926.73	0	$ 12,478.32	$ 16,956.00	ASHRAE package - additional $613.33 maintenance costs EE package - additional $4,382 maintenance costs
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14607	None	442,950.00	-8.6	2,176.80	13401.19	3.7	$ 52,595.41	N/A	$ 12,261.40	$ 129,509.22	ASHRAE package - additional $183.78 maintenance costs, only recommended measures are included
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	None	6,030,934.00	N/A	32,400.90	183,017 peak 173,011 avg	3.39	$ 550,169.00	N/A	$ 127,719.00	$ 856,090.00	ASHRAE package - additional $6,704 maintenance costs
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY 14607	None	464,871.00	-13	2,171.60	1.8	1.8	$ 55,376.32	N/A	$ 24,968.65	$ 242,809.00	ASHRAE package - additional $421.18 maintenance costs
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	UVGI	1,062,242.00	N/A	7,046.00	16,897 peak 14,757 avg	1.21	$ 98,788.51	N/A	$ 33,327.58	$ 65,190.00	ASHRAE package - additional $3,435 maintenance costs EE package - additional $6,139 maintenance costs

WP-01 RMSC Museum Measure–Level Data

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
WP-01	Museum - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14607	ASHRAE Operational Guidance - Flush Cycle	Ventilation	Institute 2 hr. Building Air Flush	Central System	ASHRAE	Yes	N/A	Yes	N/A	ME	N/A	N/A
WP-01	Museum - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14608	ASHRAE Operational Guidance - 100% OA during Occupied Hours	Ventilation	Increased OA%	Central System	ASHRAE	Yes	N/A	Yes	N/A	ME	N/A	N/A
WP-01	Museum - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14609	Install HEPA Filters in SAF-1 and SAF-2 Common Areas	Filtration	HEPA Filtration	Local In-Room	ASHRAE	Yes	N/A	Yes	N/A	ME	N/A	N/A
WP-01	Museum - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14610	Install In-Duct UVGI on SAF-1 and SAF-2 Heat Pumps and Back off Purge	UVGI	In-Return Duct UVGI	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	R	N/A	UV Resources X-Plus Side Mount UVG
WP-01	Museum - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14611	Install UVGI on RTUS 1-5 and Back off Purge	UVGI	In-AHU UVGI	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	R	N/A	UV Resources X-Plus Side Mount UVG
WP-01	Museum - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14612	Install UVGI on SAF-4 Heat Pumps	UVGI	In-AHU UVGI	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	R	N/A	UV Resources X-Plus Side Mount UVG

WP#	Building Name and Address, Campus or Complex	Measure Description	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-01	Museum - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14607	ASHRAE Operational Guidance - Flush Cycle	N/A	N/A	ASHRAE Guidelines	18,660	10,617	0	114	-$1,025.75	$0.00	-$616.37	$1,642.12	$0.00	$0.00	
WP-01	Museum - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14608	ASHRAE Operational Guidance - 100% OA during Occupied Hours	N/A	N/A	ASHRAE Guidelines	18,660	29,797	0	763	-$2,878.79	$0.00	-$4,123.35	$7,002.13	$0.00	$0.00	
WP-01	Museum - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14609	Install HEPA Filters in SAF-1 and SAF-2 Common Areas	1.88	N/A	ASHRAE Guidelines	N/A	36,598	0	0	-$3,535.79	$0.00	$0.00	$3,535.79	$613.33	$25,000.00	
WP-01	Museum - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14610	Install In-Duct UVGI on SAF-1 and SAF-2 Heat Pumps and Back off Purge	2.47	N/A	UVGI Design Approach by First, Nardell, Chaisson, and Riley	8,010	4,094	0	0	$395.54	$0.00	$0.00	$1,139.13	$1,534.67	$4,766.00	
WP-01	Museum - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14611	Install UVGI on RTUS 1-5 and Back off Purge	2.18	N/A	UVGI Design Approach by First, Nardell, Chaisson, and Riley	6,094	-3,302	0	-463	$319.05	$0.00	$2,501.46	-$1,660.09	$1,160.42	$4,742.00	
WP-01	Museum - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14612	Install UVGI on SAF-4 Heat Pumps	1.64	N/A	UVGI Design Approach by First, Nardell, Chaisson, and Riley	0	2,619	0	0	-$253.05	$0.00	$0.00	$1,940.69	$1,687.64	$7,448.00	

