A Hybrid Solution to Heating, Cooling, and Ventilation in Schools

Advantages of Decentralized Air in the Classroom

In 2020, the entire world changed forever. We encountered the effects of COVID19, and we've been playing catch-up to a virus that seems to have the upper hand. We've known about pollutants in outdoor air for decades, and now the attention is focused on the removal of pollutants indoors, namely, in our homes, in our workplaces, and in our schools.

Generally, when we talk about pollutants amongst ourselves, we might think of outdoor air pollution. While outdoor air pollution does affect the air we breathe, potentially resulting in adverse health effects, human exposure to indoor air pollutants can be 2 to 5 times, and sometimes more than 100 times, higher than outdoor air pollutants, according to studies by the EPA.[1] This is concerning because most people spend up to 90% of their time indoors.

With the advent of central heating and air, schools could efficiently heat or cool air from a large, single air handling unit (AHU). This system worked because it was cost-effective, energy-efficient, and did not contribute as much noise pollution when compared to the single room horizontal unit ventilator at the time. However, by itself, a central heating & air system cannot adequately ventilate individual rooms in a large school building. We need a better solution to protect our faculty and students from the adverse effects of poor indoor air quality.

When designing a new school building or designing how to retrofit an older school building, a one-size-fits-all approach could cause more problems in the long run than developing an approach to fit all areas of the school building.

Systems that run throughout the building and from classroom-to-classroom are inefficient and potentially harmful to faculty and students. In this situation, a case-by-case solution is ideal. When first designing an HVAC system for an older building, it can be very expensive and sometimes not even possible to add central duct distribution without current ventilation. A way to counteract this issue would be to build a hybrid HVAC system. Each classroom would have an HVAC vertical unit ventilator, common areas such as gymnasiums, theaters, and cafeterias would use a stand-alone AHU, and a central HVAC system would cover the hallways, offices, and breakrooms. Offices and breakrooms, connected to the central HVAC system, would employ the use of a portable HEPA filtration system for cleaner, recirculated air.

Importance of Indoor Air Quality

Why is indoor air quality important? The EPA's Science Advisory Board (SAB) has consistently placed indoor air pollutants as one of the top 5 risks to public health. When schools work to eliminate indoor air pollutants, they contribute to healthier faculty and students, performance improves, and students are more attentive and retain information better. On the other side of the spectrum, a high number of upper respiratory symptoms and high rates of school absenteeism were significantly associated with inadequate ventilation and dampness or moisture damage in 4,248 6th grade students.[2]

Importance of Indoor Air Quality

Poor IAQ can induce the following symptoms:

- Coughing
- Eye irritation
- Headaches
- Allergic reactions
- Asthma and/or other respiratory issues

How Poor IAQ Affects Performance

Nearly 1 in 13 kids in school has asthma. Asthma is the leading cause of missed school time due to chronic illness. Evidence suggests that indoor exposure to allergens such as dust mites, pests, and mold plays a role in triggering asthma symptoms.[1] These allergens are common in schools, and they contribute to many problems.

These problems can:

- Affect student attendance, comfort, and grades
- Reduce faculty performance,
- Increase the possibility of school closings
- Cause communication breakdowns among school administration, faculty, and parents
- Result in negative exposure
- Erode community trust
- Result in liability problems[1]

