ADDRESSING VENTILATION IN SCHOOLS

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Fairfax County Public Schools

A COMPREHENSIVE REVIEW OF CLASSROOM AIR FLOW AND HVAC MAINTENANCE IN LIGHT OF CORONAVIRUS.

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FAIRFAX COUNTY PUBLIC SCHOOLS

EXECUTIVE SUMMARY

On July 21, 2020 the Superintendent and School Board of Fairfax County Public Schools (FCPS) reached consensus to open schools virtually to begin the 2020-21 school year. One safety concern expressed was FCPS' ability to provide a safe and comfortable learning environment through building ventilation systems. To ensure that school facilities were safe, The Office of Facilities Management began the task of reviewing outside air ventilation in all schools. Information was gathered and has been compiled to aid in determining appropriate measures to undertake for reducing the potential spread of coronavirus through building heating, ventilation and cooling systems. FCPS' current practices for improving indoor air quality were also reviewed along with the development of short and long-term strategies to aid in the protection of students and staff members.

FCPS follows the Center for Disease Control (CDC) and Health Department guidance to prevent the spread of coronavirus – guidance that is currently based on person-to-person transmission. The CDC and Health Department maintain that increased ventilation in facilities is the best way to prevent disease spread. Ventilation rates from each school have been reviewed and confirm that FCPS' design standards meet the recommended amounts of outside air ventilation. Additionally, maintenance technicians have confirmed that all schools are following the manufacturer's design specifications. Should health guidance regarding the spread of coronavirus change, FCPS would need to adjust its approach to adapt to whatever guidance may be provided to better protect students and staff members. Within this report we provide the measures we have taken and continue to undertake to ensure all schools are ready to return to 100% in-person learning. These measures include:

- Ensuring all schools and offices have sufficient outside air ventilation.
- Purchasing initial allocation of MERV 13 filters (based on availability) and upgrade school HVAC systems.
- Purchasing HEPA filters and air purifiers for use in select areas.
- Continuing to review and assess the use of ultraviolet lighting to include the use of third-party engineering.
- Piloting third-party health and safety verification programs for schools.

CONTENTS

OVERVIEW

FCPS' return to school plans are being developed in accordance with the mandates and guidelines of several organizations, including the Governor's Office, the Virginia Department of Education (VDOE), World Health Organization (WHO), the Centers for Disease Control (CDC), the Virginia Department of Health (VDH), the Fairfax County Health Department (FCHD), other local and state officials and guidelines, industry experts, and the most current scientific data available. The main theme in those plans is social distancing and the wearing of face masks for all. Social distancing will be achieved in FCPS by reducing the number of students present in school, which will give each student more space. Current plans call for partial in-class attendance when health conditions allow, with only 50% of the student population in school at any one time. A 50% limit is considerable because reducing the occupancy by such an amount will double the ventilation rates in all schools. Increased ventilation is recommended by all organizations concerned with airborne transmission.

This report will discuss FCPS' current practices for reducing indoor odors and pollutants through building Heating, Ventilation and Cooling (HVAC) systems. It will discuss how school ventilation systems operate to increase circulation of outside air as much as possible. It will also provide some short-term measures which can be taken to further reduce contaminants and improve indoor air quality. The most significant short-term measure is reducing the number of occupants in a building by adhering to guidance recommending only 50% of the student population be present at any one time when school resumes.

This report will also outline some long-term strategies that can be taken to reduce the possibility of airborne transmission of the coronavirus. Some of the actions discussed here require substantial financial investments, which would require School Board approval, material lead time and labor, which limit the ability to provide them without months of preparation.

FCPS designs and operates many different types of equipment to maintain an acceptable indoor air temperature and indoor air quality in buildings.

Ventilation at A Glance
- FCPS operates 220 facilities every day of the year
- At 27 million square feet of covered space, FCPS is larger than 4 Pentagons
- There are nearly 37,000 pieces of HVAC equipment in FCPS
- Including over 5,000 different types and models of HVAC equipment
- There are more than 45,000 active air filters in FCPS
- Including nearly 800 different sizes and types
- Air filters are changed every 90 days
- FCPS replaces over 180,000 filters each year

Facility Operations and Maintenance

All HVAC systems are maintained and operated efficiently and effectively using the latest procedures and technology. FCPS performs scheduled preventive maintenance to all HVAC systems. OFM uses a maintenance management system that documents HVAC maintenance requests and actions. Larger buildings such as middle, high and secondary schools are provided with on-site operating engineers available to immediately address any HVAC concerns.