WP-01 RMSC Planetarium Measure–Level Data

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
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14607	ASHRAE Operational Guidance - Flush Cycle	Ventilation	Institute 2 hr. Building Air Flush	Central System	ASHRAE	Yes	N/A	Yes	N/A	R	N/A	N/A
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14607	ASHRAE Operational Guidance - 100% OA during Occupied Hours	Ventilation	Increased OA%	Central System	ASHRAE	Yes	N/A	Yes	N/A	R	N/A	N/A
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14608	ASHRAE Operational Guidance - MERV 13 Installation AHUs 5-7	Filtration	Increased MERV rating	Central System	ASHRAE	Yes	N/A	Yes	N/A	R	N/A	N/A
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14608	ASHRAE Operational Guidance - Run Exhaust fans 24/7	Ventilation	Exhaust System	Central System	ASHRAE	Yes	N/A	Yes	N/A	R	N/A	N/A
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14608	ASHRAE Operational Guidance - Maintain Humidity at 40%-60%	Humidifcation	Increased RH	Central System	ASHRAE	Yes	N/A	Yes	N/A	NR	Implementation costs	Condair HPRO100 humidifier
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14608	ASHRAE Operational Guidance - Set VAVs to Max settings when economizing	Ventilation	Increased OA%	Central System	ASHRAE	Yes	N/A	Yes	N/A	R	N/A	N/A
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14608	ASHRAE Operational Guidance - Install HEPA filter in area served by AHU-5	Filtration	HEPA Filtration	Local In-Room	ASHRAE	Yes	N/A	Yes	N/A	NR	Increased energy usage	Carrier OptiClean air scrubber
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14608	Implement In-Duct UVGI	UVGI	In-Return Duct UVGI	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	NR	Increased energy usage and maintenance cost	Steril Aire Rapid Install Kit (RIK) UVGI fixtures
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14608	Implement Upper-level UVGI on AHU-3	UVGI	Upper Room UVGI	Local In-Room	Energy Efficiency	Yes	N/A	Yes	N/A	NR	Higher maintenance cost than portable HEPA filter, requires further studies	Medical Illumination's VidaShield all-in-one light fixture/UV-C irradiation chamber with built-in fance and a MERV 6 filter to pull 50 CFM of room air at all times
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14608	Replace HEPA Filters with Upper-level UVGI	UVGI	Upper Room UVGI	Local In-Room	Energy Efficiency	Yes	N/A	Yes	N/A	NR	Higher maintenance cost than portable HEPA filter, requires further studies	Medical Illumination's VidaShield all-in-one light fixture/UV-C irradiation chamber with built-in fance and a MERV 6 filter to pull 50 CFM of room air at all times