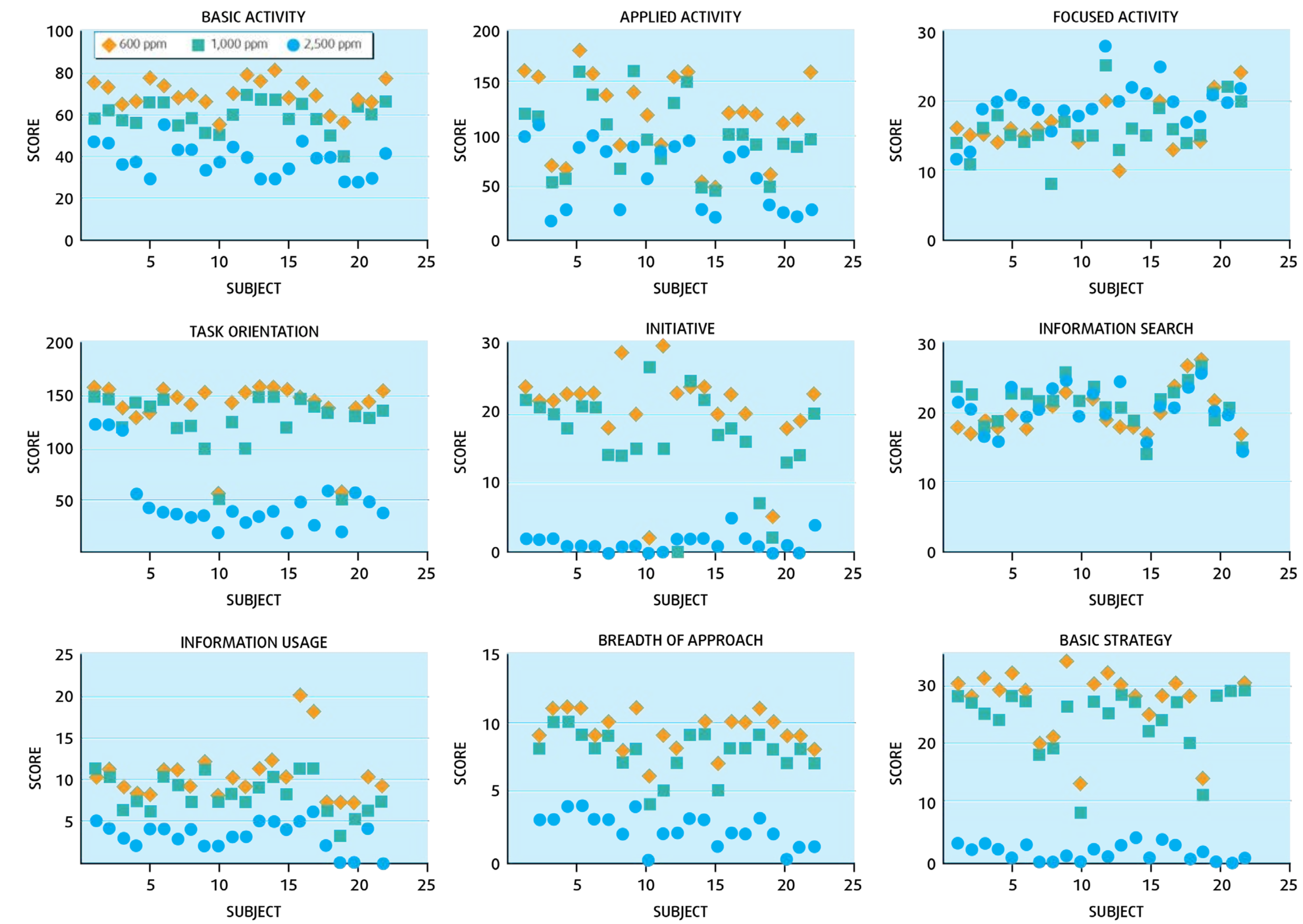
When we improve IAQ in schools, we help our community. Adverse effects of COVID19 and indoor air pollutants on faculty and students hurt their ability to perform well and be in attendance in class. Also, better IAQ can mitigate the issues from asthma and airborne allergens, and moving the poor air out allows for a fresh, open-window feel to the classroom that everyone will appreciate.

So far in this paper, we have covered the effects from poor IAQ on faculty and students. What effects will faculty and students experience from having better IAQ? Experts agree that schools with better indoor air quality have students that perform better than schools with poor IAQ.

Improved Decision-Making

From a study published in 2012, 22 people were placed in rooms exposed to CO_2 levels of 600, 1,000, and 2,500 parts per million (ppm). These rooms mimicked a traditional office setup. Over the span of 2.5 hours, these participants were subjected to these CO_2 levels, but had no knowledge of the actual amount of ppm CO_2 in the room. In each room, participants were tasked with completing a computerized decision-making test. This test, called the Strategic Management Simulation (SMS), has been used to study the decision-making abilities of individuals while under the influence of different drugs. The SMS test has also been used to test individuals' decision-making abilities after breathing in volatile organic compounds (VOCs) from house painting, as well as stress overload, head trauma, etc. Participants were tasked with completing questionnaires on health symptoms and the perceived air quality of the room. Participants were mainly science and engineering students.

