United States Environmental Protection Agency

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SCHOOLS AS COMMUNITY CLEANER AIR AND COOLING CENTERS

MULTNOMAH COUNTY, OR

ACKNOWLEDGMENTS

U.S. Environmental Protection Agency

Multnomah County Health Department

Multnomah County Office of Sustainability

Portland Public Schools

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Cover
Map: Wildfire locations from 2003-2022, Urban Heat Islands, and annualized frequency of heat wave events.

Moderate to severe wildfire between 2003-2022

Urban Heat Island

Annualized Heat Wave Frequency between 2005-2017

15

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Data taken from: Federal Management Agency (FEMA); Wildland Fire Interagency Geospatial Services (WFIGS); U.S. Department of Commerce; U.S. Census Bureau; Esri; Garmin International, Inc.; U.S. Central Intelligence Agency; Center for International Earth Science Information Network (CIESIN), Columbia University. Basemap: Esri; USGS; NOAA

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PROJECT OVERVIEW

Communities across the United States are facing the impacts of climate change, including severe health consequences from disasters like heat waves and wildfires. Extreme heat and wildfire smoke disproportionately affect people who have existing health issues, such as cardiovascular disease, or who already experience poor air quality because they live, work, or go to school near industry or highways. Children are uniquely vulnerable to extreme heat and wildfire smoke, because of their size, physiology, and factors that include playing outdoors and having less control over their environment and exposure to harm.

EPA launched a small round of pilot projects in 2021 called Schools as Community Cleaner Air and Cooling Centers to address the combined hazards of extreme heat and wildfire smoke with a focus on spaces that serve a known vulnerable population: children. The pilots included Pima County, Arizona; Multnomah County, Oregon; and Kittitas County, Washington, and the overall project had four goals:

- Improving ventilation and filtration systems in public school facilities to reduce the risk of COVID-19 transmission and other airborne illnesses in schools.
- Creating healthy learning environments through improved indoor air quality in schools.
- Keeping schools open over the long-term in the face of increased frequency and severity of extreme heat events and wildfire smoke events.
- Creating cleaner air shelters and cooling centers located in areas known to have a higher number of people who are susceptible to serious health impacts from extreme heat and wildfire smoke.

Each of the partner counties, led primarily by public health agencies, found a local school district to partner with on these pilots. Most of the participating schools had already taken steps to address the first goal around COVID-19 reopening, either though portable air cleaners or more extensive upgrades to filtration within the HVAC systems. EPA's assistance focused more on additional steps to increase the resilience of school facilities to address wildfire smoke and extreme heat risks to students during the school day. The following report provides four sections that lay out these steps:

- The **Design Condition**, or potential scenarios for heat and smoke events that may help communities plan for school facility upgrades;
- **Technical Guidance** for facilities upgrades;
- **Education and Outreach** materials to explain the risks from heat and smoke, and ways to stay safe, both in school and at home; and
- Additional ideas **Beyond the HVAC Equipment** for building a holistic approach that considers the roof, campus landscape, classroom, and even transportation to and from school.

COMMUNITY PARTNERS

A major theme in the pilots was the issue of partnerships. Natural disasters and climate change are often seen as the realm of emergency management agencies. But the impacts of disasters on public health requires the expertise and partnerships of a broader coalition to build trust, to understand impacts, and to take appropriate action. For these pilots, workshop participants included:

- Public health agencies
- School district and local school leadership
- School facilities managers
- Environmental/natural resources programs
- Emergency management agencies
- Community-based organizations
- Faith-based organizations

This report, and the sections listed above, are not written to be used by each and everyone one of these different partners. The more technical sections may only be relevant to facilities managers and contractors. The education and outreach section may be most useful for teachers or community-based organization staff who are talking to students or users of shelters about the risks from heat and smoke. But as a whole, this report is meant to offer guidance for the variety of partners that must collaborate on making safer spaces for people during this increasingly frequent and more severe climate change impacts.

WHERE SHOULD RETROFITS HAPPEN FIRST?

Schools were chosen for this program because schools serve a population known to be more or most vulnerable to the impacts of extreme heat and wildfire smoke. This round of EPA projects focused on public school facilities owned by local government entities. But the lessons can be useful for other spaces serving children, including private schools, daycares, and other childcare centers.

All the pilot partners were interested in how the technical guidance and overall partnership approach could be applied to nursing homes, public libraries, wellness centers, and other spaces that serve both the public and other groups of people known to be more vulnerable, including older people, pregnant women, and people who are unhoused.

An early step in the pilots was to understand where there are people in the community that are more vulnerable to poor air quality and heat events. Pilot partners requested mapping that would help them determine which school locations might be prioritized for retrofits based on the population of children served. For instance, it may make more sense to retrofit a school facility in a neighborhood in a heat island area with a majority of homes lacking air conditioning, so that the children attending that school can be provided with a cool space to spend the day. Ongoing work, with local mapping and community input, is needed to help decision makers prioritize when and where any facility retrofits or upgrades happen.

KEY LESSONS

Across the pilots, the common lessons learned have included:

- The need to upgrade school facilities with improved filtration and cooling to keep kids safe during school days when extreme heat or wildfire smoke events occur.
- The need for the public, elected officials, and school boards to better understand the risks posed to both children's health and to the ability of schools to stay open and keep kids safe during extreme heat and/or wildfire smoke events.
- A long-term need to better understand how well people are prepared in their own homes to stay safe during these events and how to balance that with the need to create more community safe spaces that serve the public.
- Questions about opening school facilities to the public as cooling centers varied among the pilot locations and should be addressed specifically in each community. Some communities welcomed the idea of hosting public clean air and cooling centers, while others expressed concerns around the fact that centers must effectively provide wraparound homeless services to best serve people who are unhoused and who are the most frequent users of cooling centers.
- The need for ongoing discussions about how communities need to create a network of spaces to be used as cooling centers and clean air shelters, including the potential for school facilities to serve the broader public or even just families served by the school.

SCHOOLS IN A CHANGING CLIMATE

A CHANGING CLIMATE

Communities across the country are facing a changing climate, and in many places, this means hotter days and more of those hotter days per year. For other communities this means more dangerous air quality events—often due to smoke from wildfires—more frequently than in the past. And in some communities, they are dealing with both—increased heat and increased smoke events. Climate projections predict these events to increase over the next 50 years, and become an ever-growing concern for municipalities and communities in these regions.[1]

Preparing for this future will require a long- term, sustained effort to address these challenges to community health, well-being, and economic stability. This Playbook examines the need for action in one critical piece of social infrastructure—our schools—and offers a series

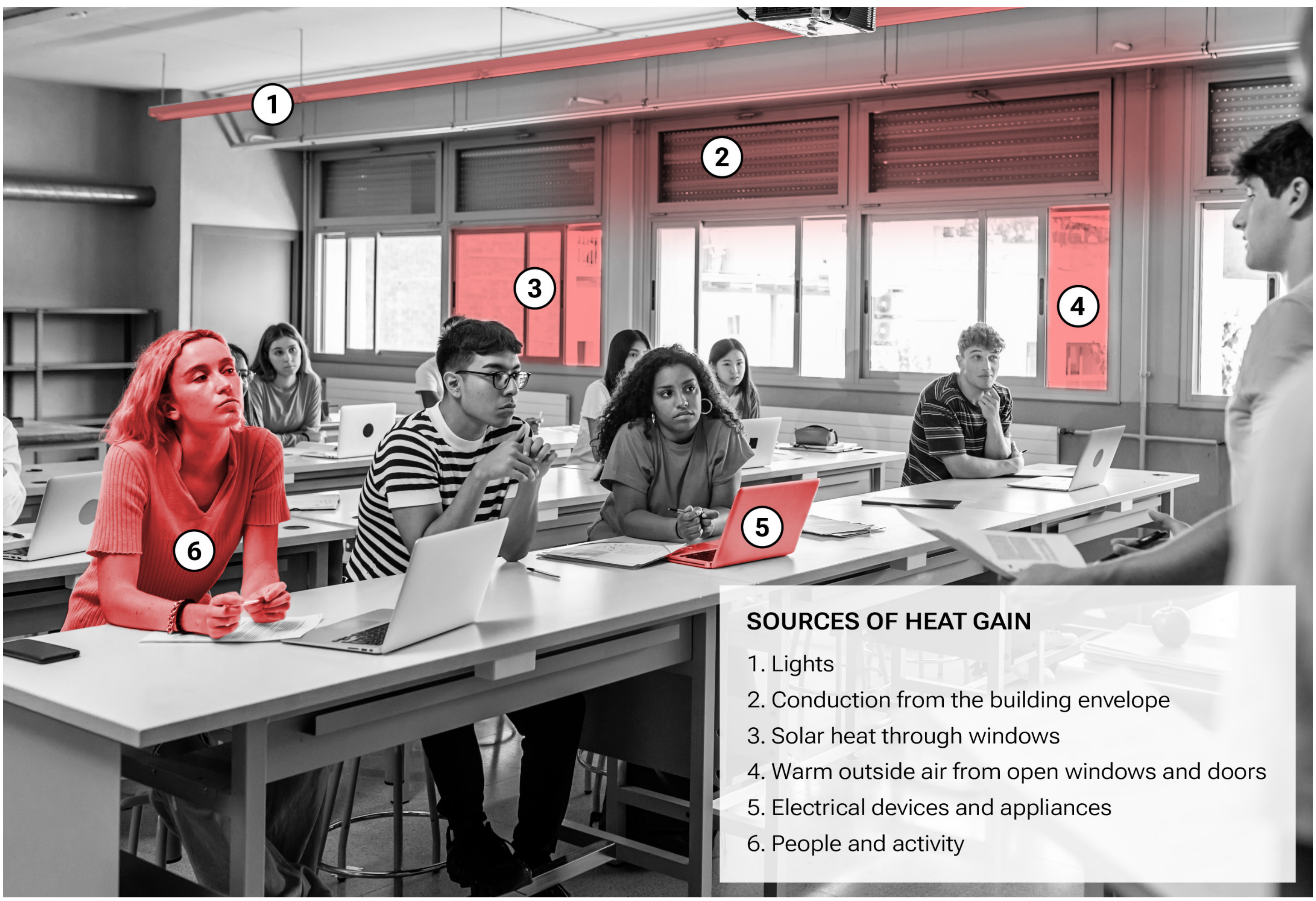


Figure 1: Sources of heat within a typical classroom.

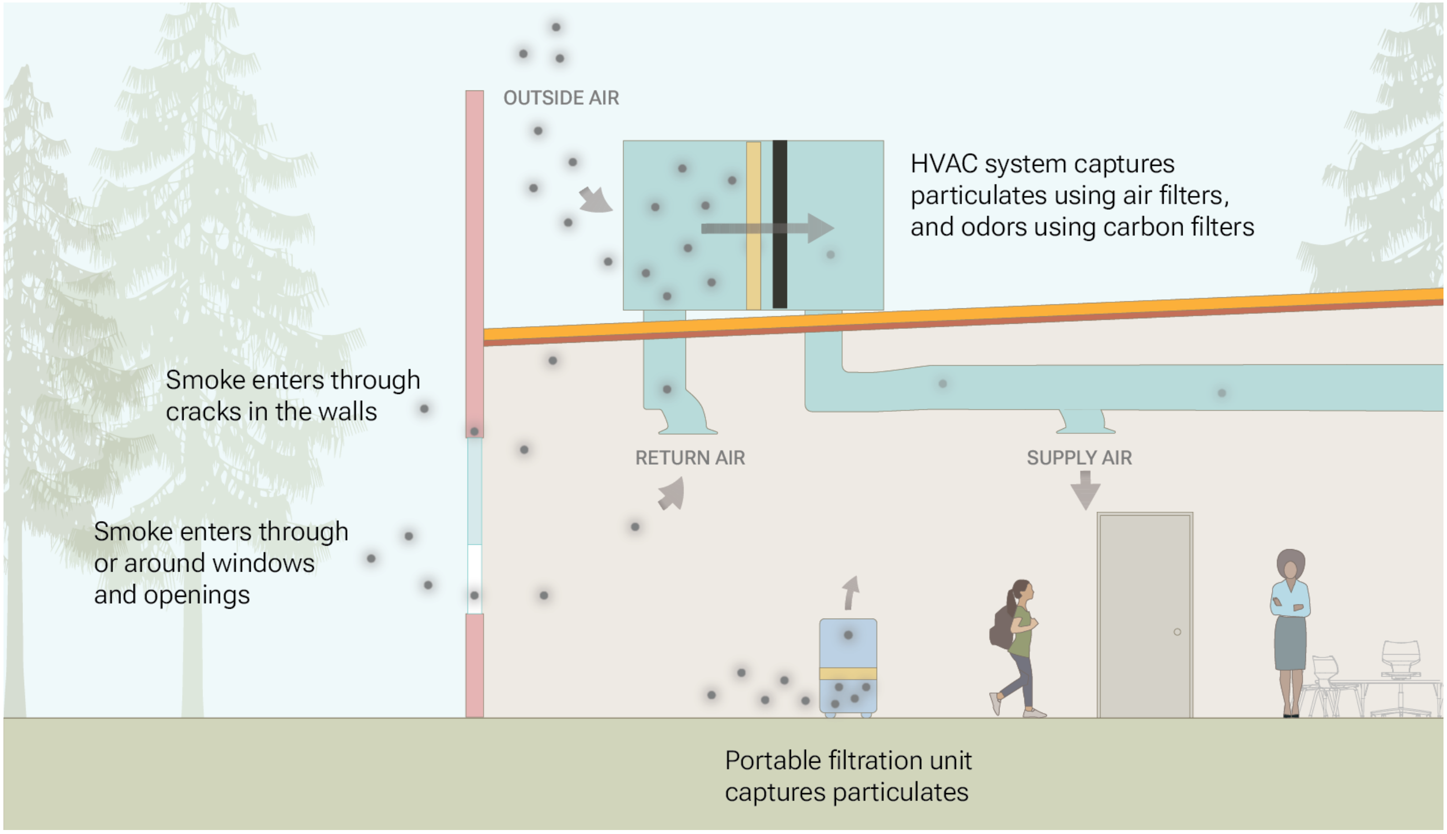


Figure 2: Sources of smoke infiltration and locations for smoke filtration during a smoke day event.

of recommendations for making them a safe place to shelter during heat and smoke events for the benefit of the children and the broader community.