WP#	Building Name and Address, Campus or Complex	Measure Description	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-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14607	ASHRAE Operational Guidance - Flush Cycle	N/A	N/A	maakes sense	13399.72	-29,697	0	144	-$3,526.19	N/A	-$812.08	-$4,338.27	$0.00	$300.00	
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14607	ASHRAE Operational Guidance - 100% OA during Occupied Hours	1.8	N/A	ASHRAE Guidelines	13399.72	-2,988	0	109	-$354.79	N/A	-$614.59	-$969.38	$0.00	$300.00	
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14608	ASHRAE Operational Guidance - MERV 13 Installation AHUs 5-7	N/A	N/A	ASHRAE Guidelines	N/A	-2,325	-1	0	-$276.07	N/A	$0.00	-$276.07	-$184.22	$184.00	
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14608	ASHRAE Operational Guidance - Run Exhaust fans 24/7	N/A	N/A	ASHRAE Guidelines	N/A	-3,651	0	0	-$433.52	N/A	$0.00	-$433.52	$0.00	$300.00	
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14608	ASHRAE Operational Guidance - Maintain Humidity at 40%-60%	N/A	N/A	ASHRAE Guidelines	N/A	-228	0	0	-$27.07	N/A	$0.00	-$27.07	$0.00	$108,125.00	
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14608	ASHRAE Operational Guidance - Set VAVs to Max settings when economizing	N/A	N/A	ASHRAE Guidelines	N/A	-11,557	-3	0	-$1,372.26	N/A	$0.00	-$1,372.26	$0.00	$300.00	
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14608	ASHRAE Operational Guidance - Install HEPA filter in area served by AHU-5	2	N/A	ASHRAE Guidelines	N/A	-22,424	-6	0	-$2,662.64	N/A	$0.00	-$2,662.64	-$368.00	$20,000.00	
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14608	Implement In-Duct UVGI	0.5	N/A	UVGI Design Approach by First, Nardell, Chaisson, and Riley	6578	-2,516	2	213	-$299.75	N/A	$1,197.70	$897.95	-$1,292.67	$7,442.00	
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14608	Implement Upper-level UVGI on AHU-3	1	N/A	UVGI Design Approach by First, Nardell, Chaisson, and Riley	1783.4	457	3	46	$54.26	N/A	$257.54	$311.80	-$3,455.56	$31,989.00	
WP-01	Planetarium - Rochester Museum and Science Center 663 East Avenue, Rochester, NY 14608	Replace HEPA Filters with Upper-level UVGI	1	N/A	ASHRAE Guidelines	N/A	7,469	4	0	$886.90	N/A	$0.00	$886.90	-$1,727.78	$42,383.00	

WP-02 FLCC Measure–Level Data

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
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Run AHUs 2 hours before and after occupancy	Ventilation	Institute 2 hr. Building Air Flush	Central System	ASHRAE	Yes	N/A	Yes	N/A	R	N/A	N/A
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Increase outdoor air levels to maximum possible	Ventilation	Increased OA%	Central System	ASHRAE	Yes	N/A	Yes	N/A	RME	N/A	N/A
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Run bathroom exhaust fans 24/7	Ventilation	Exhaust System	Central System	ASHRAE	Yes	N/A	Yes	N/A	R	N/A	N/A
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Open VAVs to 100% when AHU is 100% economizing	Ventilation	Increased OA%	Central System	ASHRAE	Yes	N/A	Yes	N/A	R	N/A	N/A
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Maintain space relative humidity at 40%-60% year round	Humidifcation	Increased RH	Central System	ASHRAE	No	Not feasible for immediate implementation, Requires further study	Yes	N/A	NR	Further study required to confirm that building envelope can handle increased humidity, other systems may have much steeper energy impacts	Condair high-pressure pumped humidification product
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Install MERV-13 filters in HVU-01 and HVU-02 (Gym)	Filtration	Increased MERV rating	Central System	ASHRAE	Yes	N/A	Yes	N/A	RNE	N/A	MERV-13 basis of design is not defined in repot
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Install portable HEPA filtration units in classrooms	Filtration	HEPA Filtration	Local In-Room	ASHRAE	Yes	N/A	Yes	N/A	RME	N/A	Carrier OptiClean air scrubber
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Install upper-air UVGI in classrooms	UVGI	Upper Room UVGI	Local In-Room	Energy Efficiency	Yes	N/A	Yes	N/A	NR	Higher maintenance cost than portable HEPA filter, requires further studies	Medical Illumination's VidaShield all-in-one light fixture/UV-C irradiation chamber with built-in fance and a MERV 6 filter to pull 50 CFM of room air at all times
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Install upper-air UVGI throughout building	UVGI	Upper Room UVGI	Local In-Room	Energy Efficiency	Yes	N/A	Yes	N/A	NR	Higher maintenance cost than portable HEPA filter, requires further studies	Medical Illumination's VidaShield all-in-one light fixture/UV-C irradiation chamber with built-in fance and a MERV 6 filter to pull 50 CFM of room air at all times
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Install AHU-level UVGI	UVGI	In-AHU UVGI	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	NR	High maintenance costs, not justified based on ROI. Requires further consideration as capital project for increased indoor air safety.	Steril Aire Rapid Install Kit (RIK) UVGI fixtures
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Roll back portable HEPA Air Cleaners due to upper room UVGI installation	Filtration	HEPA Filtration	Local In-Room	Energy Efficiency	Yes	N/A	Yes	N/A	ME	High maintenance costs, not justified based on ROI. Requires further consideration as capital project for increased indoor air safety.	N/A
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Roll back maximum OA levels to pre-pandemic operation due to upper room UVGI installation	Ventilation	Reduced OA%	Central System	Energy Efficiency	No	Cannot roll back AHU operation since no single AHU serves classrooms alone	Yes	N/A	ME	Cannot roll back AHU operation since no single AHU serves classrooms alone	N/A
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Roll back maximum OA levels by 0.5 ACH due to AHU-Level UVGI	Ventilation	Reduced OA%	Central System	Energy Efficiency	No	Cannot roll back AHU operation since no single AHU serves classrooms alone	Yes	N/A	ME	Cannot roll back AHU operation since no single AHU serves classrooms alone	N/A