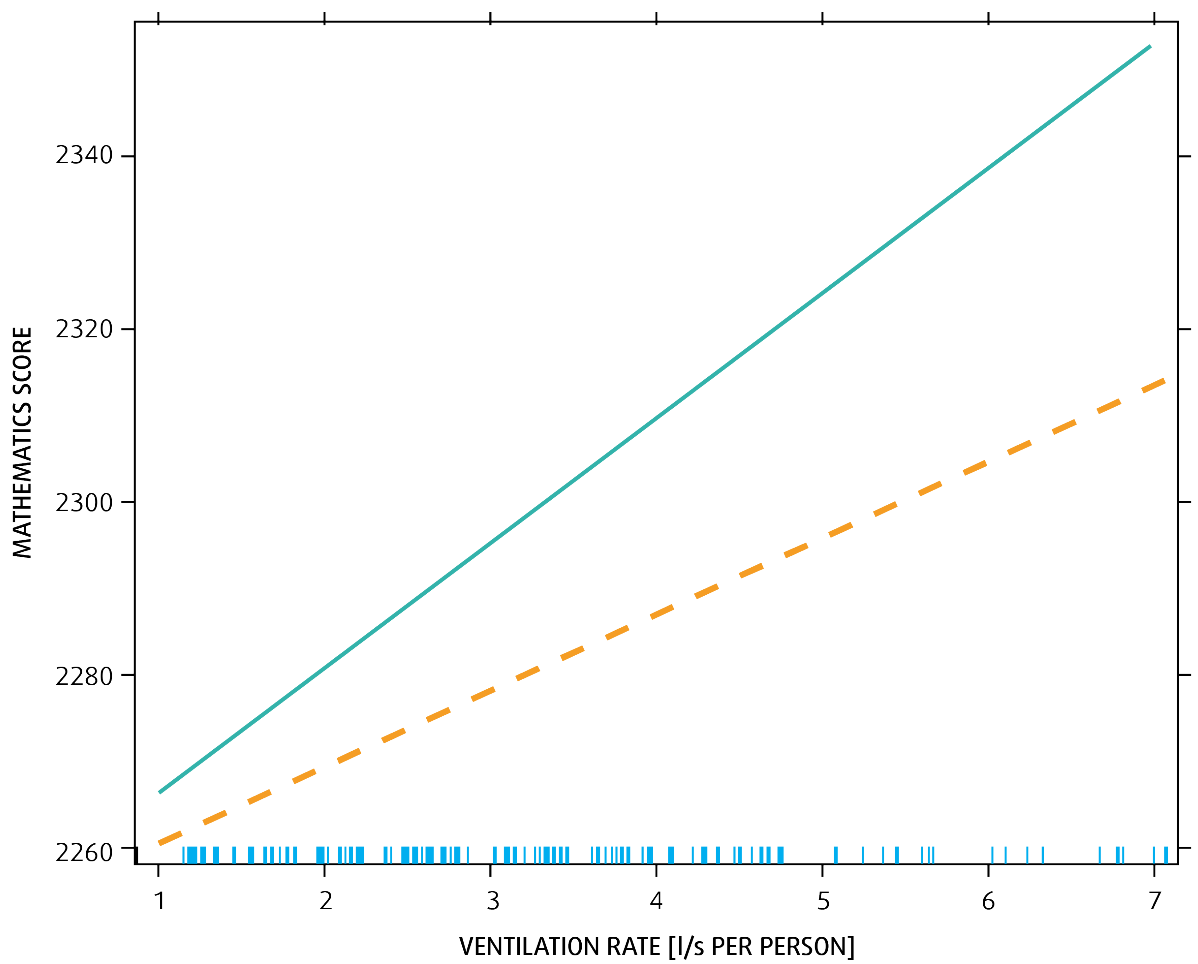
Improved Decision Making



ABOVE: Figure 1 shows participants in rooms with 1,000 or more ppm CO_2 had significant reductions in their raw scores.[3]

From the chart above, the data reflect there is correlation between raw scores and CO_2 levels for all performance measures except for focused activity and information search. In rooms with 2,500 ppm CO_2, participants had significant reductions in their raw scores.[3] Therefore, in 7 of 9 categories, participants in rooms with higher indoor CO_2 levels had lower raw scores when compared to participants in rooms with lower CO_2 levels.