VULNERABILITIES TO HEAT AND SMOKE

While high heat and poor air quality can be harmful to everyone, children, older adults, pregnant people, and people with preexisting health conditions like asthma are notably vulnerable.[2] Children are particularly sensitive to heat and smoke. Children have a smaller body mass to surface ratio than adults, making them more vulnerable to heat-related events. Children also are more easily dehydrated and overheat more quickly than adults, adding to their susceptibility to high-heat situations.[3]

Polluted air is especially harmful to children because they breathe faster and breathe in more air for their body weight compared to adults, even while resting. They are also more likely to be highly active while outdoors, causing them to breathe in more air at a faster rate than less active people. Children also have more permeable skin than adults, allowing more toxins from the air to enter their body through their skin. They have a more permeable blood-brain barrier and less effective filtration system in their nasal passages, which causes toxins from the air to affect their vital organs more readily.[4]

Heat and smoke are not just acute threats during extreme weather events. Chronic exposure to air pollution, including repeated exposure to wildfire smoke, can have lifelong health impacts for children, such as lowered lung function and a higher rate of asthma.[5] Research also suggests that exposure to particulate matter may have neurocognitive effects in children, including associations with Attention Deficit Hyperactivity Disorder (ADHD), school performance, and memory.[6]

VULNERABILITIES VARY FROM COMMUNITY TO COMMUNITY

More than 40% of people in the United States live in communities with poor air quality, places with failing grades for unhealthy levels of particle pollution or ozone, according to the 2022 State of the Air Report.[7] Within this group, people of color are over three times more likely to live in polluted counties than the white population.[8]

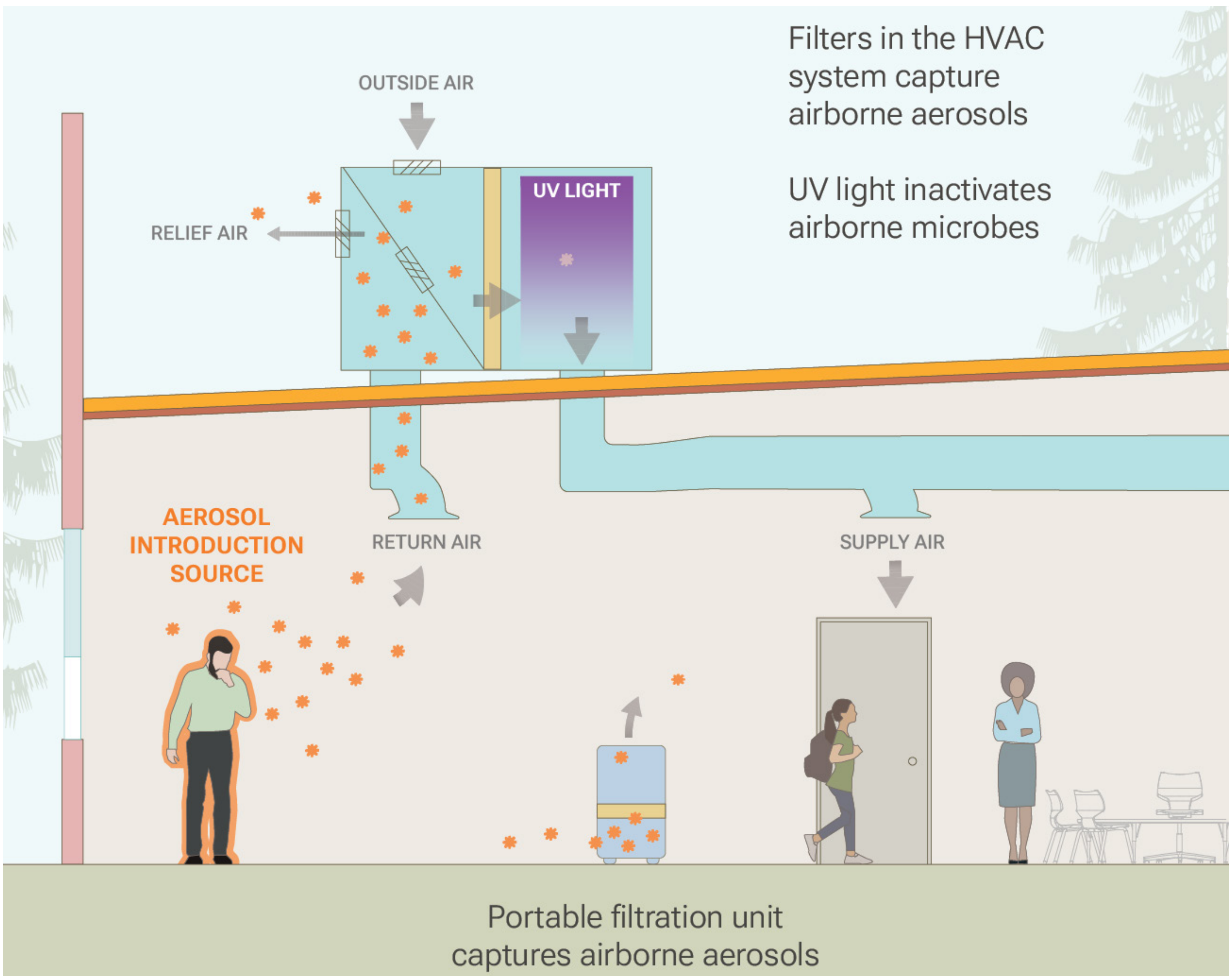


Figure 3: Sources of airborne aerosols and locations for aerosol filtration and deactivation of microbes.

During heat and smoke events, the lowest income residents within our communities are often at the highest risk and have the fewest available resources to seek refuge in other places. They often suffer the most detrimental effects because they have less flexibility to work from home, fewer resources to mitigate risks during these events, and often reside in homes that are less well insulated from outdoor heat and smoke.[9] While it is best practice during a wildfire event to ensure outside air openings such as windows and doors remain closed, people without air conditioning rely on opening windows for cooling, which exposes them to wildfire smoke if both disasters happen at once.

During heat and smoke events, a cool, cleaner-air environment at school may be the safest place for children, especially in high-risk communities. The transportation of children during these events, and ensuring that a parent or guardian is able to care for the child if they must leave school, are major logistical challenges for school systems, emergency management teams, and parents. The possibility of unintentionally putting children in harmful situations increases as the logistical issues become more complex.

SCHOOLS ARE CRITICAL RESOURCES DURING EMERGENCIES

Keeping schools functioning for a full school day during extreme weather events such as heat waves and smoke events is even more critical because the stressors on a community are likely to be the highest during these times. A school shutdown puts more people on the roads during potentially high congestion times and puts an extra burden on first responders—doctors, nurses, police—to balance ensuring the safety of their children and responding to the emergency.

Schools are also vital to the local economy. Maintaining cool, comfortable spaces at school, with cleaner air, during heat and smoke events helps reduce unexpected shutdowns during the school day. When schools are shut down unexpectedly, people from all walks of life must leave their workplace and care for their children, including those who would otherwise be responding to the heat and/or smoke emergency. As the frequency of heat and smoke events increases over the coming decades, these types of repeated disruptions can be a burden on the economic vitality of families and be a special hardship on low-income members of the community.

HEALTHY LEARNING ENVIRONMENTS BENEFIT THE SCHOOL SYSTEMS

Schools are central to a community. Schools provide many more services beyond education—they facilitate intergenerational bonding, provide vital health and welfare support for families and disseminate information throughout the community. Schools are central to the well-being of some of the most vulnerable members of our community. The minimum recommendations for air quality control to address viruses such as COVID-19 have also changed within the last three years. Keeping children safely in school—and learning—during dangerous heat and smoke days in addition to improving facilities to meet post pandemic air quality standards is a strong investment for a school system.

Healthy learning environments equal higher test scores and lower absenteeism. Asthma is the leading cause of school absenteeism and is often related to air quality. Students with uncontrolled asthma score lower on standardized tests than other students.[10] Higher temperatures in the classroom also adversely impact student performance on academic work.[11]

Even modest improvements in room temperatures have been shown to positively affect a student's ability to perform tasks successfully, especially those that require mental concentration. Schools and their partners can use recommendations from this Playbook to make investments that alleviate these barriers to learning, help keep schools open as a critical resource during heat and smoke events, while also improving the performance and outcomes for students.

DESIGN CONDITION

WHAT IS A DESIGN CONDITION?

Design Condition is the term used to describe a period of time that an HVAC system was designed to maintain the desired indoor temperature and humidity. The Design Condition helps establish potential scenarios a community may face in the future or are already dealing with but in lesser frequency. These scenarios help communities plan for future challenges and evaluate the resources needed to prepare for these events.

The Design Condition used in this Playbook responds to the request from partners to better understand the type of event that might trigger a school closure.

DESIGN CONDITION FOR HIGH HEAT EVENTS

As communities across the country face the effects of climate change, the number of days temperatures will climb to dangerous levels is forecast to increase significantly. The National

Heat Index

Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution | Extreme Caution | Danger | Extreme Danger

Figure 4: Heat Index Chart.

Weather Service has established a guideline for “Dangerous” and "Extremely Dangerous” heat conditions. These designations are based on the Heat Index, which is a combination of heat and humidity, and are determined using information on the adverse health effects of high heat.[12]

On Dangerous days—when the Heat Index is between 103°F - 124°F—prolonged exposure to or activity during these conditions could result in heat stroke or related heat illnesses, even death. On Extremely Dangerous days—at 125°F or higher— any exposure to these conditions is considered potentially harmful or life-threatening.[13]

Many communities already see a significant number of days in the Dangerous or Extremely Dangerous range. In most of these places, the number of these days is forecasted to increase significantly over the next 20 years.[14] As these events increase in frequency, common activities like outdoor sports and exercise, outdoor jobs in construction or landscaping, and even walking between buildings will become more hazardous.

Events that raise the Heat Index into the Dangerous and Extremely Dangerous levels are considered the Design Condition for the Playbook.

Since HVAC systems are not often designed and selected for extreme peak events, it is likely that the Design Condition for High Heat Events exceeds the Design Condition for selecting HVAC equipment which often is limited to the design temperature at which there are no more than 0.1% to 0.5% of hours greater than that design temperature. It is important that each location take into consideration the risk for extreme heat events and climate change, in addition to historical weather trend data such as the 0.1% or 0.5% design day. Tools such as Weather Shift factor into changing climate conditions to inform decisions about equipment for buildings that are anticipated to be in use for 25+ years.

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

Figure 5: Air Quality Index Basics for Ozone and Particle Pollution.

DESIGN CONDITION FOR SMOKE EVENTS

Wildland fire events have become a more common occurrence from 2013-2023 and are forecasted to increase in the coming decades.[15] In addition to anticipated increases in wildfires, there are plans to increase prescribed fire activity over the next 10 years as well. Smoke from these events is a serious health risk for children, older adults, and other groups that are sensitive to smoke, such as people with asthma or other preexisting health conditions. The Environmental Protection Agency (EPA) uses a category system called the Air Quality Index (AQI) to report on air quality, and the greater the AQI value, the greater the health concern.

AQI measures how clean the air is and focuses on potential health impacts of breathing unhealthy air. AQI is measured on a range from 0 (the cleanest air) to 500 (the most dangerous air). Poor air quality can go beyond the AQI scale, however, and recent events have measured PM2.5 concentrations "beyond the AQI" 500 level.[16] When smoke events release particulate matter into the air, they affect the AQI, making the air less healthy to breathe.[17]

EPA analysis of air quality data during three recent wildfire events showed one to twelve consecutive days with an AQI over 150 at locations impacted by the Labor Day Fires in 2020.[18] These levels of pollution have a potential negative health effect on all people, regardless of age or health status, and are especially threatening for people that are sensitive to smoke or poor air quality. As wildland fires increase in frequency, the need for ways to protect people from poor air quality will increase.

However, the AQI is based on 24-hour averages, so some events that are shorter in duration or intermittent may not immediately raise the AQI to unhealthy levels despite impacts on visibility and potentially health. People may have to rely on personal observations or shorter-term data from low-cost sensors to respond appropriately, and these situations can be complex for schools to manage. To the extent possible, schools should use air quality sensors in classrooms to determine site-specific conditions.

AQI levels from smoke events that rise into the Unhealthy for Sensitive Groups and above range are considered the Design Condition for the Playbook.