Definition of Ventilation and Applicable Standards

The general purpose of ventilation in buildings is to provide a healthy indoor environment for occupants by bringing in fresh outside air, filtering out particles and conditioning within the physical space. Commercial buildings are required to comply with the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) 62. ASHRAE 62 provides minimum ventilation rates and indoor air quality for human occupants and is intended to minimize the potential for adverse health effects. In the past ten years, FCPS has regularly (over 450 times at more than 135 locations) proven compliance with ASHRAE 62 through verification by a third-party professional engineer as part of the US EPA's ENERGY STAR® commercial buildings certification program.

The amount of ventilation required has changed over the years. However, all FCPS schools are designed, built and operated according to the standard that applied at the time the building was built or at the time of a major renovation. The AHRAE

recommended ventilation rate for classrooms is 15 cubic feet per minute (cfm). FCPS maintains a minimum 20 cfm per classroom and office space throughout the division.

ASHRAE 62-89 Recommended Ventilation Rates

Application	Ventilation Rate/Person	Application	Ventilation Rate/Person
Auditorium	15 cfm	Hotel Rooms	30 cfm/ room
Bars/Cocktail	20 cfm	Laboratory	20 cfm
Beauty Salon	25 cfm	Office Space	20 cfm
Classrooms	15 cfm	Operating Rooms	30 cfm
Conference Rooms	20 cfm	Restaurants	20 cfm
General Retail	15 cfm	Smoking Lounge	60 cfm
Hospital Rooms	25 cfm	Supermarkets	15 cfm

Reducing Pollutants and Cleaning

One of the most effective complements to ventilation is to reduce or eliminate the sources of contamination that might be present in a building. For example, walk-off mats at building entrance points reduce the amount of dust, pollen and other pollutants that are brought into a facility. Custodial staff follow comprehensive routine cleaning schedules using EPA recommended and Green Seal-approved cleaners, sanitizers, and disinfectants according to manufacturer's directions to further reduce the amount of pollutants within the facility. FCPS uses mechanical ventilation instead of opening windows to provide outside air as the air coming through mechanical systems is filtered. This method allows for fresh outside air to be pre-conditioned before it enters the space.

Minimum Efficiency Reporting Value (MERV) Rating, Air Filtration and Special Ventilation Cases

ASHRAE established the Minimum Efficiency Reporting Value (MERV) rating in 1987 as a method of testing and rating filters for removal efficiency by particle size. According to the National Air Filtration Association, there are 16 MERV values, with the tested filter efficiency increasing as the MERV number increases. Filters are tested against 12 size ranges of particles, with the smallest range being around 0.3 micrometers, and the largest range around 10 micrometers.

MERV ratings can be broken down in the following classifications:

MERV 1 to 4 – effective at controlling larger particles such as, sanding dust, spray paint dust, lint and carpet fibers. Applicable in residences and in window air conditioning units.

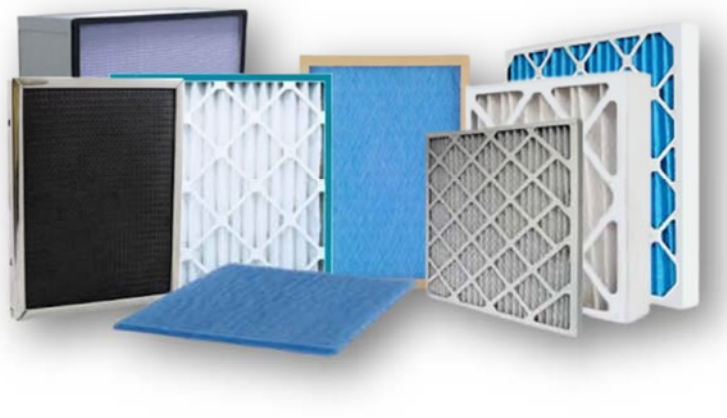
MERV 5 to 8 – effective at controlling mold spores, hair spray, dust. Applicable in most commercial buildings, residences, industrial workplaces and paint booths. MERV 8 filters have 90 percent efficiency on particles that are 3 to 10 micrometers in size.