Improved Test Scores



ABOVE: Figure 2 shows with increased ventilation, math scores improved by an average of 74 points.[4]

Improving indoor ventilation in schools has been proven to improve decision-making. What else can better IAQ do for our schools?

From a study performed in 2008 and 2009, 70 elementary schools with over 3,000 5th grade students in a Southwestern state were monitored to assess the rates of ventilation and the correlation between test scores. For all subjects, the state used a range for test scores. Test scores ranged on a scale between 2100, classified as “met standard,” and 2400, classified as “commended performance.”[4] Student-level data were based on various socioeconomic variables, classroom-level variables, and standardized test scores.

According to this study, 5th grade students’ math scores increased in conjunction with increased ventilation (see Figure 2) and decreased temperature (see Figure 3). Students’ math scores (average of 2,286) increased by 74 points from the lowest observed ventilation value (0.9 liters per second/person) to the recommended (ASHRAE Standard 62.1) minimum ventilation rate (7.1 liters per second/person). When indoor temperatures were kept lower during the summer and winter months, math scores increased by an additional 64 points. This data are based on a recommendation by ASHRAE Standard 55, which recommends temperature during the winter stay between 68-75 (°F) and during the summer months between 73-79 (°F). When added together, in theory, these effects combined would surpass the “commended performance” (>2400) score.[4] Scores for science and reading increased at similar levels as well, but there is more variability with these two subjects than the math scores.

These studies confirm theories that have long been accepted as true. When ventilation is improved, students perform better. When temperature control is at the teacher’s fingertips, students do even better. Improving ventilation in classrooms, and other learning spaces, has never been as important as it is today. Even with today’s challenges, ventilation can improve the health of students, can improve students’ decision-making, and can improve students’ test scores.

How to Measure and Increase Ventilation

Based on classroom default densities in ASHRAE Standard 62.1-2019 (25 students/1,000 sq ft for 5- to 8-year-olds), the Harvard T.H. Chan School of Public Health recommends classrooms need at least 5 air changes per hour (ACPH).[5]

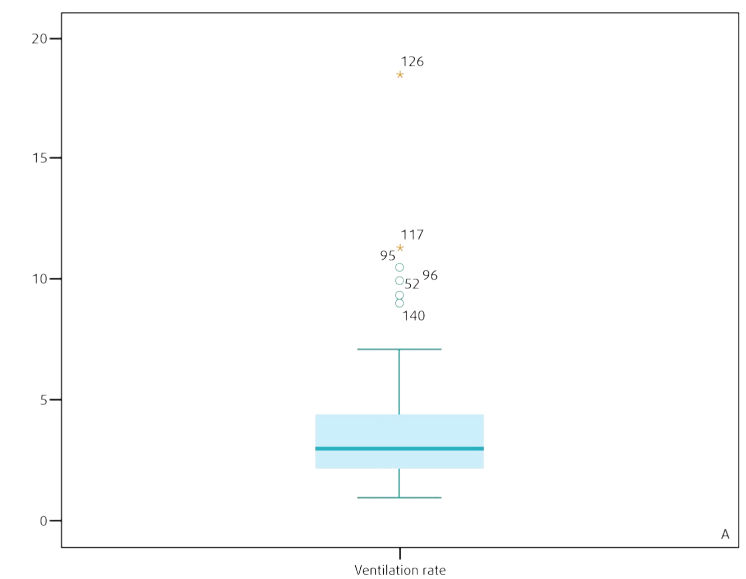
What is ACPH and how can we calculate it?