DESIGN CONDITION MATRIX OVERVIEW BY SYSTEM

Please refer to the following high-level recommendations for each design condition in Figure 6. Note that the effectiveness of these recommendations and the varying levels of effectiveness of combining these recommendations in different ways is explained in more detail throughout the report. Refer to the General Recommendations sections for additional information as well as the Readiness Checklists enclosed.

	SARS-COV-2[1]	SMOKE (WILDFIRES)	HEAT WAVES	HEAT AND SMOKE
PM 2.5/PM 10 Filtration[2]	MERV 13 filters	MERV 13 filters	Code minimum MERV 13 filters recommended for increased air quality	MERV 13 filters
Enhanced Air Scrubbing[2]	Ultraviolet light (optional)	Carbon filters to address smoke odors.	N/A	Carbon filters to address smoke odors.
Ventilation	Enhanced ventilation to achieve recommended equivalent air changes	Occupant density based ventilation per local code requirements	Occupant density based ventilation per local code requirements	Occupant density based ventilation per local code requirements
Equivalent Air Changes	2 ACH min 4 ACH good 6 ACH very good 8 ACH excellent Recommended 5-6	N/A	N/A	N/A
Cooling Capacity	Increased capacity to address increased ventilation	N/A	Meet increased cooling requirements via mechanical and passive cooling solutions	Meet increased cooling requirements via mechanical and passive cooling solutions
Heating Capacity	Increased capacity to address increased ventilation	N/A	N/A	N/A
Fan Performance	Improve fan performance to overcome increased filtration pressure drop	Improve fan performance to overcome increased filtration pressure drop	Improve fan performance to achieve max supply design airflow	Improve fan performance to overcome increased filtration pressure drop & achieve max supply design airflow
Max Temperature Equipment Concerns	N/A	N/A	Confirm with equipment manufacturers for max operating temperature limitations. 125F is a common limit, however, it is not a universal limitation and manufacturers should be consulted.	Confirm with equipment manufacturers for max operating temperature limitations. 125F is a common limit, however, it is not a universal limitation and manufacturers should be consulted.
Building Pressurization	N/A	Positive	N/A	Positive
Portable Filtration Units	Portable filtration units provide benefit	Portable filtration units provide benefit, but addressing filtration at the outside air source likely performs better.	N/A	Portable filtration units provide benefit, but addressing filtration at the outside air source likely performs better.
Additional Notes	Health protocols such as social distancing, mask use, cleaning surfaces, etc. that extend beyond HVAC should be deployed. Refer to your local health agency and the Center for Disease Control for additional guidance.	Monitor indoor air quality in a representative space. Consider mask use should poor air quality persist after exhausting applicable HVAC modifications. Repairs to the building envelope and keeping doors and windows shut will also reduce smoke entrainment.	Passive and proactive solutions for cooling can be deployed to address heat waves. Repairs to the building envelope and keeping doors and windows shut will also reduce heat entrainment.	Monitor indoor air quality in a representative space. Consider mask use should poor air quality persist after exhausting applicable HVAC modifications. Passive and proactive solutions for cooling can be deployed to address heat waves. Repairs to the building envelope and keeping doors and windows shut will also reduce smoke and heat entrainment.
NOTES	1: Strategies for SARS-CoV2 should be considered for all design conditions as a post pandemic best practice. 2: Refer to Appendix C for warnings associated with adding filters to existing systems.			

Figure 6: Design Condition Matrix Overview by System. Refer to General Guidance and Design Condition Guidance for Additional Information.

MULTNOMAH COUNTY - CLIMATE FORECAST FOR HEAT AND SMOKE

Historically, "Oregon rarely experiences days classified as Dangerous or Extremely Dangerous according to the NWS Heat Index," according to the States are Risk report. However, in the summer of 2021 a heat dome event raised temperatures to unprecedented levels in the Portland region for more than 4 consecutive days, with a high of 118°F.[19] By 2050, the state is projected to see nearly 10 days a year that are classified as Dangerous or Extremely Dangerous[20] and the number of heat wave days will be almost 4 times as high in 2050, projected to go up from around 10 days per year to 40 days per year.[21] According to the States are Risk report, "Oregon has more than 100,000 people aged 65 and older, or less than 5 years old, living below the poverty line." These groups are considered to be especially vulnerable to extreme heat.[22]

Smoke challenges in Oregon are acute, and forecasted to increase.[23] Again, the States at Risk report says, "More than 1.2 million people in Oregon—about 30 percent of the state's population—live within the wildland-urban interface, where developed and wild lands converge and intersperse, and vulnerability to wildfire is elevated." By 2050, the average number of days in Oregon with high wildfire potential is projected to increase more than two fold from just under 15 to more than 30 days each year.[24]

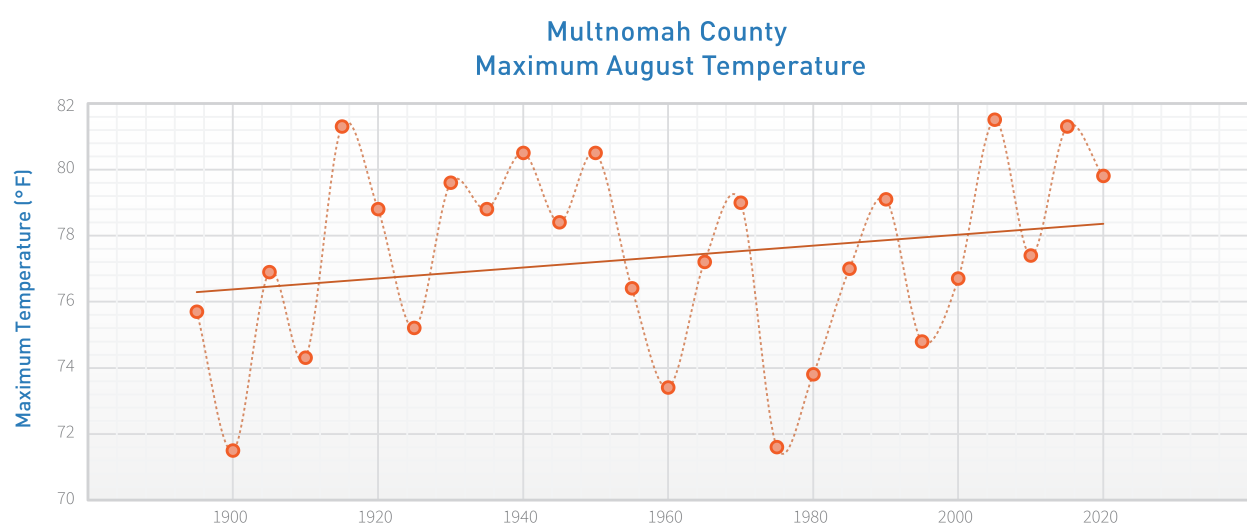


Figure 7: Multnomah County August maximum temperature between 1895-2020

PORTLAND PUBLIC SCHOOLS EXISTING RESOURCES

Portland Public Schools (PPS) has a 2022-2023 School Closure Plan which outlines protocols and thresholds for various conditions including Extreme Heat and Air Quality events during the school year.

In regards to extreme heat, events that raise the heat index to 95°F or higher for the day while school activities are in session is considered the Design Condition that will prompt a meeting of the School Closure Decision Team. A heat index of at least 105°F for more than three hours per day for two consecutive days, or a heat index of between 91°F-103°F for three consecutive days or more is the design condition for which a school closure is considered.[25]

Regarding smoke events, the PPS School Closure Decision Team considers an event when the AQI is 101 or higher as the design condition that activates a plan to move all outdoor activities and sports indoors. An AQI of 250 or greater prompts the closure of all schools.[26]

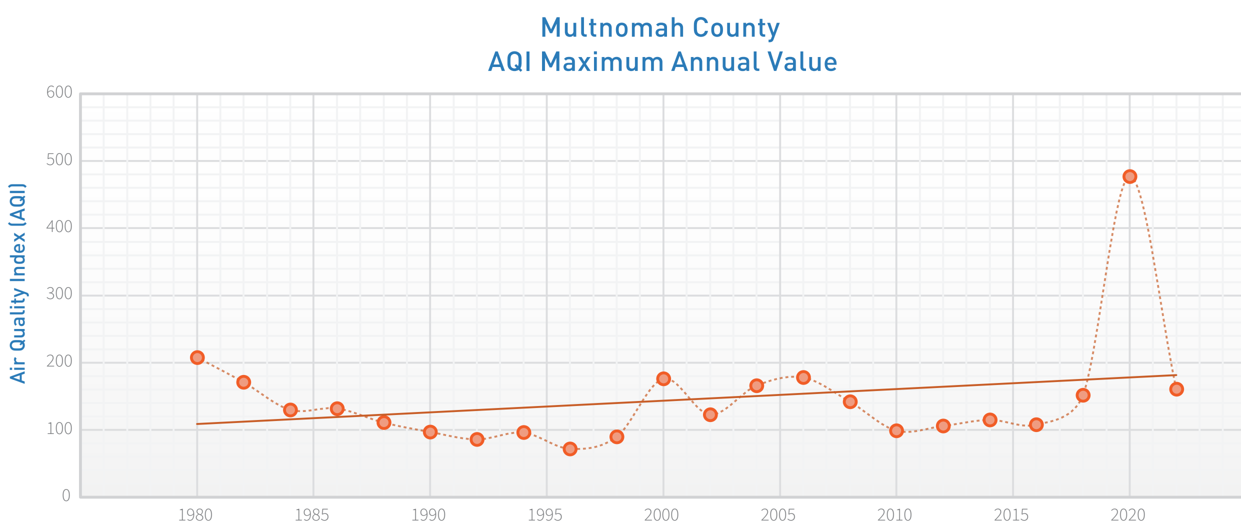


Figure 8: Multnomah County AQI maximum annual value between 1980-2022

TECHNICAL GUIDANCE

DESIGN CONSIDERATIONS

While the three design considerations - COVID-19, Smoke Days, and Heat Waves - are different, COVID-19 and Smoke Days are similar in that they have a primary focus on addressing indoor air quality. There are some differences in approaches and techniques, but they are more similar to each other than Heat Waves. Refer to Figure 6 with summary recommendations of each Design Day condition as well as recommendations for compounding conditions.

COVID-19 CONSIDERATIONS

The COVID-19 pandemic has resulted in greater research on transmission of infectious aerosols such as SARS-CoV-2. This research has informed us on necessary HVAC system modifications that improve the indoor environment while reducing conditions that lead to increased infections. Note that HVAC Systems are only a part in the larger list of considerations when addressing COVID-19. Social distancing, wearing masks, cleaning and sanitization practices, quarantining when ill, etc. all factor into the exposure of COVID-19 and similar diseases. Where available, federal, state, and local regulations for these practices should be followed first. Any recommendations made are in the effort to mitigate the spread of COVID-19 and not a guarantee expressed or implied that it will fully prevent the spread of airborne infectious diseases.

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) is a leading international professional organization that establishes standards and recommendations for HVAC systems. ASHRAE formally published recommendations on October 19, 2021 for addressing COVID-19 in the built environment.[27] The following subjects are covered as part of ASHRAE's recommendations:

1. Public Health Guidance
2. Ventilation, Filtration, Air Cleaning
3. Air Distribution
4. HVAC System Operation
5. System Commissioning

Public Health Guidance includes following all current regulatory and statutory requirements and recommendations at a national and local level.

The use of enhanced filtration is recommended as a part of increasing the space's equivalent air change rate. The filter Minimum Efficiency Reporting Value (MERV) recommended for filtration to filter airborne viruses should be no less than a MERV-13. MERV-13 filters have been observed as the point of diminishing returns for filtering airborne viruses such as influenza, as seen in Figure 9.

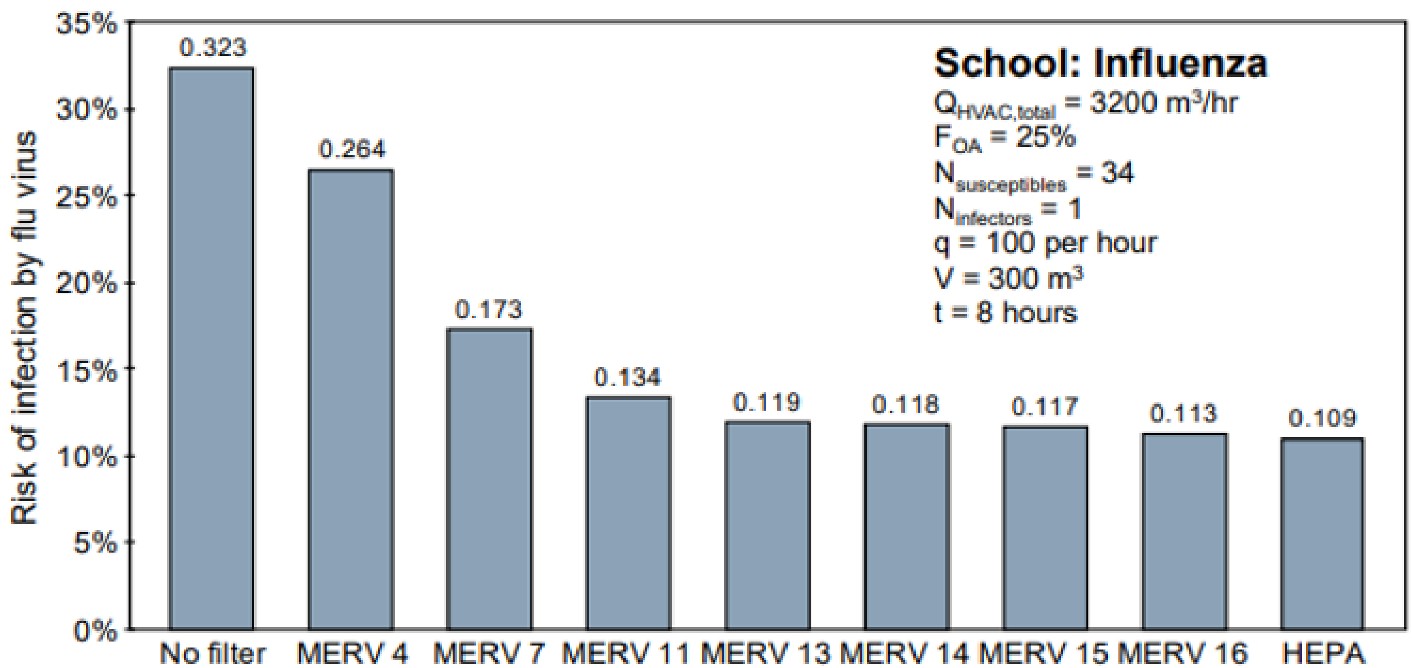


Figure 9: Projected risk of infection by influenza virus during an 8-hour day in a hypothetical classroom environment with 35 child occupants and 25% outside air supply using a range of HVAC filters installed in a system with a recirculation rate of 8.14 per hour.