MERV 9 to 12 – effective at controlling humidifier dust, lead dust, vehicle emissions, and welding fumes. Applicable in residences with superior HVAC systems, hospital labs and commercial buildings.

MERV 13 to 16 – effective at controlling airborne bacteria, most tobacco smoke and pollutants released through sneezing. Applicable in general surgery suites, smoking lounges and commercial buildings with superior HVAC systems.

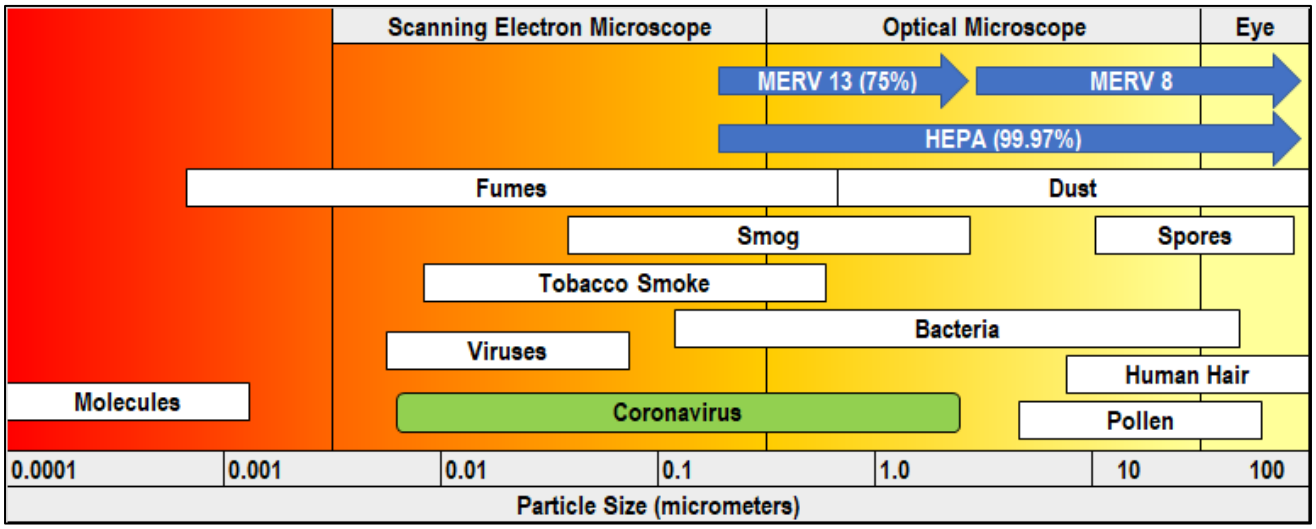
High Efficiency Particulate Air (HEPA) filters fall under their own classification but would be equivalent to a MERV 20 rating.

Central or local air filtration (depending on mechanical system type) is provided within all interior spaces in FCPS. FCPS replaces the filters every 90 days. In most spaces, FCPS uses MERV 8 filters. FCPS may use HEPA filters in specific areas, but HEPA filters may not appropriate for some equipment because of its age or design specification. Source-capture ventilation is provided as needed for spaces such as exhaust hood workstations in science labs, particle filters in shop areas and dedicated exhaust fans for chemical storage closets and bathrooms.



HEPA filters are a pleated mechanical filter designed to trap up to 99.97% of particles as small as 0.3 microns – coronavirus particles are between .06 and 1.4 microns in size. The next chart provides an outline for filter efficacy as it relates to particle sizes. The majority of particle sizes for which a MERV 8 or higher filter is needed is 3 microns – roughly the size of dust or pollen. MERV 13 and HEPA filters have a higher degree of

efficacy in catching particles as small as a bacteria, heavy smoke or fog and even coronavirus in its developed state. However, no filter is 100% effective at catching all airborne based diseases, including coronavirus.