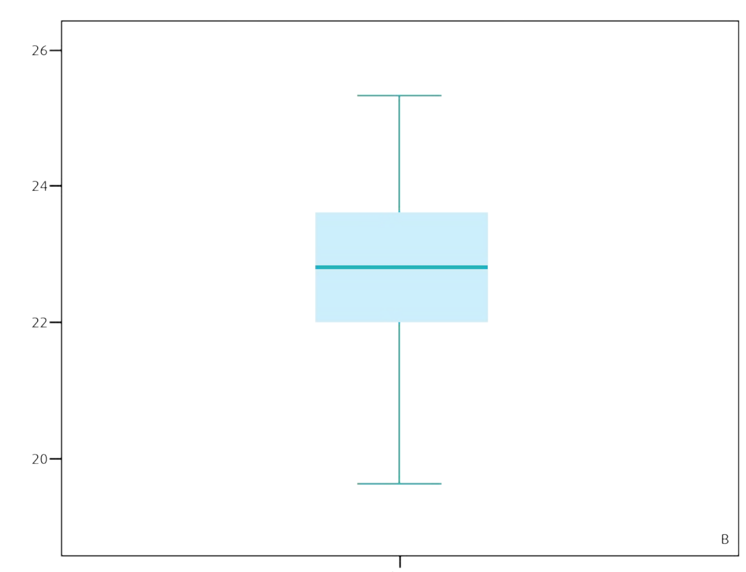
ACPH measures the amount of times air changes each hour. In other words, each classroom in the school should have outside air replace the inside air at least 5 times per hour to remove potentially harmful air particles from the room. And how do we know if the air changes? By calculating the ACPH of the room. To calculate ACPH, we need to know the "clean" air rate going into the room. To find the clean air rate, multiply the air flow rate (measured in cubic feet per minute, or CFM) by the outdoor air supply percentage. The product is the clean air rate. Then, multiply the clean air rate 60 minutes, or 1 hour, divided by the volume of the room (square footage multiplied by ceiling height), and we have air changes per hour.

Researchers at the Harvard T.H. Chan School of Public Health performed a study measuring the ACPH in two different classrooms: one classroom that shares a central HVAC system with other classrooms and another classroom that uses a horizontal unit ventilator. How do they compare to one another?

The classroom that shares a central HVAC system is 700 square feet and has a ceiling height of 9.8 feet. In this example, the volume of the room is 6,883 cubic feet. The clean air rate is the air flow rate multiplied by the outdoor air supply percentage. In this instance, the air flow rate is 760 CFM and the outdoor air supply percentage is 20%. The total amount of clean air rate going into the room is 152 CFM. To find the amount of ACPH that takes place inside the room, we take the clean air rate, which is 152 CFM, multiplied by 60 minutes, and divide that by 6,883. The result is 1.3 ACPH,[5] well below the recommendation of at least 5 ACPH.

The classroom with a horizontal unit ventilator is 1,010 square feet and has a ceiling height of 9.5 feet. In this example, the volume of the room is 9,595 cubic feet. In this instance, the air flow rate is 800 CFM and the outdoor air supply percentage is 29%. The clean air rate going into the room is 231 CFM. To find the amount of ACPH that takes place inside the room, we take the clean air rate, which is 231 CFM, multiplied by 60 minutes, and divide that by 9,595. The result is 1.4 ACPH.[5] This is a slightly better result, but still not the targeted 5 ACPH recommended by the Harvard T.H. Chan School of Public Health.





LEFT: Figure 3 shows with decreased temperatures, test scores increased by an average of 64 points.[4]

Expert Recommendations to Increase Ventilation

In both classrooms, we have inadequate ACPH. The experts recommend the following three options:

1. Improving Ventilation

- a. Natural ventilation
  - i. Open windows/doors
- b. Mechanical ventilation
  - i. Set the unit ventilator or the central HVAC system to the maximum outdoor air supply percentage the unit can handle.