Maintaining minimum outdoor airflow rates for ventilation is required by code and national ventilation standards. ASHRAE 62.1 and ASHRAE 62.2 dictate minimum ventilation for most of the country, but some local code authorities have more stringent codes, such as in California where the Building Energy Efficiency Standards include additional compliance measures for minimum ventilation. Enhanced ventilation can be beneficial to lead to additional dilution when enhanced filtration cannot be deployed. Refer to the General Recommendation Sections on Ventilation and Equivalent Air Changes.

While proper filtration standards have shifted in response to COVID-19, increasing focus on airborne pathogens and using filters that aid in slowing their transmission, code minimum for education facilities in many states still allows for MERV-8 filtration.

Refer to the Particulate Matter Filtration Section of this document for additional information and considerations when retroactively changing or upgrading filters. The existing conditions such as the space to install a filter, the frequency of filter changes, and the cost of the filters should all be considered when making final decisions.

In-room air cleaning or in-duct air cleaning by way of UV-light will also aid in reducing airborne aerosol transmission by disabling the ability for the airborne infectious disease to spread. UV-lights should be installed with special attention to ensure no occupant exposure. Refer to the Enhanced Air Scrubbing section of this document for additional information.

The deployment of portable filtration units also increases the equivalent air changes of a space by increasing the number of times the air is passed through a filter. UV-light are also available as an option for most portable filtration units for additional sanitization of the air. Refer to the Portable Filtration Unit section of the document for additional information.

Air distribution should increase the mixing of air within a space to mitigate spot concentrations of airborne viruses and reduce person to person exposures. Air distribution modifications are beyond the scope of the recommendations included in this report.

HVAC System Operation recommendations by ASHRAE also include the following:

1. Maintain temperature and humidity design set points.

2. Maintain equivalent clean air supply required for design occupancy whenever anyone is present in the space served by a system.

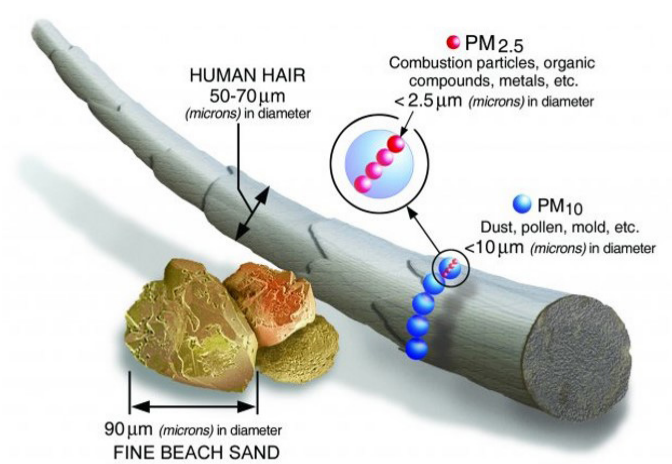


Figure 10: Particulate Matter.

3. When necessary to flush spaces between occupied periods, operate systems for a time required to achieve three air changes of equivalent clean air supply.

4. Limit re-entry of contaminated air that may re-enter the building from energy recovery devices, outdoor air, and other sources to acceptable levels.

ASHRAE's final recommendation is to perform commissioning,[28] which is a process to verify that a facility and systems meet operational requirements. Commissioning, whether at the time of new construction completion or retroactive commissioning, is a good building ownership practice to verify systems are operating per the original design intent.

SMOKE DAY CONSIDERATIONS

Regional wildfires present issues with smoke infiltration affecting indoor air quality. Ventilation requirements under normal conditions are made on the assumption that the outdoor air quality is better than the indoor air quality. HVAC systems are designed to maximize outside air intake while minimizing the energy costs associated with heating, cooling, and controlling humidity. When outside air quality reaches the orange level on the AQI risk index, Unhealthy for Sensitive Groups, HVAC operators and building managers need to adjust operations to maintain safe indoor conditions. If the AQI levels rises above 100, the below considerations are recommended. In addition to the recommendations below, guidance provided by local governing authorities are to be observed.

Smoke-laden air includes a mixture of microscopic particles and chemicals that can produce odors and can have detrimental effects on human health. Filtration systems with up to MERV-8 filters will not be effective for smoke removal. Increased filtration up to MERV-13 or better and the addition of carbon filtration can create cleaner indoor air if used properly. Filters must fit correctly, the HVAC system needs to be leak free, and the system must run continuously to provide continual filtration.

Adding higher efficiency filters to existing HVAC systems may introduce additional resistance (static pressure losses) that the original fans and motors may not be able to overcome. If deeper filters are compatible with the filter rack, the resistance may not be increased. It may be possible to retrofit existing fans with larger motors to accommodate new filters. High efficiency filters are usually deeper than standard filters and may not physically fit within existing equipment. The highest efficiency filters, HEPAs, often have a different mounting system that is not compatible with or able to be retrofitted to existing equipment.

Where new filters are able to be retrofitted, and existing fans can handle their added resistance, there is an energy cost penalty associated with the additional pressure losses caused by the filter. The benefit of centralized filtration is that it addresses the particles at the source and does not bring them into the room. Since poor air quality days can be forecasted, the increased filtration can be deployed on an as needed basis. Ensure that consideration is given to the negative impacts of adding additional filtration could have on the larger system. Refer to the Particulate Matter Filtration section of this document for additional information.

Portable filtration units can also be deployed to assist the central filtration. Monitoring the indoor air quality can be an indicator if portable filtration units should be used in addition to centralized filtration. Refer to the Portable Filtration Unit Section for additional information.

Existing HVAC controls may need to be modified, either through building management software or through physical alteration of equipment to reduce outside air intake to the minimum level that maintains positive pressure and adds filtration to the intake where possible, when outdoor conditions are poor.[29] This includes closing outside air intakes, reducing building exhaust, and resetting building pressurization setpoints.

Buildings are generally designed to be slightly positively pressurized, meaning more outside air is introduced to the building than is exhausted or relieved to the outdoors. This is done to reduce infiltration and manage building humidity. Modern buildings are very tightly constructed with low leakage, and it takes a small amount of air to maintain nominal pressurization. However, in practice, many buildings fall out of equilibrium and do not operate under positive pressurization in all conditions. For this reason, older buildings tend to be more susceptible to needing adjustments to ensure positive building pressure.

Maintaining positive building pressurization during a regional smoke event is important to keep smoke from entering the building. Overriding normal building operations for a smoke event should including resetting the normal building pressurization setpoints to a high differential and ensuring the fans and dampers are coordinated to maintain the control of airflow. Refer to Building Pressurization for additional information.

Improving indoor air quality during a smoke event requires minimizing outside air intake, high levels of filtration, and maintaining positive building pressurization. Non-HVAC interventions can also be deployed such as making repairs to the envelope to reduce the leakiness of the building as well as limiting the number of outside air openings such as doors and windows during a smoke event. Some, but not all systems can be retrofitted to include these strategies.

HEAT WAVE CONSIDERATIONS

As seen in the data presented by Berkeley Earth,[30] temperatures are rising, and the frequency of heat waves are increasing. Building heating and cooling loads are calculated using historical weather data and calculating the temperature where there are no more than 0.1% (8.76 hours) or 0.5% (43 hours) of the year at or above that temperature. Due to the effects of climate change, these extreme conditions are occurring on a more regular basis. When the design conditions used for sizing equipment are surpassed, HVAC systems may not be able to keep up, resulting in uncomfortable or otherwise unacceptable indoor conditions. When the temperature climbs into the dangerous and extremely dangerous zones on the Heat Index Chart in Figure 4, the below considerations are recommended. In addition to the considerations below, guidance provided by local governing authorities are to be observed.

Right-sizing building HVAC systems is important to reducing equipment first costs and on going energy consumption. Oversized equipment that operates at a high turn down is generally less efficient than right-sized equipment. Ensuring that equipment is right-sized for extreme conditions requires consideration of how that equipment will perform under normal conditions.

Addressing a heat wave may include adding supplemental standby equipment that is only deployed in emergencies. Where possible, shedding any unnecessary loads would allow systems to maintain operations. It may be possible to modify duct, pipe, and electrical systems to allow for less critical areas to be isolated or turned-down during critical times.

Reducing loads during a heat wave may include usage and behavioral changes. Allowing higher indoor air setpoints, minimizing the use of heat generating equipment (computers, kitchens, laboratories), going to hybrid work schedules (some work hours are performed off-site, lowering occupancy at certain times), and shifting events to off-peak hours are behavioral changes that would reduce loads.

Buildings that have increased outside air ventilation rates above code minimum for the benefits of improved indoor air quality may consider lowering those rates during extreme temperature conditions.

Various HVAC systems will have different responses to extreme temperature conditions. Refrigeration based systems (DX cooling coils) that rely on air cooled condensing units will continue to operate but fall short of hitting their setpoints resulting in warmer indoor air temperature. Water-cooled systems that rely both on outdoor air temperature but also outdoor wetbulb temperature (a measure of the air's ability to evaporate water) are more susceptible to degradation at extreme conditions. There is often only a few degrees of wet-bulb temperature separating a piece of equipment from operating at 100% to dropping off to near zero capacity.

PROJECT PRIORITIZATION

As many of the recommendations included throughout this playbook have associated costs, establishing a decision-making process for projects that aligns with other ongoing project prioritization techniques is recommended.

As an initial step, making decisions and commitments for new designs or system replacements by updating design standards will allow for future systems to include technologies, strategies, and/or options that will assist in addressing COVID-19, Smoke Days, and Heat Waves.

When making decisions for improving existing systems, finding ways to align with already budgeted/planned deferred maintenance cycles where money is already provisioned for improvements can result in gaining better alignment from stakeholders who approve projects.

When seeking additional funding off-cycle, aligning with goals around the following key performance indicators can be used in setting priorities. Note that the following list is not exhaustive, and the ideas for aligning priorities are not listed in any particular order.

CRITICAL SPACE DESIGNATION

Investments can be made for a specific space that could be used as a designated space during the design consideration days. While the feedback from multiple campuses is that hosting the students in a single large space without an activity or education program is not feasible, the space could be either set up to serve a group of people that are more at risk, serve as a test taking center, or serve the outer community.

The best spaces for this designation include those spaces that include the following design features:

1. High occupancy densities
2. High cooling capacities
3. Have permanent or temporary standby power capability
4. Won't impact normal school operations or function by their use
5. Example spaces include:
    - Gymnasiums
    - Auditorium
    - Performing Arts Centers
    - Cafeteria

NUMBER OF STUDENTS/FACULTY IMPACTED

As a part of this study, user feedback received indicates that priority is placed on impacting the most students and faculty with each project. Portland Public Schools in Multnomah County prioritized major renovations at high schools since more total students would benefit from upgrades over time as even young children in the district would eventually attend high schools within the school district.

STUDENTS/FACULTY MOST AT RISK

Based on the risk assessment programs made available through the EPA, investments should focus on campuses or student / faculty populations that are most at risk. A mapping and screening process based on categories of data that identify and evaluate the groups of people that are most vulnerable, similar to those listed in Figure 11, can guide a community in determining which school buildings to prioritize.

Starting with available data on present threats, like heat or smoke, this information can be layered with considerations of vulnerable populations in the community using indicators like income and age. Analyzing access and density can further zero in on how the community can select facilities that serve the greatest number of people. Once an area has been identified through the data screens, a review of facilities that would be best suited for the upgrades will help identify which locations should be selected. For this report, we are evaluating school buildings, however, this methodology can be applied to other buildings such as libraries or hospitals.