Here are a few observations regarding HEPA filters and FCPS:

- HEPA filters are most commonly used in buildings that recirculate air rather than ventilate fresh outside air. All FCPS schools are designed to ventilate outside air.
- HEPA filters are significantly thicker (12") than current FCPS equipment could accommodate which would require filter frame replacement.
- HEPA filters cost significantly more than MERV 8 filters. The retrofit costs to allow for HEPA filters to be added would also include a need to air seal the filter pathway; air would not be allowed to bypass the filter. FCPS' filter frames are not required to be air sealed.
- Due to the increased filtration level, HEPA filters have to be changed more regularly, which increases the cost by requiring a greater number of filters.
- HEPA filters create additional resistance to air flow – aging FCPS equipment would likely experience more mechanical failures since it is not designed for use with HEPA filters.
- HEPA filters are very effective in areas designed for negative air flow to prevent internal contaminates from leaving the room (Ex. – hospital ICU and operating rooms).
- FCPS has identified portable HEPA filtration units for large space application and has begun purchasing units.

SCHOOL VENTILATION ASSESSMENTS

OFM sampled more 2,400 individual pieces of equipment, covering all makes and models of heating and air conditioning systems in FCPS. The types of equipment sampled include unit ventilators (UV), make up air (MAU), packaged rooftop (RTU), energy recovery (ERU), multizone (MZ), air handler (AHU), variable refrigerant flow (VRF), fan coil units (FCU), water source heat pump (WSHP), variable air volume (VAV) and constant air volume (CAV). All airflow measurements were conducted with the facilities in the active occupied mode.

OFM conducted targeted sampling in all schools to ensure FCPS is providing the proper cfm of airflow per person in our classrooms and large gathering spaces as recommended by ASHRAE. The airflow sampling was taken from randomly selected spaces at schools, learning cottages (trailers) and the Gatehouse administration facility. Airflow was measured in more than 20% of all rooms within FCPS. OFM also performed targeted airflow sampling in many large gathering spaces such as auditoriums, gyms, cafeterias and main office areas to ensure appropriate airflow per person in each facility. To collect samples, OFM utilized digital thermo-anemometers to measure the airflow and ensure accuracy. The air samples were taken from the supply air, return air, mixed air and outside (fresh) air provided to each space.

Classroom sampling was split into three methods depending on the type of equipment supplying airflow to the space. The method for those classrooms with individual HVAC equipment rated at 4 tons and below (floor mounted), was to first measure the airflow and temperature of the supply conditioned air being delivered to the space from the HVAC equipment. Second, the airflow and temperature of the return air (air being brought back into the equipment) was measured, and lastly the airflow and temperature

of the outside air (fresh air being brought into the space to be mixed with return air and delivered to the classroom) was measured. The classrooms that have ventilation provided through ceiling diffusers were measured at each supply diffuser for airflow. The area of each diffuser (in^2) was measured and factored in for total space cfm. For each large air flow distribution system rated 5 tons and above approach (Roof Top Units), airflow and temperature measurements were taken on the return air. Second, the airflow and temperature of the outside air was measured. Last, the airflow and temperature of the mixed air and supply air (conditioned air delivered to the classroom) was taken.

One trailer at each facility was sampled. Airflow and temperature of the supply air was measured. Second, the airflow and temperature of the return air was measured, and lastly the airflow and temperature of the outside air was measured.

Maintenance technicians followed ASHRAE 62's formula for calculating the total volume of fresh outside air entering a system. This formula requires taking air samples from multiple points as it traverses through the duct system. The equation used to determine this percentage is as follows:

$$\%OA = \frac{Total\ Return\ Air - Total\ Mixed\ Air}{Total\ Return\ Air - Total\ Outdoor\ Air} \times 100$$

The method to determine the airflow of supply air to the space is first measure airflow at any point on the discharge vent in the cfm setting. Then measurements are taken to determine the area (in^2) of discharge, then multiply the two answers for total cfm distributed.

Airflow measurement results were compared to the as-built design plans for each building to determine if systems are providing adequate airflow based on the classroom dimensions.

The qualification metric is: One cfm is needed per square foot (1 cfm/sq. ft) of floor area and provides about 7.5 air changes per hour.

PILOT STUDIES

More than 60% of air flow in schools is provided through either built-in classroom unit ventilators or roof mounted air handling systems. To ensure compliance with ASHRAE 62, OFM developed a pilot study to sample the impact of MERV 13 filters on existing HVAC

equipment to gain further insight on the resource requirements regarding frequency of filter changes as well as impact to equipment lifecycle using increased filtration.