2. Use MERV13, or better, filters on recirculated air

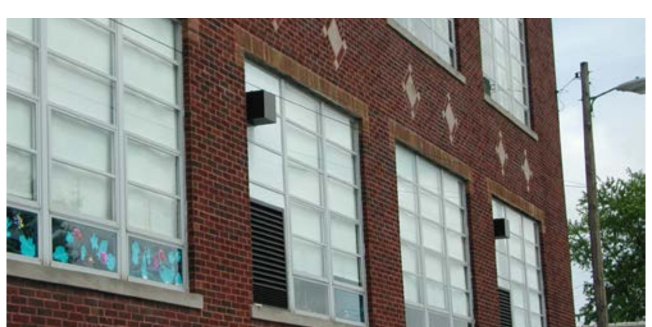
- a. Recirculated air that passes through a higher efficiency filter can be added to the CFM calculations to reach ACPH targets.
  - i. For calculations, assume 80% of the air is now "clean" air.

3. Add portable HEPA filtration systems to classrooms or other rooms that do not meet the recommendation.[5]

A Hybrid Solution

The Classroom

How would a Systemair vertical unit ventilator, such as the Changeair series vertical unit ventilator, compare to both of these examples? Using the same classroom specifications of 6,883 cubic feet, and using the Changeair non-compressorized vertical unit ventilator speciications, we can estimate the result. The vertical unit ventilator has packages that can be installed to reach maximum airflow that ranges from 800-2,200 CFM. For our purposes, we will use the 800 CFM package. Our Changeair series vertical unit ventilators can open up to allow up to 450 CFM of total outdoor air supply. Also, our Changeair series vertical unit ventilators use 2" MERV (8, 11, or 13) filters. Remember, the clean air rate is the air flow rate multiplied by the outdoor air supply percentage. The total amount of clean air rate in the room is 450 CFM. 450 CFM multiplied by 60 minutes, divided by 6,883 cubic feet and we get a total of 4 ACPH. If we were to introduce MERV13 2" filters, we can improve this number. We must take the 800 CFM and subtract it from clean air rate of 450 CFM, which comes out to 350 CFM. Take 350 CFM, multiply by 0.8 (clean recirculated air rate through MERV13), and we have 280 CFM. Take the clean air rate, 450 CFM, and add it to the clean recirculated air rate through MERV13, 280 CFM, and we have 730 CFM. 730 CFM multiplied by 60 minutes, divided by 6,883 cubic feet and we get a total of 6.4 ACPH; well above the recommendation presented by the Harvard T.H. Chan School of Public Health.



With our Changeair series vertical unit ventilators, faculty and students in classrooms can breathe better. No more sharing air—when the doors and windows are closed, the air that is in the room stays in the room. This kind of control allows for ease of temperature control from classroom-to-classroom. Also, with a nominal output of up to 450 CFM of clean air, and the MERV13 2" filter package, better, filtered air enters into the classroom, and one can assume at least 5 ACPH. This kind of capability may not be energy-efficient to run with other unit ventilators, but our Energy Recovery Wheel (ERW) with an Electronically Commutated Motor (ECM) relief, provides top-notch energy-efficiency when ventilation matters the most. Speaking of energy-efficiency, Changeair series vertical unit ventilators can be equipped with occupancy sensors and/or carbon dioxide sensors to further increase energy-efficiency. Also, our Changeair series vertical unit ventilators have the capability to be shut off or turned down at night because the units do not take long to warm-up or to cool-down the space for the day.

With a plethora of road-tested designs, an almost fully configurable cabinet, and internal options, our units can fit any classroom design. The Changeair series vertical unit ventilators retrofit abilities allow for minimal installation cost with 16" or 24" plenums that easily fit into exposed or covered ducts, or into false ceilings with diffusers. Our Changeair series vertical unit ventilators run in accordance with AMCA Standard 300, which is the Sound power testing standard, and the units also meet AMCA Standard 210 for airflow performance. Compared to other brands, we have a quiet, configurable, and energy-efficient system all rolled into one unit. Our Changeair series vertical unit ventilators are ideal for the classroom, and in our current times, are more necessary than ever.