WP#	Building Name and Address, Campus or Complex	Measure Description	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	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Run AHUs 2 hours before and after occupancy	N/A	N/A	ASHRAE Guidelines	140,466 peak	-165,750	0	-1,304	$15,083.25	N/A	$5,177.75	$20,261.00	$0.00	$600.00	Half a day's work for a controls technician to modify the equipment scheduling at the BMS
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Increase outdoor air levels to maximum possible	N/A	N/A	ASHRAE Guidelines	191,997 peak	-79,242	-233	-15,911	$7,211.02	N/A	$62,735.98	$69,947.00	$0.00	$9,300.00	Controls technician to reprogram outdoor air control for all AHUs to increase OA to the max permitted by coil capacities
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Run bathroom exhaust fans 24/7	N/A	N/A	ASHRAE Guidelines	N/A	-1,370	0	0	$125.00	N/A	$0.00	$125.00	$0.00	$600.00	Half a day's work for a controls technician to modify the equipment scheduling at the BMS
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Open VAVs to 100% when AHU is 100% economizing	N/A	N/A	ASHRAE Guidelines	152,676 peak	-51,792	-17	-29	$4,713.07	N/A	$124.93	$4,838.00	$0.00	$1,200.00	A day of work for a controls technician to modify programming at the BMS for the relevant AHUs
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Maintain space relative humidity at 40%-60% year round	N/A	N/A	ASHRAE Guidelines	140,466 peak	-15,827	-7	0	$1,444.00	N/A	$0.00	$1,444.00	$0.00	$648,750.00	Installation of a high-pressure pumped humidification system, with high pressure pump skids, distribution piping, and AHU-mounted dispersion units
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Install MERV-13 filters in HVU-01 and HVU-02 (Gym)	N/A	N/A	ASHRAE Guidelines	140,466 peak	-1,439	-1	0	$131.00	N/A	$0.00	$131.00	$1,920.00	$640.00	Material cost of the MERV-13 filters and the labor for an HVAC technician to replace the filters
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Install portable HEPA filtration units in classrooms	2	N/A	ASHRAE Guidelines	N/A	-219,586	-91	0	$20,032.00	N/A	$0.00	$20,032.00	$4,784.00	$195,000.00	Purchase 78 air cleaners
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Install upper-air UVGI in classrooms	2	N/A	UVGI Design Approach by First, Nardell, Chaisson, and Riley	N/A	115,362	13	0	$10,524.00	N/A	$0.00	$10,524.00	$45,943.00	$327,900.00	Purchase 205 VidaShield units and 2 hours of installation time/unit for an electrician
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Install upper-air UVGI throughout building	2	N/A	UVGI Design Approach by First, Nardell, Chaisson, and Riley	N/A	573,579	65	0	$52,325.00	N/A	$0.00	$52,325.00	$228,430.00	$1,630,300.00	
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Install AHU-level UVGI	0.5	N/A	UVGI Design Approach by First, Nardell, Chaisson, and Riley	183,017 peak	129,403	15	0	$11,805.00	N/A	$0.00	$11,805.00	$32,748.00	$111,300.00	Steril Aire UVGI equipment and 4 hours of labor for every 4 lamps installed
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Roll back portable HEPA Air Cleaners due to upper room UVGI installation	N/A	N/A	ASHRAE Guidelines	N/A	-219,586	-91	0	-$20,032.00	N/A	$0.00	-$20,032.00	-$24,816.00	-$195,000.00	Steril Aire UVGI equipment and 4 hours of labor for every 4 lamps installed
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Roll back maximum OA levels to pre-pandemic operation due to upper room UVGI installation	N/A	N/A	ASHRAE Guidelines	N/A	-79,242	-233	-15,911	-$7,211.02	N/A	-$62,735.98	-$69,947.00	-$69,947.00	-$9,300.00	
WP-02	Finger Lakes Community College 3325 Marvin Sands Drive, Canandaigua, NY 14424	Roll back maximum OA levels by 0.5 ACH due to AHU-Level UVGI	N/A	N/A	ASHRAE Guidelines	N/A	-6,572	-17	-1,380	-$598.05	N/A	-$5,438.95	-$6,037.00	-$6,037.00	$0.00	