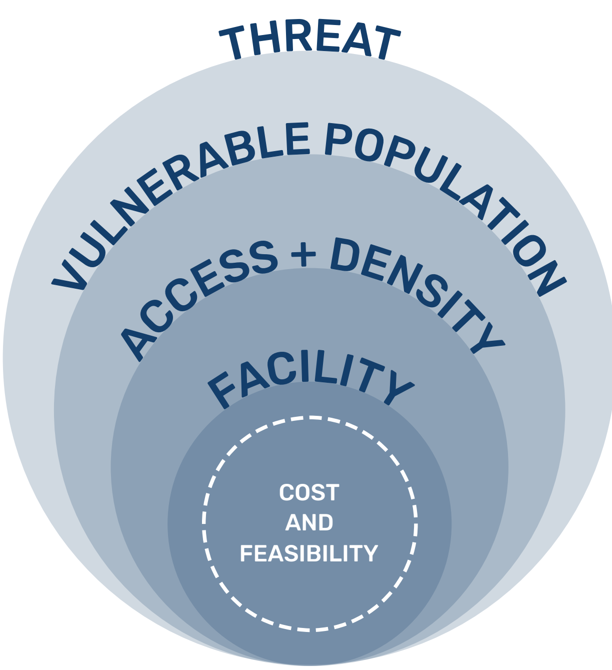


Figure 11: Risk Assessment Prioritization Process Diagram.

EPA also developed an environmental justice (EJ) mapping and screening tool called EJScreen based on an approach that combines environmental and demographic indicators in maps and reports.

OPERATIONAL COST SAVINGS & SIMPLE PAYBACK

The initial capital investment for an energy improvement project is often weighted against its break-even point. This is the point where the operational cost savings have accumulated over time to have paid for the initial capital cost. This point is called the simple payback. Simple payback is financial management and facility planning agnostic and the savings associated with the capital improvement can go into a green revolving fund or into the general fund. If improvements are being made to achieve operational cost savings, consider including features and techniques that are described as best practices throughout this report.

GREEN REVOLVING FUNDS

Green revolving funds are financial tools to track operational cost savings associated with infrastructure improvements then reinvesting those savings into future projects. This allows an avenue to continue to reinvest in more energy efficient equipment and couple other improvement projects such as improvements to address COVID-19, Smoke Days, and Heat Waves that may not have a good financial return on investment as a standalone project. See the dynamic scenario planner below as an example.

ENERGY SAVINGS

Upgrades to equipment can be tied into a larger energy savings program. The state of Washington is an example where the Washington Clean Buildings Act, or House Bill 1257, requires operating existing buildings below specific energy thresholds by certain year milestones. Failure to do so will result in financial penalties of the building owners. Other larger institutions have energy performance commitments and/or goals where energy use reductions are priorities. Finding opportunities to make improvements for the preparation for smoke days and heat wave days that correspond to energy savings not only will align with existing stakeholder missions, but it will also expand the applicability for government financial assistance such as the Inflation Reduction Act. These projects are often identifiable via an Energy Audit, during which an electricity consumption and energy efficiency assessment is made.

When determining retrofit, an analysis of HVAC units that are nearing the end of their life-cycle or units that are highly inefficient should take precedence. Strategies to mitigate infectious

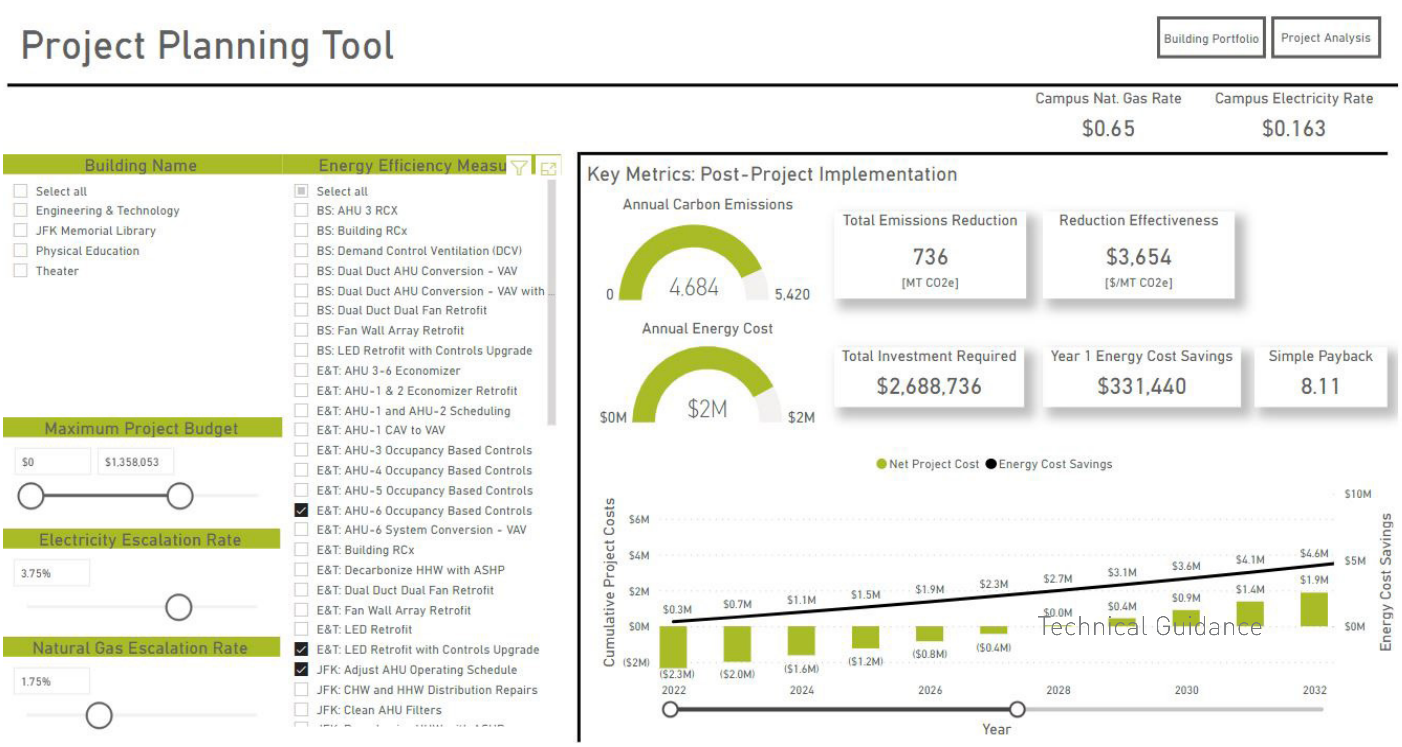


Figure 12: Example Dynamic Scenario Planner.

diseases such as COVID-19 and to mitigate smoke from wildfires may negatively impact a building and increase its Energy Use Intensity (EUI). By prioritizing the replacement of existing inefficient HVAC systems with a new efficient system, it is expected that buildings will have a net positive energy savings even with the energy loss associated with high efficiency filters.

OPERATIONAL CARBON EMISSION REDUCTIONS

Many school districts and education campuses have committed to clean energy and decarbonization. These schools, however, have several pieces of equipment that leverage natural gas or other fossil fuels and have associated operational carbon emissions. As equipment is evaluated for replacement, the on-site carbon reductions can be factored into the decision for equipment replacement as well as the energy use and indirect carbon emissions from fossil-fuel burning power plants (Scope 2 emissions). If financial analysis is required to couple with the operational carbon emissions, the social cost of carbon can be considered and, as of March, 2023, is estimated at $185 per ton of CO2e.[31]

RESILIENCE PLANNING

Resiliency concerns are allowing K-12 institutions to receive additional funding to overcome discrete events like utility power outages, rather than forcing them to use "snow days" or similar when HVAC systems are not working. While investing in resilience, additional capacity/systems can be built into the program to ensure that COVID-19, Smoke Days, and Heat Waves are factored into the resilience plan.

EXAMPLE DYNAMIC SCENARIO PLANNER

Figure 12 contains an example of a dashboard used for dynamic scenario planning. These dashboards can be used to allow the school to select different project options to optimize the return on investment, energy impacts, first capital cost, and review the cumulative cash flow in the form of a green revolving fund. These planners are developed using the ASHRAE Level II Energy Audit framework, however, the reporting and modeling is more

Figure 13: (Top) California State University Long Beach Housing Commons and Administrative, (Bottom) Energy Model & Load Calculation Building Massing.

targeted to actionable solutions. Improvements around COVID-19, Smoke Days, and Heat Waves can consider being incorporated into a dynamic scenario planner to include pertinent information that key stakeholders require when executing a project.

NEW CONSTRUCTION CONSIDERATIONS

New construction projects are often easier to implement design decisions that address COVID-19, Smoke Days, and Heat Wave Days. It is important to include the intent of addressing these scenarios in the owner project requirements as well as ensure that they are in the basis of design for the design team. Throughout the design, construction, and commissioning process, the owner project requirements and basis of design can be referenced to reinforce the priority of ensuring these systems and techniques are included in the design.

Energy models and dynamic load calculation software can be used to optimize the building's shape and mass with regard to solar heat gain. Mitigating the compounding effects of hot ambient temperature days, paired with high intensity solar radiation, will passively benefit the building's performance during heat wave events. Landscape can also be leveraged to provide additional shading and evapotranspiration during high temperature days.

GENERAL RECOMMENDATIONS

PARTICULATE MATTER FILTRATION

General Description

Filters are classified using the MERV rating system, which describes the expected capture efficiency of particles at various diameters. Figure 15 depicts the efficiencies of several MERV ratings at removing particles of different sizes from the airstream. HVAC systems are commonly provided with MERV 8 filters to capture dust and particles to protect equipment. Smaller diameter particles not effectively captured by MERV 8 filters affect indoor air quality and have an impact on occupant health. In high performing buildings, we typically specify MERV 13 filters.

Additional filters come with higher replacement cost and energy consumption considerations. Systems may not be compatible with some filters and could require fan modification to make them work.

Air quality monitors (also known as air sensors), can also be used to monitor the particulate matter within the space. Figure 14 depicts examples of air quality monitors from Carrier and Atmos Air. Air quality monitors can also monitor volatile organic compounds, carbon dioxide, and more. Should the school use a centralized air handling system, the monitor could be placed in a central location that is representative of the building. Should the school

Figure 14: Particulate Matter Filters.

Ratings	0.3-1 microns	1-3 microns	3-10 microns	Filter Type	Controlled Particles
MERV 8	-	-	70-85%	Low Quality MERV Filter	Dust
MERV 9	-	>=50%	85-90%	Standard MERV Filter	Fine dust
MERV 11	-	65-79%	85-90%		
MERV 13	>=75%	>=90%	>=90%	Superior MERV Filter	Bacteria, viruses, smoke
MERV 14	75-84%	>=90%	>=90%		
MERV 15	85-94%	>=90%	>=90%		
MERV 16	>=95%	>=95%	>=95%		
MERV 17	99.97%	>=99%	>=99%	HEPA / ULPA Filter	Small bacteria and viruses
MERV 18	99.997%	>=99%	>=99%		
MERV 19	99.9997%	>=99%	>=99%		
MERV 20	99.99997%	>=99%	>=99%		

Figure 15: MERV Ratings and Associated Performance by Particle Size.

Figure 16: Air Quality Monitors.

use unitary equipment per classroom, consider locating several air quality monitors throughout the school to sample multiple classrooms. Additional information is available from the EPQ on Air Sensor Technology[32] as well as the use of Air Sensor Technology.[33]

Should the school implement air quality monitoring, alarms can be set up through emails to the instructor or by installing a red light/green light indicator within the classroom. Once an alarm is sent out or the red light/green light light indicator goes off, the instructor may be notified to use a portable air filtration unit.

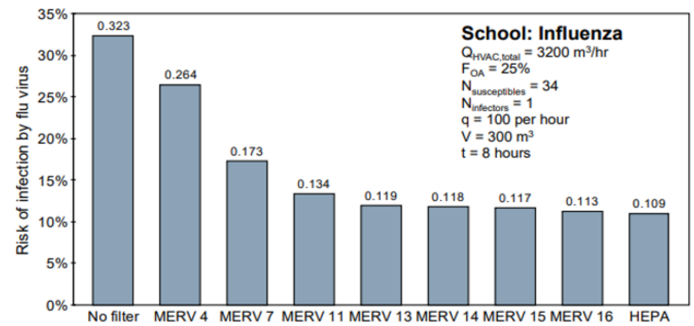


Figure 17: Projected risk of infection by influenza virus during an 8-hour day in a hypothetical classroom environment with 35 child occupants and 25% outside air supply using a range of HVAC filters installed in a system with a recirculation rate of 8.14 per hour.

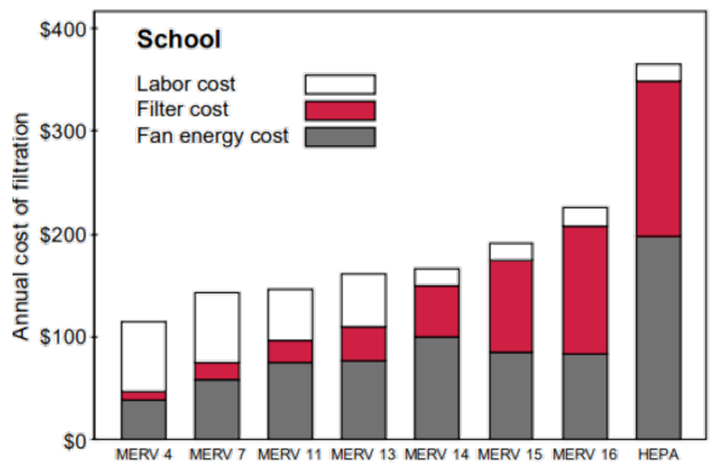


Figure 18: Estimated annual cost of filtration in the hypothetical school classroom environment.