The following locations were piloted as a part of this study:

Oak View Elementary School
Exceeds ASHRAE 62 Recommendations

Measurements indicated an airflow reading of 598 cfm using a MERV 8 filter. On application of the MERV 13 filter, an initial airflow of 533 cfm was noted. Saturation caused a reduction of airflow within the first week of 4 cfm but did not decline further over the second week. Overall, from MERV 8 to MERV 13, a minimal decrease (12%) in airflow was observed. Based on room occupancy, a minimum of 37 cfm is anticipated per person, exceeding ASHRAE 62 recommendations.

The compact construction of the unit ventilator was not conducive to monitoring changes in motor efficiency. However, thermal measurements were taken of the motor case and indicated no adverse effects to its operational capability throughout the study period.

Robinson Secondary School
Exceeds ASHRAE 62 Recommendations

Measurements with the MERV 8 filter in place indicated an airflow of 855 cfm and a running amperage (on the fan motor) of 8 amps. On application of the MERV 13 filters, an initial airflow of 810 cfm was noted, accompanied by an increase amperage to 10 amps. Over the course of three weeks, the airflow decreased to 720 cfm and energy usage increase (30%) to 13 amperes. Overall, from MERV 8 to MERV 13, a reduction in airflow (16%) was observed. Based on 30 occupants, a minimum of 24 cfm is anticipated per person, exceeding ASHRAE 62 recommendations.

Notes:

Although this study was performed in occupied mode of the mechanical units, there was minimal occupancy which may result in increased demand on HVAC systems when occupancy increases. Filter saturation would likely increase with the occupant load -

resulting in a need of more frequent filter replacement and potential life cycle equipment operation reduction.

The current supply of MERV 13 filters has been reduced: current supply manufacturers have redirected the production of filter material stream to produce N95 masks as part of the global pandemic relief efforts. This will impact lead time for obtaining some (non-standard) filters to accommodate low supply.

OFM was unable to test UV-C lighting as part of this assessment due to product availability and the time needed to install/test UV-C lighting exceeded the initial timetable for this pilot study. However, a pilot study is planned for the Fall and OFM will engage a third-party firm to better evaluate its use and efficacy.

Additional Observations:

- The saturation rate of the MERV 13 rated filter will require more frequent filter replacements – every 60 days instead of the current 90-day replacement cycle used with MERV 8.
- Increased amperages indicate a higher load for the fan motor to move air across MERV 13 filters. Some aging equipment could experience reduced life expectancy due to this increased workload. However, other contributing factors, such as humidity, occupancy, design, filter saturation, etc. could also contribute to the reduced life expectancy on aging equipment.

PREVENTATIVE MEASURES

The Office of Facilities Management continues to monitor what role HVAC can play in reducing coronavirus transmission inside FCPS facilities. The following technologies suggest inherent potential to reduce disease spread, and it is important to recognize one solution may be more appropriate in certain locations over others.

MERV 13 filters are the recommended industry choice for reducing the potential spread of airborne diseases. FCPS currently utilizes 2" box filters rated at MERV 8 within our facilities and researched two types of filter upgrades, MERV 13 and HEPA. Higher MERV ratings will help to provide a cleaner space, but MERV 13 filters are not able to capture all particles as small as coronavirus (between .06 and 1.4 microns in size). MERV 13 can capture up to 75% of particles that are 0.3 microns or greater in size, providing a significant increase in particulate matter being removed from the classroom. Therefore, OFM has begun purchasing MERV 13 filters for immediate areas of need and will begin

procurement procedures for a phased approach to replacing all FCPS filters with MERV 13 in the future.

HEPA filters provide thicknesses of 11.5" and up, equipment modifications would be required in all cases to adapt our equipment to these filters. To date, OFM has identified only a small number of spaces that could accommodate this type of modification – mostly in large areas like gymnasiums, auditoriums, and cafeterias. In those cases, some motors and fans would require upgrades in order to maintain required airflow per ASHRAE recommendations. OFM has begun purchasing HEPA filters for use in select areas as appropriate and to supplement existing ventilation provided by fresh outside air.

Not all spaces have the type of HVAC system that uses a filter, and these spaces require alternate means of air purification. Ceiling mounted VRF units and VAV boxes with above ceiling open return are two instances wherein the filter housing is not expandable, and air is circulated within a space, augmented only by the addition of outside air. OFM addresses these areas individually using HEPA filters or portable air purifiers when needed but is researching additional measures for air cleaning like UV-C lighting.