WP-03 GCCS Measure–Level Data

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
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY 14607	Upgrading MERV 8 filters to MERV 13	Filtration	Increased MERV rating	Central System	ASHRAE	Yes	N/A	Yes	N/A	R	N/A	MERV-13 basis of design is not defined in repot
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY 14607	Flush Cycle	Ventilation	Institute 2 hr. Building Air Flush	Central System	ASHRAE	Yes	N/A	Yes	N/A	R	N/A	N/A
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY 14607	100% OA during Occupied Hours	Ventilation	Increased OA%	Central System	ASHRAE	Yes	N/A	Yes	N/A	R	N/A	N/A
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY 14607	Run Bathroom Exhaust fans 100%	Ventilation	Exhaust System	Central System	ASHRAE	Yes	N/A	Yes	N/A	R	N/A	N/A
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY 14607	Maintain Humidity at 40%-60%	Humidifcation	Increased RH	Local In-Room	ASHRAE	Yes	N/A	Yes	N/A	NR	Risk for humidification to generate condensation that can negatively impact building envelope and indoor air quality.	No indication of model of humidification equipment.
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY	Install HEPA filters in all classrooms	Filtration	HEPA Filtration	Local In-Room	ASHRAE	Yes	N/A	Yes	N/A	NR	Implementation costs	Carrier OptiClean air scrubber
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY 14607	Implementation of In-Duct UVGI	UVGI	In-Return Duct UVGI	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	NR	High maintenance costs, not justified based on ROI. Requires further consideration as capital project for increased indoor air safety.	Steril Aire Rapid Install Kit (RIK) UVGI fixtures
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY 14607	Reduce OA levels for all AHUs as a result of Implementing In-Duct UVGI	Ventilation	Reduced OA%	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	NR	High maintenance costs, not justified based on ROI. Requires further consideration as capital project for increased indoor air safety.	NR
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY 14607	Implementation of Upper-level UVGI	UVGI	Upper Room UVGI	Local In-Room	Energy Efficiency	Yes	N/A	Yes	N/A	NR	Higher maintenance costs than portable HEPA filter, requires further studies for capital improvement	Medical Illumination's VidaShield all-in-one light fixture/UV-C irradiation chamber with built-in fance and a MERV 6 filter to pull 50 CFM of room air at all times
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY 14607	Replacing HEPA Filters with Upper-level UVGI	UVGI	Upper Room UVGI	Local In-Room	Energy Efficiency	Yes	N/A	Yes	N/A	NR	Higher maintenance costs than portable HEPA filter, requires further studies for capital improvement	NR