If the school is able to, controls can be used to increase the unit's airflow upon detection of poor air quality. As the airflow increases, the effective number of air changes in the room will increase and also will increase the airflow through the unit's filtration system.

COVID-19

The SARS-CoV-2 virus and similarly sized airborne aerosols are too small to be captured by standard (MERV 8) filters. However, viruses tend to cluster together with dust, water vapor and other particles in the air creating larger particles able to be captured by filters. Improving filtration levels to MERV 13 or better will have a significant improvement in the rate of capture.

HEPA filters (MERV 17 and higher) begin to have diminishing returns on their effectives versus the penalty associated with filter costs and fan energy consumption as observed in Figure 17 and Figure 18.

Smoke Days

High efficiency filters are effective at removing most components of wildfire smoke but may not completely eliminate odors. Based on ASHRAE's current recommendations in planning for wildfire events, their recommendation is to use MERV 13 filters or better during smoke events. Refer to the Enhanced Air Scrubbing section of this document for additional information on addressing odors.[34]

Heat Wave Days

Particulate filtration has little to no impact on heat wave days, however, it is important that the filters are checked to ensure that they are clean to allow the system to operate at its full airflow.

Design Considerations

When adding filters to any system, this should be performed with care as adding filters without first considering the capacity and capability of the fan system may damage the equipment. Refer to Appendix A on Filter Guidance and the cautions associated. Refer to the Fan Performance section of this document for additional information.

Additionally, consider the right level of filtration for your application. First cost, replacement cost, and energy penalty should

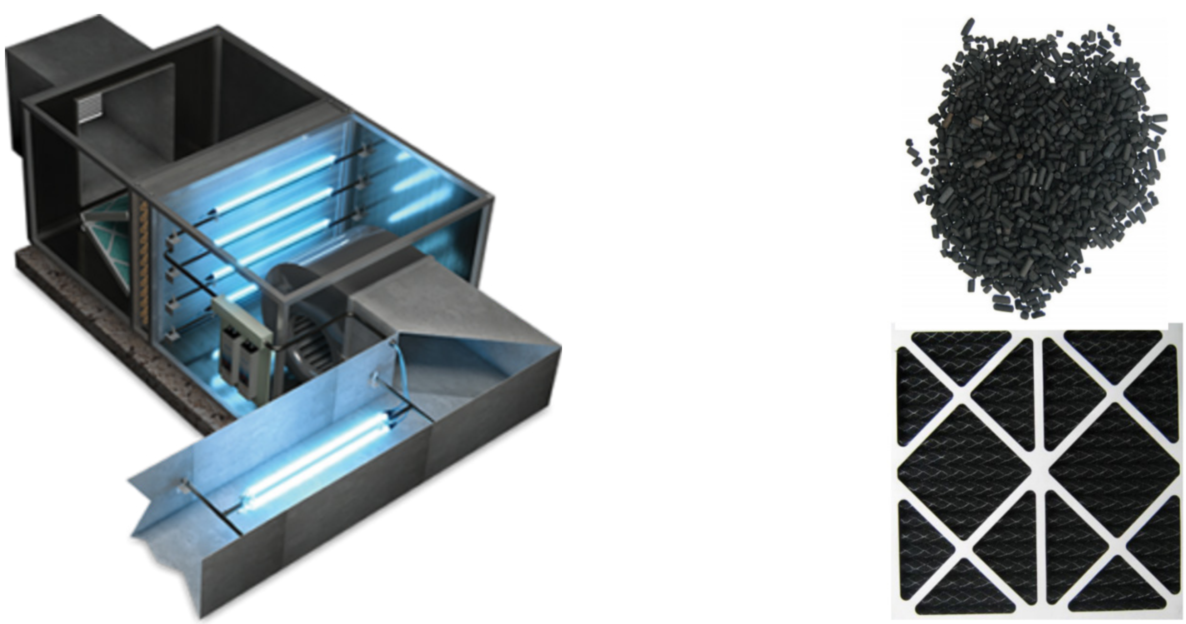


Figure 19: (Left) UV Filtration (Right) Carbon Filtration.

	High Efficiency/ HEPA Filters	UV Light	Activated Carbon
Effectiveness against Viruses	Very Good	Good (Depending on contact time)	Poor
Effectiveness against Bacteria	Excellent	Good (Depending on contact time)	Poor
Eliminates Odors	Not Effective	Not Effective	Excellent
Effectiveness against pet dander/pollen	Excellent	Not Effective	Not Effective
Effectiveness against dust mite excreta	Excellent	Poor	Poor
Cost per cartridge	Moderate	Moderate	Inexpensive
Cartridge life expectancy estimate	1 Year	1 year	3-12 Months

Figure 20: Filter Performance / Effectiveness / Cost by Filter Type.

be considered against improved filtration efficiency. Filter banks in existing units may not be able to accommodate the additional depths of high efficiency filters. Fan systems with variable frequency drives or EC motors can be rebalanced to accommodate the change in system air pressure drop. It may be necessary to replace fan motors or entire fans within air handlers. When replacing motors with larger motors, there is an electrical consideration of providing additional power at the unit.

Filters should be replaced routinely. Ensure that there is a regular maintenance plan in place for routine filter replacement and inspection of filter rack. Filters should also be evaluated for replacement after a poor air quality event, such as wildfire smoke event. Electrostatically charged filters in particular become loaded quickly during smoke events. It is suggested that filters be purchased and stored on site to avoid filter shortages due to high demand during poor air-quality events. Outdoor air intake hoods are often unfiltered during normal conditions, but could be filtered during poor air quality events.

ENHANCED AIR SCRUBBING

General Description

Enhanced air scrubbing includes additional treatments to the air in the HVAC system or in the room to address air quality. Enhanced air scrubbing techniques for the purposes of this report include UV Irradiation (ultraviolet light) and Activated Carbon Filtration. There are other types of enhanced air scrubbing, but the EPA and the Design Team do not promote the use of air cleaning technologies of unknown or unclear performance against pollutants in wildland fire smoke such as bipolar ionization, ozone generator, ionizing air cleaners, and oxidizing air cleaners.

Note that cartridge life expectancy for MERV 13+ filters shown in Figure 20 is assumed to have a MERV 8 prefilter. MERV 13 filters that are used without a prefilter will experience a reduction in anticipated life expectancy.

COVID-19

UV-C systems damage cellular particles rendering them harmless. These systems work well against viruses, bacteria, and mold spores. Activated carbon filters are not effective against microorganisms including SARS-CoV-2.

Smoke Days

Activated carbon filters are generally effective against odors and gases such as formaldehyde. UV irradiation should not be considered for smoke days. If possible, arrange in a bypass standby configuration that allows the system to only be used when needed.

Heat Wave Days

UV irradiation and activated carbon filtration do not address the design implications associated with heat waves.

Design Considerations

UV irradiation should not result in direct exposure to occupants. UV lights require power connections, so electrical will need to be extended to power the UV irradiation system. Shall the UV lights be installed in ductwork, the intensity of the UV array needs to be balanced against the velocity of the air since slower air will have a longer exposure time. Existing ductwork and shafts may not have sufficient surface area for retrofit applications. Lamps require replacement and should be in an accessible location with automatic switching to disable the system when access doors are opened to protect operators. When the UV lights are installed within the occupied space, the architectural finishes should be evaluated to ensure they are suitable for long term UV exposure. UV installed within the occupied space is more challenging to position and direct to eliminate occupant exposures.

Activated carbon filters are most commonly installed in series with the HVAC system's particulate filters. Activated carbon filters can also be installed on the outside air intake since the primary benefit of activated carbon filtration is to address the smoke of wildfire days that is entrained with the minimum outside air. Since activated carbon filters result in additional pressure drop, please refer to ASHRAE's warnings on adding filters to existing systems. Shall the activated carbon filters be installed on the outside air intake, the minimum outside air will need to be rebalanced, and the filter needs to be reviewed to ensure the filter is not vulnerable to rain entrainment. For new systems, activated carbon filter banks can be provided where activated carbon filters are installed manually during fire season. More advanced systems can also be provided such that the activated carbon filters are installed and regularly replaced throughout the year. As an energy savings measure, when the systems are not operating to address a smoke day, a motorized bypass damper can be used to bypass the additional pressure drop of the carbon filters. Portable air filtration units generally have options for activated carbon filters as well as UV filtration.

COOLING CAPACITY

General Description

Cooling capacity is the ability of a system to be able to remove heat from a space (cool a space). Cooling can occur at a central location, at a distributed zone terminal unit, or local to the space. Increasing outside air intake to the building will affect a system's cooling capacity due to the increased energy required to heat, cool, and dehumidify the outside air. Cooling capacity can also be impacted if smoke clogs air source heat pump/condensing unit coils and cooling coils that are exposed to high particulate matter air. The covering of coils can reduce the effectiveness of heat exchange. It is important that unfiltered or under filtered exposures used in the heat exchange process are cleaned following a smoke event.

COVID-19

The rate at which the air in a space is replaced by fresh air is known as Air Changes (ACH). The equivalent amount of air cleaned by filtering or air scrubbing is known as Equivalent Air Changes (ACHe). Increasing ACHe is a common response to COVID-19 to dilute the air and reduce exposure time to the virus. This is often done in conjunction with increasing filtration efficiency and/or the total outside air of the system. When outside air intake is increased, heating, cooling, and dehumidification loads increase.

Smoke Days

While smoke days are not often directly related to cooling capacity concerns, excessive particulate matter associated with smoke days may result in clogged condensing units of heat pump systems, radiators, and/or cooling towers.

Heat Wave Days

Maintaining and/or increasing the cooling capacity available to condition the building is important on heat wave days. Increasing cooling capacity without adding additional equipment may not be achievable if the equipment is unitary/package or if there is no cooling at all.

Design Considerations

Adding additional equipment to add cooling capacity could trigger improvements required by other trades such as electrical, structural, architectural.

Adding additional capacity to an existing system should be evaluated by a mechanical engineer to ensure proper tie in. For central plant-based systems such as for chilled water air handling units, chilled water hydronic fan coil units, and water source heat pumps, this could include expanding to add additional chillers and/or cooling towers. Hydronic upgrades in capacity would also require analysis of the existing pumps and pipe system to ensure there is adequate water flow and that there are no restrictions in the system causing excessive pressure drop.

As an alternative, supplemental unitary systems could be considered, such as single zone split systems and variable refrigerant flow systems to provide additional cooling capacity via new fan coil units. Since these units would be supplemental to the base building system that provides the primary filtration and ventilation, the use of wall mounted fan coil units or ceiling mounted fan coil units could be considered to limit excessive ductwork and air distribution.

Temporary cooling can also be considered as a resource. However, the temporary cooling would need to be deployed to all areas that are susceptible to overheating. Electrical capacity and availability for tie in must be coordinated in advance of the equipment being delivered to tie into the building. If there is no electrical capacity or electrical tie in point available, the temporary cooling system could be served by a temporary generator. Furthermore, agreements for accessing temporary cooling systems and/or generators if not owned and stored by the school district can create logistical challenges that would need to be overcome.

For spaces that either do not have a cooling system or where the cooling capacity is undersized for the heat wave, the following proactive comfort strategies can be deployed. This list is not exhaustive and the intent of the strategies can be achieved in a variety of ways. These strategies can also be deployed for buildings with air conditioning systems as a method to peak load shift.

1. Preconditioning: Operating the air conditioning systems throughout the night or starting the air conditioning systems early to achieve lower internal space temperatures at the start of the day can result in thermal mass benefits and keep the interior temperatures cooler throughout the day. Note that if preconditioning is used, and spaces are cooled beyond normal comfort limits (below 70°F) communication should be sent to the students/parents to anticipate cooler interior temperatures in the morning so they can bring the proper attire.

2. Night Flush: If the outside air condition drops below the average interior temperature, opening operable windows and/or running the outside air systems will assist in flushing out the excessive heat from the building. This method can be paired with a preconditioning system. Note that heat domes often result in elevated temperatures throughout the evenings/nights which limit the ability to perform night flushes.

3. Heat Island Mitigation: Ensure the area around the equipment is not creating a heat island effect by painting the area around the equipment white. Painting the area around the equipment white increases the percentage of solar radiation that is reflected away from the building.