Ultraviolet-C (UV-C) Irradiation Lamps have been purported to kill bacteria and virus cells, but studies vary and, in some cases, are divided regarding their effectiveness – even claiming that over exposure to UV-C light can be carcinogenic for humans. OFM researched two implementation options for UV-C lighting in FCPS. The first is a ceiling mounted light fixture system, but this application can only be used

while no one is in the room due to the potential carcinogenic hazard. The second option is an internal lighting array consisting of several UV-C lighting fixtures irradiating air particles as they pass through the ductwork. This option has potential because of its enclosed application. However, many older facilities may not be able to handle the extra power requirements for operating this technology. OFM continues to assess this technology and will work with third-party engineers to better determine UV-C lighting's potential for FCPS.

Portable air purifiers equipped with HEPA filters can add air purification to any room with a single unit. Portable air purifiers require no modification to the existing equipment and consume approximately two square feet of floor space. Power requirements can be satisfied with a standard 120-volt outlet, and the purifier is able to provide complete filtration of the air in a 900 square foot space every 14 minutes. Maintenance can be completed concurrent with the regular HVAC filter change schedule, and an inoperable unit can be replaced quickly. Air purifiers are regularly used by OFM in spaces with indoor air quality concerns. OFM will continue to utilize them to the fullest extent possible.

Third-Party Verification OFM staff recently began assessing the use of a third-party verifier for its facility health and safety procedures. We recognize a need for additional evidence-based review – with emphasis on operational policies, maintenance protocols, stakeholder engagement and emergency plans in light of coronavirus. Such a third-party certification rating would help guide FCPS in preparing its spaces for re-entry in a post-coronavirus environment, instilling confidence in occupants and the broader community.

The WELL Health-Safety Rating™ is one group that other Virginia school divisions are using for their return to school preparations. It was created by the International WELL Building Institute (IWBI), an organization that oversees the world's premier framework for advancing health in buildings and spaces of all kinds - the WELL Building Standard (WELL). It includes 21 features across the following core areas, a minimum of 15 which need to be met, including:

- Cleaning and Sanitization Procedures
- Emergency Preparedness Programs
- Health Service Resources
- Air and Water Quality Management
- Stakeholder Engagement and Communication

The strategies within the WELL Health-Safety Rating are informed by existing features within the WELL Building Standard, IWBI's Task Force on coronavirus and guidance by WHO, CDC, global disease control and prevention centers and emergency management agencies, as well as recognized standard-making bodies such as ASTM International and ASHRAE, and leading academic and research institutions.

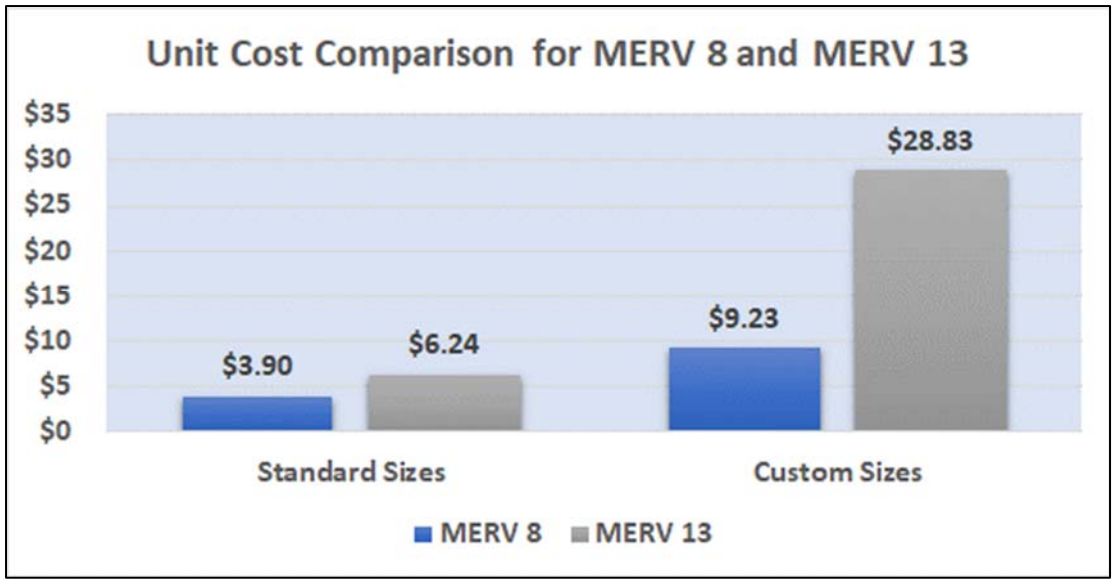
Health and safety verification models are new for FCPS buildings. Unlike other certification programs used by OFM, programs that measure equipment optimization and energy savings, WELL focuses on the health and safety components for FCPS' overall operational management – including communication practices and community engagement. Further investigation is required to determine the feasibility of using external health and safety benchmarking groups as information continues to develop around coronavirus. OFM is conducting preliminary reviews of WELL and other groups to determine their benefits as FCPS prepares for in-classroom learning.