WP#	Building Name and Address, Campus or Complex	Measure Description	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	Genesee Community Charter School 657 East Avenue, Rochester, NY 14607	Upgrading MERV 8 filters to MERV 13	N/A	N/A	ASHRAE Guidelines	N/A	-1,812	0	0	-$215.85	N/A	$0.00	-$215.85	-$421.18	$421.00	
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY 14607	Flush Cycle	N/A	N/A	ASHRAE Guidelines	7,312	9,998	0	-579	$1,190.98	N/A	-$3,048.02	-$1,857.04	$0.00	$1,200.00	
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY 14607	100% OA during Occupied Hours	1.4	N/A	ASHRAE Guidelines	7,312	-42,257	0	-1,593	-$5,069.47	N/A	-$8,382.05	-$13,451.52	$0.00	$1,200.00	
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY 14607	Run Bathroom Exhaust fans 100%	N/A	N/A	ASHRAE Guidelines	N/A	-3,322	0	0	-$395.72	N/A	$0.00	-$395.72	$0.00	$300.00	
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY 14607	Maintain Humidity at 40%-60%	N/A	N/A	ASHRAE Guidelines	N/A	-90	0	0	-$10.72	N/A	$0.00	-$10.72	$0.00	$162,188.00	
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY	Install HEPA filters in all classrooms	2	N/A	ASHRAE Guidelines	N/A	-50,768	-13	0	-$6,047.58	N/A	$0.00	-$6,047.58	$0.00	$77,500.00	
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY 14607	Implementation of In-Duct UVGI	N/A	N/A	UVGI Design Approach by First, Nardell, Chaisson, and Riley	N/A	-6,784	-1	0	-$808.12	N/A	$0.00	-$808.12	$0.00	$10,623.00	
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY 14607	Reduce OA levels for all AHUs as a result of Implementing In-Duct UVGI	3.7	N/A	ASHRAE Guidelines	5,554	34,871	45	132	$4,153.90	N/A	$691.95	$4,845.85	-$2,981.50	$0.00	
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY 14607	Implementation of Upper-level UVGI	N/A	N/A	UVGI Design Approach by First, Nardell, Chaisson, and Riley	N/A	-25,324	-3	0	-$3,016.64	N/A	$0.00	-$3,016.64	$0.00	$0.00	
WP-03	Genesee Community Charter School 657 East Avenue, Rochester, NY 14607	Replacing HEPA Filters with Upper-level UVGI	1	N/A	ASHRAE Guidelines	N/A	42,370	11	0	$5,047.20	N/A	$0.00	$5,047.20	-$7,947.78	$73,574.00	

WP-04 Webster Ice Measure–Level Data

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
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Run AHU-1 2 hours before and after occupancy	Ventilation	Institute 2 hr. Building Air Flush	Central System	ASHRAE	Yes	N/A	Yes	N/A	R	N/A	N/A
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Increase AHU-1 outdoor air to the maximum permitted by coil capacity	Ventilation	Increased OA%	Central System	ASHRAE	Yes	N/A	Yes	N/A	RME	N/A	N/A
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Disable DCV on the Munters unit (increases OA to 100%)	Controls	Disable DCV	Central System	ASHRAE	Yes	N/A	Yes	N/A	RME	N/A	N/A
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Install humidifier in AHU-1 to maintain space humidity above 40%	Humidifcation	Increased RH	Central System	ASHRAE	Yes	N/A	Yes	N/A	NR	High Installation cost	Condair HPRO100 humidifier,
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Install MERV 13 filters in AHU-1 and the Munters unit	Filtration	Increased MERV rating	Central System	ASHRAE	Yes	N/A	Yes	N/A	R	N/A	No MERV 13 filters defined.
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Use portable HEPA air cleaners in common areas other than the ice rink	Filtration	HEPA Filtration	Local In-Room	ASHRAE	Yes	N/A	Yes	N/A	RME	N/A	Carrier OptiClean air scrubber
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Install upper-air UVGI in areas other than lobby, ice rink	UVGI	Upper Room UVGI	Local In-Room	Energy Efficiency	Yes	N/A	Yes	N/A	NR	this project is not justified on its own on from a return on investment standpoint. High Maintenance Costs	VidaShield UV-C
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Roll back portable HEPA Air Cleaners due to upper room UVGI installation	Filtration	HEPA Filtration	Local In-Room	Energy Efficiency	Yes	N/A	Yes	N/A	ME	this project is not justified on its own on from a return on investment standpoint. High Maintenance Costs	Carrier OptiClean air scrubber
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Install AHU-level UVGI in AHU-01 and Munters unit	UVGI	In-AHU UVGI	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	NR	this project is not justified on its own on from a return on investment standpoint. High Maintenance Costs	VidaShield UV-C
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Roll back OA airflow by 0.5 ACH at AHU-1 due to AHU-Level UVGI	Ventilation	Reduced OA%	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	ME	this project is not justified on its own on from a return on investment standpoint. High Maintenance Costs	N/A
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Roll back OA airflow by 0.5 ACH at Munters unit due to AHU-Level UVGI	Ventilation	Reduced OA%	Central System	Energy Efficiency	Yes	N/A	Yes	N/A	ME	this project is not justified on its own on from a return on investment standpoint. High Maintenance Costs	N/A