4. Increase Air Speed: Ceiling fans and portable

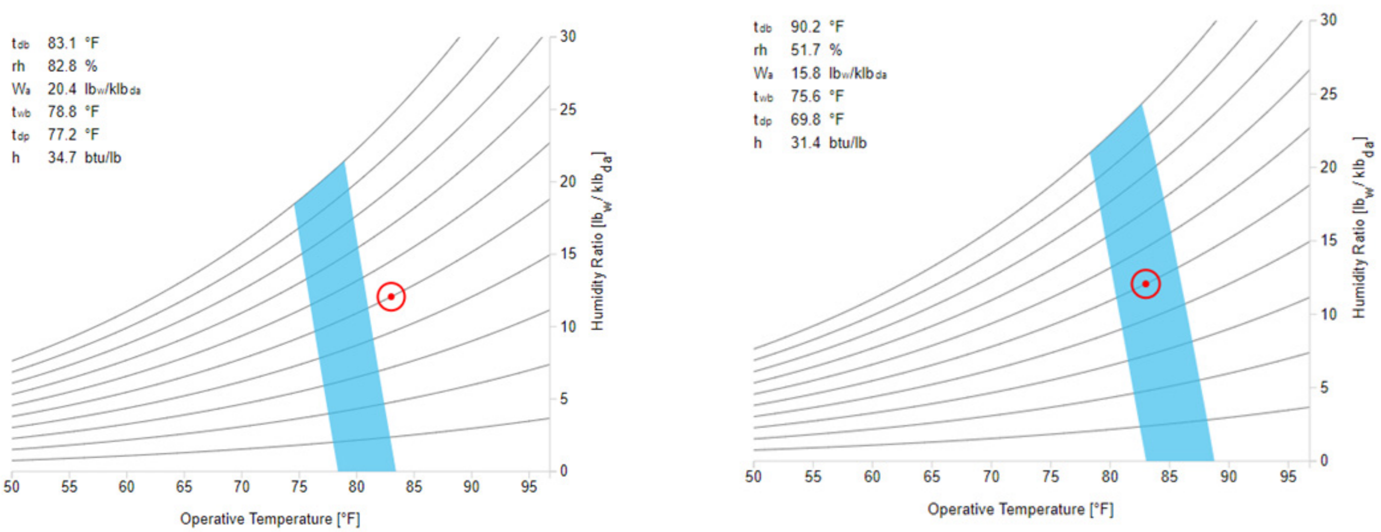


Figure 21: CBE Thermal Comfort ASHRAE 55 Compliance for similar indoor and occupant conditions with (left) limited air speed (right) 100 fpm air speed.

fans can be leveraged for increasing the air speed to achieve a wider range of acceptable thermal comfort. This is shown in Figure 21. Using fans inside of a space does not remove heat from the space and is not a solution on its own.

5. Evaporative Cooling: For climates where the heat wave days are drier and allow for evaporative cooling, direct and indirect evaporative cooling techniques such as cool pads and misters can be considered. Smoke days present conditions that may not be suitable for the use of evaporative coolers if they bring in unfiltered outside air. Consult with the specific manufacturers prior to using any technique that will restrict airflow through either the condensing unit or air intake sections of equipment. Note that direct and indirect evaporative cooling is a strategy that can result in scale build up on equipment with prolonged use. This is an ad hoc solution, and these techniques are not long term solutions and should be addressed with a specific design that is fully engineered and confirmed for use by the manufacturer.

For spaces that do not have a cooling system at all or where the cooling capacity is undersized for the heat wave, the following passive comfort strategies can be deployed. This list is not exhaustive and the intent of the strategies can be achieved in a variety of ways.

1. Solar Heat Gain Reduction: Reducing the heat gain from the sun is best addressed on the exterior of the building. This includes exterior shading devices, exterior window coverings, and landscape shading. Window blinds and curtains can also assist in reducing the solar heat gain within the space.

2. Occupant Density Reduction: If the students have reliable access to cooling at home, a program could be developed where students can opt into a hybrid learning day. By reducing the number of students in the space, it will decrease the amount of heat gain from people and the computers/electronics they use that also discharge heat.

3. Occupant Activity Reduction: The more active the occupant, the more heat is generated by the occupant. Instead of performing high energy activities, heat wave days are better spent performing more passive activities to reduce the overall heat gain within the space.

4. Internal Heat Gain Reduction: Computers and other electronics generate heat within the space. Limiting computer and larger electronic use will reduce overall heat gain. Reductions in lighting use will also reduce overall heat gain. This includes operating the lighting at a dimmed level or using a reduced number of lights within the space.

5. Adjustable Dress Code: Per ASHRAE 55, the national standard on thermal comfort, clothing level is a contributor to thermal comfort. Longer sleeves and multiple layers will result in further discomfort at higher space temperatures. For schools with strict dress codes that require multiple layers, long sleeve shirts, suit jackets, neck ties, etc., this should be reconsidered if interior space temperatures cannot be maintained during heat wave events.

6. Direct Evaporative Cooling: The use of misters can be considered for outdoor spaces. However, they should not be used in humid climates as they can increase the heat index to unsafe conditions.

HEATING CAPACITY

General Description

Heating capacity is the ability of your system to be able to add heat into a space. Heat production can occur at a central location, at a local zone terminal unit, or local to the space. Heating capacity can be put into question when additional ventilation is required as an increase in outside air at a colder temperature will result in additional cold air requiring to be heated to the room temperature. Heating capacity can also be impacted if smoke clogs combustion air openings, air source heat pump/condensing unit coils, and heating coils that are exposed to high particulate matter air. Obstructing combustion air openings can restrict airflow used in the combustion process, causing inefficient appliance firing and can even be life-threatening if products of combustion are pulled back into the room through the flue vents. The covering of coils can reduce the effectiveness of heat exchange. It is important that unfiltered or under filtered exposures used in the combustion air and/or heat exchange process are cleaned following a smoke event.

COVID-19

Increasing ACHe is a common response to COVID-19, and that often is achieved by increasing filtration efficiency and/or the total outside air of the system. When outside air is being increased, additional heating is required at the design day condition to warm up additional cold air.

Smoke Days

While smoke days are not often directly related to heating capacity concerns, excessive particulate matter associated with smoke days may result in clogged combustion air openings of gas fired heating systems and/or condensing units of heat pump systems. Refer to the ASHRAE guidance included in the Appendix on adding particulate filters to systems and the cautions about starving combustion air systems. It is important that all components used in the combustion air or heat exchange processes subject to blockage be thoroughly cleaned following a smoke event.

Heat Wave Days

Since heat wave days imply a high ambient temperature condition, heating capacity is not affected during this design condition.

Design Considerations

If the outside air rate increase minor (less than 10%), the spaces should be monitored first at the higher ventilation rates for thermal comfort performance prior to making large scale infrastructure changes to add supplemental heating. It is common for major HVAC systems to include factors of safety both in design and within the nominal sizing of the equipment.

If the outside air change is substantial, consider having an engineer evaluate the system to assess where additional heaters could be installed. Adding additional equipment to add heating capacity could trigger improvements required by other trades such as electrical, structural, architectural.

Adding additional capacity to an existing system should be evaluated by a mechanical engineer to ensure proper tie in. For central plant-based systems such as for heating water air handling units, heating water fan coil units, and water source heat pumps, this includes adding additional heating appliances such as boilers (electric or gas fired) or air source heat pumps. Hydronic upgrades in capacity would also require analysis of the existing pumps and pipe system to ensure there is adequate water flow and that there are no restrictions in the system causing excessive pressure drop.

As an alternate, supplemental unitary systems could be considered such as inline electric resistance coils, in room radiant heaters, single zone split systems fan coil units, and variable refrigerant flow fan coil units to provide additional heating capacity. Since these units would be supplemental to the base building system that provides the primary filtration and ventilation, the use of wall mounted fan coil units or ceiling mounted fan coil units could be considered to limit excessive ductwork and air distribution.

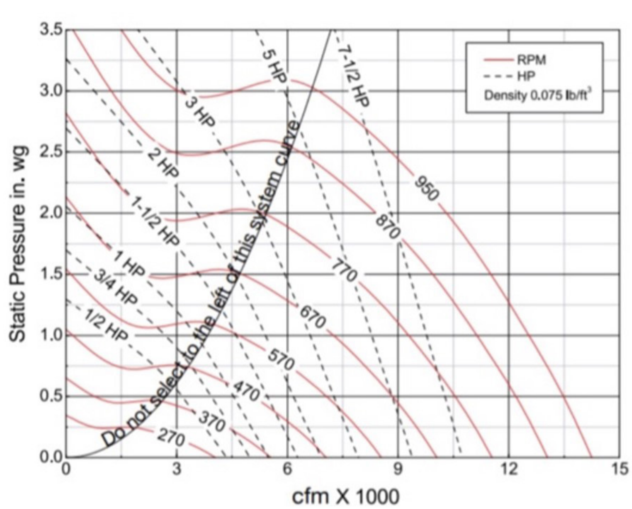


Figure 22: Example Fan Curve.

FAN PERFORMANCE

General Description

Fan performance becomes a concern when addressing two primary areas of focus: increasing airflow and increasing pressure drop. Fans operate on a fan curve that is specific to the fan shape, size, and rotational speed. When a fan needs to increase in airflow the rotational speed and/or pressure drop needs to change. When a fan needs to increase in pressure drop performance, the rotational speed and/or the airflow needs to change.

COVID-19

If additional filters are being added to the system as a response to COVID-19, the system will likely incur additional pressure drop. Ensure the fan is tested to ensure proper fan operation and that the airflows are met. This could include rebalancing the fan, adjusting or replacing the fan sheave, and/or adjusting the fan variable frequency drive.

Smoke Days

If additional filters are being added for smoke days, the system will likely incur additional pressure drop. Ensure the fan is tested before a smoke event to ensure proper fan operation and that the airflows are met. This could include rebalancing the fan, adjusting or replacing the fan sheave, and/or adjusting the fan variable frequency drive.

Heat Wave Days

Heat Wave Days require additional airflow in the spaces/zones to address the increase in heat load for each space.

Design Considerations

Fans with electronically commutated motors, ECM, or variable frequency drives, VFD, may simply need to have their airflow setpoints changed to ensure proper operation. Permanent Split Capacitor fans, PSC fans, may require a test and balance contractor to adjust the fan to achieve the new desired airflow. PSC fans are normally on/off type fans without an ECM or VFD.

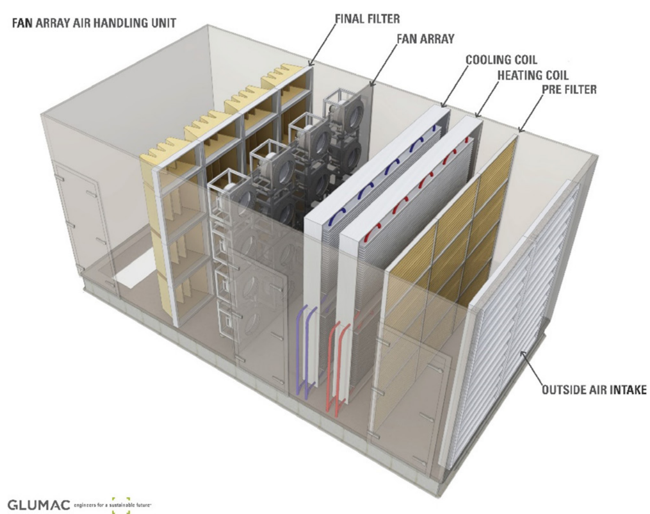


Figure 23: Air Handling Unit Fan Wall Arrangement Example.

Should additional airflow be needed, fans can also be modified to have their impeller or sheave modified or retrofit a larger motor to achieve additional airflow. Note that as a fan rotates faster, it will become louder. It is important to ensure that it has proper vibration isolation. Larger fan motors may require electrical upgrades, so capacity would need to be verified to confirm the available additional electrical load.

When increasing airflow at a fan while using the same size duct system, the velocity of the air increases as a result. When the velocity of the air increases, it can result in acoustical challenges and potentially unnecessary pressure drop in the system. Performing a review of the duct system to identify and replace abnormal fittings that have high pressure drop factors or identifying and replacing pinch points in the distribution system can reduce pressure losses through the system as well as reduce the speed of the air thus addressing acoustical concerns.

Note that when adding additional pressure drop to a system, it may damage a fan. Refer to Appendix C on the cautions associated with adding filters to fan systems.

MAX TEMPERATURE FOR EQUIPMENT OPERATION

General Description

Air cooled equipment typically includes a maximum operating temperature. Currently, an ambient air temperature of 125°F is an operational threshold for some refrigerant based equipment. High temperature ambient kits are available for new equipment and are offered as retrofits to existing equipment. While there is a range of equipment that are susceptible to this operational limit, it is important to check with the specific manufacturer on the equipment's operational limits. Any air-cooled equipment (motors, controllers, etc.) is susceptible to failure at high ambient temperature events. However, the equipment that has been identified by multiple manufacturers that could be more susceptible include compressors that are single speed (on/off) or staged with single speed/staged condenser fans.

Figure 24: (Left) Air Cooled Variable Refrigerant Flow Condensing Units (Right) Package Air Cooled Rooftop Unit.

COVID-19

While maximum temperature concerns are more related to heat wave days, the operation of the HVAC equipment during a COVID-19 event is important, and COVID-19 events happening during heat waves is possible.

Smoke Days

While maximum temperature concerns are more related to heat wave days, the operation of the HVAC equipment during a smoke event is important to ensure air is being filtered and the building is positively pressurized. Smoke events happening during heat waves is possible.

Heat Wave Days

Ensuring the cooling equipment is operational during heat wave days means the design day condition of the heat wave should be evaluated. The design day condition should be compared to the maximum operating condition of the mechanical equipment (existing and new).

Design Considerations

Confirm the high temperature maximum for operation of the equipment and be aware of which equipment may start to have performance issues or may ultimately fail when exposed to a heat wave event. As noted above, high temperature ambient kits can be installed as a retrofit application (if available from the manufacturer), and it is common to see new equipment can be ordered with the option already installed.
If a high ambient kit is not available, the following steps can be taken in an effort to reduce the ambient air temperature around the equipment.

1. Heat Island Mitigation: Ensure the area around the equipment is not creating a heat island effect by painting the area around the equipment white. This is sometimes referred to as increasing the albedo. Painting the area around the equipment white increases the percentage of solar radiation that is reflected away from the building.