The Offices and Breakrooms

Our Changeair units supplement much needed outdoor air flow and bring in cleaner air than is generally recommended. For smaller rooms in schools, such as breakrooms or the offices of faculty members, the Harvard T.H. Chan School of Public Health recommends a portable air cleaner with HEPA filters for rooms that do not meet the recommended ACPH. While there is no formal recommendation by the CDC for use of portable air cleaners with HEPA filters for decontamination of COVID19 air particles, prior CDC guidance of the SARS outbreak from 2002-2004 suggests theoretical efficacy for HEPA filters to remove COVID19 air particles; however, direct studies have not yet been performed.[6] Something else to consider would be the central HVAC system bringing recirculated air into the offices. For this issue, Systemair offers a portable filtration system called the PHS300. The PHS300 is a portable HEPA filtration system that comes with two different operating speeds. The PHS300 is a free-standing unit that draws the recirculated air from the central HVAC system and filters the recirculated air through the HEPA filters. The HEPA filters are 99.97% effective down to .3 microns. With easy maintenance, these filters can last for several years before needing to be replaced.

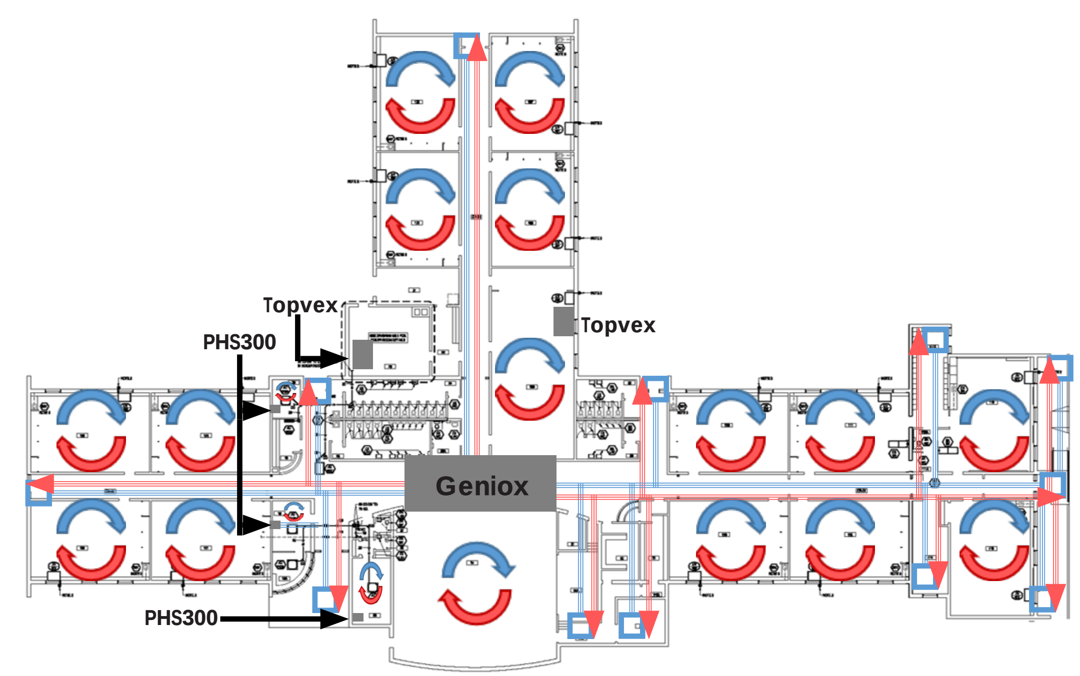
The Larger, Common Areas

In our schools, it has never been as important as it is today to upgrade our HVAC systems. Our Changeair series vertical unit ventilators are the ventilation solution for your classrooms, and our PHS300 portable HEPA filtration systems offer cleaner air for offices and breakrooms, but what about the larger, common areas such as gymnasiums, theaters, cafeterias, and hallways?

According to a nationwide survey conducted by the Government Accountability Office (GAO), an estimated 41% of public schools need to update or replace their HVAC systems.[7] In about half of the 55 schools GAO visited, the main complaints described by administrative personnel were leakage and damaged flooring and/or ceiling tiles.[7] These older systems are inefficient and are more expensive to run than newer equipment. Usually, when retrofitting, much of the ducts need to be replaced, and when they are replaced, long ducts can be harder to maintain.

In larger spaces of schools, bigger AHUs are needed. Naturally ventilating larger areas in common areas like gymnasiums, theaters, cafeterias, and hallways is difficult. During the summer months, schools can open an exit door to let some air in naturally, but during the winter months, doors are shut to keep the heat in. In the era of COVID19 and with many schools needing upgrades anyway, Systemair offers a seamless solution to cover these larger, common areas.