WP#	Building Name and Address, Campus or Complex	Measure Description	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	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Run AHU-1 2 hours before and after occupancy	N/A	N/A	ASHRAE Guidelines	5,901 peak	5,831	0	96	$542.28	N/A	$454.72	$997.00	$0.00	$150.00	
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Increase AHU-1 outdoor air to the maximum permitted by coil capacity	N/A	N/A	ASHRAE Guidelines	10,425 peak	14,407	23	546	$1,339.85	N/A	$2,579.15	$3,919.00	$0.00	$300.00	
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Disable DCV on the Munters unit (increases OA to 100%)	N/A	N/A	ASHRAE Guidelines	10,000	0	0	523	$0.00	N/A	$2,472.00	$2,472.00	$0.00	$300.00	
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Install humidifier in AHU-1 to maintain space humidity above 40%	N/A	N/A	ASHRAE Guidelines	7,544 peak	334	0	0	$31.00	N/A	$0.00	$31.00	$0.00	$40,600.00	
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Install MERV 13 filters in AHU-1 and the Munters unit	N/A	N/A	ASHRAE Guidelines	7,544 peak	3,026	0	0	$281.00	N/A	$0.00	$281.00	$1,920.00	$640.00	
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Use portable HEPA air cleaners in common areas other than the ice rink	2	N/A	ASHRAE Guidelines	N/A	52,025	11	0	$4,836.00	N/A	$0.00	$4,836.00	$1,515.00	$23,200.00	
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Install upper-air UVGI in areas other than lobby, ice rink	2	N/A	UVGI Design Approach by First, Nardell, Chaisson, and Riley	N/A	18,570	2	0	$1,726.00	N/A	$0.00	$1,726.00	$5,702.00	$52,800.00	
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Roll back portable HEPA Air Cleaners due to upper room UVGI installation	N/A	N/A	ASHRAE Guidelines	N/A	-34,683	-7	0	-$3,224.00	N/A	$0.00	-$3,224.00	-$1,231.00	-$15,700.00	
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Install AHU-level UVGI in AHU-01 and Munters unit	0.5	N/A	UVGI Design Approach by First, Nardell, Chaisson, and Riley	16,897 peak	9,224	1	0	$857.00	N/A	$0.00	$857.00	$1,668.00	$9,100.00	
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Roll back OA airflow by 0.5 ACH at AHU-1 due to AHU-Level UVGI	N/A	N/A	ASHRAE Guidelines	N/A	-1,085	0	-17	-$100.91	N/A	-$79.10	-$180.00	$0.00	$0.00	
WP-04	Webster Ice Arena 865 Publishers Parkway, Webster, NY 14580	Roll back OA airflow by 0.5 ACH at Munters unit due to AHU-Level UVGI	N/A	N/A	ASHRAE Guidelines	N/A	0	0	-332	$0.00	N/A	-$1,569.00	-$1,569.00	$0.00	$0.00	