OPERATIONAL IMPACT

FCPS has more than 45,000 air filters throughout the school division – with nearly 800 different types of filters. More than half (59%) of the air filters in FCPS are built based on a standard size, with the other 41% based on custom size and specification.

Total Filters:	Standard Size:	Custom Size:
45,066	26,646	18,420

OFM compared costs between MERV 8 and MERV 13 filters based on these standard and custom sizes. The average cost for standard size MERV 13 filters is slightly higher than MERV 8 (+$2.34 per unit). However, the average price is significantly higher for specialty and custom air filters, which may result in an increase of $19.60 per unit.



MERV 13 filters catch more particles than MERV 8 and need to be replaced more frequently. Typical replacement cycles for MERV 13 filters are every 60 days as opposed to every 90 days for MERV 8. This cycle would require FCPS to replace twice as many filters each year. As this pandemic is often referred to as a temporary (although significant) event initial cost variances reflect a reasonable investment and is being undertaken. If the determination that continuation for increased filtration than the longer term financial and physical impact must be further addressed.

OFM will procure enough standard sized MERV 13 filters to use at critical sites over the next 90 days (est. cost $332,542). To offset this increase, OFM is reviewing the existing supply contract to determine if additional reductions can be made. FCPS' current supply contract is limited to MERV 8 filters. Additional pricing and availability for MERV 13 filters have been requested from the supplier. However, the materials used to produce MERV 13 filters were initially repurposed for N95 masks, making supply availability limited. OFM is reaching out to other suppliers to obtain fair pricing and availability quotes.

Based on this information, OFM is initiating formal solicitations for air filters. A formal solicitation would lead to better pricing based on FCPS' purchasing power (volume purchase) and ensure a new contract is more advantageous for FCPS – one that includes all the filter sizes and provides FCPS with choice selection

CONCLUSION AND NEXT STEPS

OFM met with school systems across the country and internationally including Colorado, Maryland, Hawaii, Illinois, Missouri, Texas, Arizona, and Germany – they are all taking different steps to prevent the spread of coronavirus. Some are choosing to increase airflow by decreasing MERV value rated filters. Schools in drier regions are increasing direct outside ventilation. Many of the approaches mentioned in this report suggest improvement to help prevent the spread through ventilation systems. It also has shown that FCPS has a myriad of systems and, due to its size, shows multiple approaches are being considered and implemented depending on application.

Once again it is important to note that FCPS meets the industry recommended standards for outside air ventilation in classrooms and offices. FCPS schools are designed to ventilate fresh outside air and mitigate the buildup of odors and pollutants. Listed in the next section are ventilation rates for each school and office in accordance with ASHRAE's recommended rate of 15 cfm per person for classroom spaces – FCPS exceeds this recommendation in all locations. This report shows FCPS' ability to provide a safe and comfortable learning environment for each return to school scenario (Virtual, 50%, 100%).

FCPS has followed the health community guidance since the beginning of the global pandemic. This guidance is based on preventing a droplet-based transmission of coronavirus. If this should change, however, FCPS would need to adjust our approach to accommodate any new requirements. Such adjustments may prove costly in terms of labor effort and facility cost. As a result of our analysis and review, the office of Facilities Management has taken immediate action to include the following:

- Ensure all schools and offices have sufficient outside air ventilation.
- Purchase initial allocation of MERV 13 filters (based on availability) and upgrade school HVAC systems.
- Purchase HEPA filters for use in select areas.
- Purchase additional air purifiers for use in areas of need.
- Continue to review and assess the use of ultraviolet lighting to include the use of third-party engineering.
- Piloting additional health and safety protocols to include the use of third-party verification.