By using a hybrid HVAC system, classrooms are heated, cooled, and ventilated by a Changeair series vertical unit ventilator, while a Topvex AHU covers the gymnasiums, theaters, and cafeterias. A PHS300 portable HEPA filtration system in each office and breakroom would be installed to improve the IAQ of the recirculated air, and the Geniox unit would be the new central HVAC system, covering the hallways, offices, and breakrooms. The figure below shows how this system would work. The Geniox HVAC system can be used to bypass ducts, and create or connect to an existing Variable Refrigerant Flow (VRF) system. What makes our Geniox product stand-out from competitors is the ease of connectivity to various companies existing VRF systems and the semi-customizable design to fit your school's various needs.



ABOVE: Figure 4 is an example of a single-floor elementary school. This hybrid HVAC system has Changeair vertical unit ventilators in the classrooms, a Geniox central HVAC system covering the hallways and some common areas, a PHS300 portable HEPA filtration system in each office and breakroom, and a Topvex AHU in the gymnasiums, theaters, and cafeterias.

With the reopening of schools, taking every opportunity possible to mitigate exposure from COVID19 should be a priority. Temperature control and ventilation will help keep our schools safe and increase comfort and productivity. Adequate ventilation increases student performance and decreases the amount of indoor air pollutants, thus improving IAQ. Better temperature control can increase comfort and increases student performance.

A hybrid HVAC system will keep air separated in rooms, and where air cannot be separated, portable HEPA filtration systems can be installed to provide cleaner, recirculated air. A central HVAC system in the hallways and common areas can provide adequate ventilation, and heating or cooling needs. A stand-alone AHU in larger areas like a theater, a gymnasium, or a cafeteria would provide adequate ventilation, and heating or cooling needs. Most importantly, separating HVAC systems can mitigate illness outbreaks by confining recirculated air to a single room. When we follow expert recommendations, recirculated air is cleaner and the outside air that is brought in is more than is necessary.

In the pandemic, upgrading your HVAC system can have future advantages that are currently unrealized. Futureproof your HVAC system today, and worry less about tomorrow.

References

[1] EPA. "Why Indoor Air Quality is Important to Schools." EPA, 2021, https://www.epa.gov/iaq-schools/why-indoor-air-quality-important-schools.

[2] Toyinbo, Oluyemi, et al. "Modeling Associations between Principals' Reported Indoor Environmental Quality and Students' Self-Reported Respiratory Health Outcomes Using GLMM and ZIP Models." International journal of environmental research and public health, vol. 13,4 385. 30 Mar. 2016, doi:10.3390/ijerph13040385.

[3] Satish, Usha, et al. "Is CO_2 an indoor pollutant? Direct effects of low-to-moderate CO_2 concentrations on human decision-making performance." Environmental health perspectives, vol. 120,12 (2012): 1671-7. doi:10.1289/ehp.1104789.

[4] Haverinen-Shaughnessy, U, Shaughnessy, RJ. "Effects of Classroom Ventilation Rate and Temperature on Students' Test Scores." PLoS ONE, 10(8): e0136165. https://doi.org/10.1371/journal.pone.0136165.

[5] Allen, Joseph, et al. "5 Step Guide to Checking Ventilation Rates in Classrooms." Harvard Healthy Buildings Program, 2020, documents1.worldbank.org/curated/en/428511521809720471/683696272_201803110085432/additional/124547-REVISED-PUBLIC-17045-TF-Annual-Report-web-Apr17.pdf.

[6] Christopherson DA, Yao WC, Lu M, Vijayakumar R, Sedaghat AR. High-Efficiency Particulate Air Filters in the Era of COVID-19: Function and Efficacy. Otolaryngology–Head and Neck Surgery, 2020, 163(6):1153-1155. doi:10.1177/0194599820941838

[7] "School Districts Frequently Identified Multiple Building Systems Needing Updates or Replacement," GAO-20-494, 2020, https://www.gao.gov/assets/710/707517.pdf.

sales@systemair.net
www.systemair.net

Zephyr Creative • January 2023