2. Evaporative Cooling: For climates where the heat wave days are dryer and allow for evaporative cooling, indirect evaporative cooling techniques such as cool pads and misters can be used as a last resort. Consult with the specific manufacturers prior to using any technique that will restrict airflow through the condensing unit section Note that indirect evaporative cooling is a strategy that can result in scale build up on equipment with prolonged use. These techniques are not long term solutions and should be addressed with a specific design that is fully engineered and confirmed for use by the manufacturer.

VENTILATION

General Description

Minimum ventilation is the amount of outside air required to serve the room or space. Minimum ventilation rates are dictated by code, industry standards such as those developed by ASHRAE, and green building standards such as LEED. Ventilation dilutes and/ or removes pollutants, particles, and aerosols. However, when the outside air has poor air quality, such as during a wildfire event, additional measures around filtration should be considered to ensure ventilation not detrimental to the occupants.

COVID-19

Ventilation is a key component to equivalent air changes. Increasing ventilation will further dilute airborne aerosol recirculation within the HVAC system. Natural ventilation and operable windows further increase the equivalent air change rates within spaces and should be considered as an additional strategy in addressing COVID-19.

Smoke Days

Ventilation during smoke days should be kept to a code minimum or at a level to maintain the desired minimum number of equivalent air changes for a space. Excessive ventilation will result in unnecessary particulate loading on the system's filters. As such, ensure economizers are disabled during smoke days.

Heat Wave Days

Ventilation during heat wave days should be kept to a code minimum or at a level to maintain the desired minimum number of equivalent air changes for a space. Excessive ventilation will result in unnecessary cooling that should be reserved to address the increased ambient heat gain.

Design Considerations

Increasing Ventilation (Decoupled Outside Air Systems): To increase ventilation in decoupled constant volume systems, the central outside air fan airflow needs to be increased and the volume dampers at the zone terminal units need to be rebalanced. Should the zone terminal units leverage variable air volume controls, the volume setpoints need to be adjusted for new airflows. Refer to the Fan Performance section of this document for more information on increasing airflows at fans. With the increase in outside air, the cooling and heating coils should be evaluated at the zone terminal units to ensure adequate heating and cooling capacity. Since the airflow is increasing in a duct system, the ductwork will need to be evaluated for velocity and pressure drop concerns and may require a retrofit to increase outside air. If a louver or hood is used, the louver or hood should be evaluated to ensure there is no rain entrainment or acoustical issues.

Increasing Ventilation (Coupled Systems): To increase ventilation in coupled systems, where outside air is mixed with the supply air at a central location, the outside air damper needs to be rebalanced in relation to the supply airflow. For outside air systems with motorized dampers and airflow measurement stations, the setpoint just needs to be adjusted. With the increase in outside air, the cooling and heating coils should be evaluated at the air handling units to ensure adequate heating and cooling capacity. If the ventilation is ducted into the central unit from the exterior, the ductwork will need to be evaluated for velocity and pressure drop concerns and may require a retrofit to increase outside air. If a louver or hood is used, the louver or hood should be evaluated to ensure there is no rain entrainment or acoustical issues.

Maintaining Minimum Ventilation: Using airflow measurement stations and motorized dampers at the outside air intake is a proven method for controlling outside air quantities to a setpoint. Many systems do not have airflow monitoring stations, including smaller unitary package air conditioning units, so the outside air damper needs to be rebalanced and calibrated at different speeds of the package unit to ensure the minimum ventilation is achieved. For variable volume systems that have a fixed outside air damper, it is recommended that the outside air damper be retrofitted with a motorized damper and balanced as noted above.

EQUIVALENT AIR CHANGES

General Description

The room air is both replaced with fresh outside air as well as diluted by particulate filtration. The equivalent outdoor air calculation indicates that the outdoor air can be calculated by using the combination of the actual outdoor air, impact of filtration, or air cleaning technologies on recirculated air, and the impact of air cleaning technologies in the space. The combination of particulate filtration and ventilation results in higher equivalent air changes. An equivalent air change rate of 5-6 air changes per hour (ACH) is recommended. The equivalent outdoor air calculator developed by ASHRAE Epidemic Task Force's Here.

2 ACH - Minimum Recommendation

4 ACH - Good

6 ACH - Very Good

8 ACH - Excellent

COVID-19

During periods with airborne pathogens such as SARS-CoV-2, a higher equivalent air change is more beneficial.

Smoke Days

Increasing outside air rates during smoke days is not recommended due to smoke entrainment. Increasing equivalent air changes needs to be addressed with either increased particulate filtration and/or portable filtration units.

Heat Wave Days

While equivalent air changes are generally beneficial for a space, increasing outside air rates during heat wave days is not recommended due to excessive heat entrainment. Increasing equivalent air changes needs to be addressed with either increased particulate filtration and/or portable filtration units.

Design Considerations

Equivalent air changes can be achieved with increased ventilation and/or additional filtration. Refer to the specific sections on Ventilation and Particulate Matter Filtration section in this document for additional information. In addition to prescriptive recommendations for increased ventilation and filtration, performance-based tools are available for evaluating equivalent air changes by using aerosol tracking within spaces.

BUILDING PRESSURIZATION

General Description

Building pressurization is the relative pressure relationship between the inside of the building and outside. In general, buildings should be maintained slightly positively pressurized to ensure particulates, smoke, odors, and water vapor (for humid climates) are pushed out of the building instead of pulled into the building.

COVID-19

Building pressurization does not have a substantial impact on COVID-19 for regular school spaces such as classrooms and offices.

Smoke Days

Positive building pressurization is recommended during smoke days to not entrain smoke and particulate matter through the building envelope and/or the opening of building openings such as doors/windows.

Heat Wave Days

Positive building pressurization is recommended during heat waves to not entrain excessive heat through the building envelope and/or the opening of building openings such as doors/windows.

Design Considerations

Positive building pressurization can be checked and established via test and balancing and retrocommissioning. The outside air, relief air, and the exhaust air needs to be reviewed such that the outside air rate is greater than the exhaust air and relief air rates. If a building pressure sensor is used in a controls sequence, ensure the building pressure sensor is in an open space that is representative of the average building pressure and in a location that is not susceptible to large variable swings in pressurization such as near an exterior door or window that is frequently opened/closed.

While the building pressurization generally fluctuates throughout the day, the building pressurization can be easily tested using a tissue test at a main door. With the door slightly open, hold a tissue paper in front of the opening. If the tissue paper is being pulled/pushed into the building, it is indicative of negative building pressurization. If the tissue paper is being pulled/pushed out of the building, it is indicative of positive building pressurization. If there is no movement in the tissue paper, it is indicative of neutral building pressure.

PORTABLE FILTRATION UNITS

General Description

Portable filtration units are devices that can be deployed into rooms or spaces to perform additional filtration. Portable filtration units have internal fans that pull air from the room through its internal filters and then discharges the air back into the room. The EPA and CARB have a lot of information regarding portable filtration units that can also be referenced for additional information on portable filtration units.

COVID-19

Portable filtration units increase the equivalent air changes of the air within the space. Portable filtration units can include high levels of particulate filtration to assist in addressing COVID-19.

Additional information is available from the EPA on air cleaners used to address COVID-19.

Smoke Days

Since portable filtration units address the design offender once it is in the space, the smoke will continue to be entrained via the ventilation system. As such, the portable filtration unit will only have an opportunity to address the smoke once it is already in the occupied space. Portable filtration units can include high levels of particulate filtration, and they can also include enhanced air scrubbing such as activated carbon filters to assist in addressing the odors associated with the smoke day.

Ensure the portable filtration unit is selected at a higher air change rate in comparison the outside air rate. However, addressing smoke at the source, at the outside air intake, will address the smoke being brought through the breathing zone. Refer to the design checklists below regarding using active air monitoring to determine if portable filtration units should be used in addition to central filtration.

Additional information is available from the EPA on air cleaners used to address Smoke Days.

Heat Wave Days

Portable filtration units do not address the design implications associated with heat waves.

Design Considerations

Portable filtration units require power and floor space within the space served. They also need to be positioned and installed per the manufacturer design guideline to ensure adequate floor coverage. This could be driven by where available outlets are within the room which could trigger additional portable filtration units being required due to the positioning of the units and the tripping hazards potential associated with running extension cords long distances. Additional challenges with portable filtration units include the sound and acoustical implications that portable filtration units have. Too many units or units that are too loud could pose a challenge for classrooms. Sound performance data should be available from the manufacturer and should be considered when doing selections. Portable filtration units come with a variety of options as noted above and should be selected to match the specific space served and the placement within the room.

REGIONAL DESIGN CONSIDERATIONS

MULTNOMAH COUNTY, OREGON

Based on the workshops held for Multnomah County, our understanding is the primary concerns of the county and Portland Public Schools (PPS) are associated with COVID-19, heat waves, and smoke days. According to Portland Public Schools there are many buildings that do not have air conditioning systems.

Based on this feedback, it is our recommendation the campus explore the following design considerations related to COVID-19, Smoke Days, and Heat Waves. Refer to the following Readiness Checklists as well as the below General Recommendation categories below.

1. Particulate Matter Filtration
2. Enhanced Air Scrubbing
3. Cooling Capacity
4. Heating Capacity
5. Fan Performance
6. Max Temperature for Equipment Operation
7. Ventilation
8. Equivalent Air Changes
9. Building Pressurization
10. Portable Filtration Units

Short Term Solutions

Since there is limited cooling and often no cooling ability, consider paying special attention to proactive and passive cooling techniques. It is imperative for the spaces without air conditioning to be pre-cooled or shaded where possible to attempt to increase the comfort time for these spaces. Since many of the buildings do not have air conditioning systems to assist with equivalent air changes, portable filtration units are recommended for deployment. These filtration units could benefit from ensuring carbon filters are included in their selection to also address smoke day considerations.

Long Term Solutions

Consider replacing equipment as a part of energy improvement or decarbonization projects or via deferred maintenance associated with equipment end of life to increase the cooling abilities and filtration abilities of the equipment. Ensure the design considerations are factored into the new equipment selection. It is also encouraged to develop a facilities conditions assessment and investment plan associated with retrofitting existing schools that don't have air conditioning to include air conditioning and filtration systems as a part of the base building infrastructure.

Reliable Power Considerations

There was also a conversation around the reliability of power. Portland General Electric and PacifiCorp serve buildings in Multnomah County. According to the Public Utility Commission of Oregon, Portland General Electric has averaged around a System Average Interruption Duration Index of 204 minutes per year from 2015 to 2020. In 2021 Portland General Electric had an atypical increase to 2,724 minutes of interrupted power that year. It was not explained as to why there was a change in performance for that year, however, the Public Utility Commission is investigating the occurrence. In the same report, PacifiCorp has averaged around a System Average Interruption Duration Index of 301 minutes per year from 2015 to 2021.[35]

While it is important to ensure that the utility provider is providing reliable power, the county and campus should continue exploring and ensuring the quality and reliability of power as temperatures continue to increase thus putting additional stress on the utility grid. Having plans in place for backup generators or workflows should the buildings lose power during a heat wave should be included as a part of the emergency response planning. As an example, Multnomah County has portable package units and portable generators in stock to deploy to specific cooling centers. Note that Portland Public Schools is currently working with Multnomah County to establish procedures for activating cooling centers in PPS facilities in the near the future.

READINESS CHECKLISTS

Systems should be properly maintained prior to the design condition season. Systems should be tested annually prior to the design condition season to ensure functional operation. The plan for each design condition should be developed and will be unique to each campus, school, and/or building. Plans and procedures should be adjusted as needed to be up to date with the basis of design conditions, installed systems, and system performance.

A person or group of people should be identified as the primary points of contact to deploy the plans to address the design conditions. Any of the following readiness checklists could be deployed for a campus, school, or individual dedicated space.

COVID-19 READINESS CHECKLIST

Item	Question	Response	Action
C1	Does the system need to consider COVID-19 as a Design Condition?	No	Ensure appropriate actions are taken to ensure compliance with Center for Disease Control, local (state/county/city) health agencies, ASHRAE, and the World Health Organization recommendations around COVID-19.
		Yes	Proceed to Item C2.
C2	Is the equipment up to date on maintenance?	No	Provide adequate maintenance and/or repair to the equipment. Consider providing an updated test and balance and recommissioning. Proceed to Item C3.
		Yes	Proceed to Item C3.
C3	Is the system able to operate with MERV 13 Filters?	No	Provide MERV 11 where possible as a partial solution. Additional outside air should be considered to increase equivalent air changes. Ensure filters are properly installed with no gaps. Proceed to Items C4 and C5.
		Yes	Install MERV 13 Filters and ensure filters are clean and properly installed with no gaps. Proceed to Item C5.
C4	Can the fans be modified to increase fan performance to accommodate the additional filtration?	No	Proceed to Item C5.
		Yes	Proceed to Item C3.
C5	Is the outside airflow rate compliant with local and national outside airflow rate minimums for all modes of air handling unit/terminal unit operation?	No	Provide Test and Balance to increase minimum ventilation rates and ensure minimum ventilation rate is maintained at all modes of air handling unit/terminal unit operation. Proceed to Items C6 and C10.
		Yes	Proceed to Item C7.
C6	Can the fans be modified to increase fan performance to accommodate the additional airflow?	No	Proceed to Item C7.
		Yes	Proceed to Item C5 and C9.
C7	Are equivalent air changes at a minimum of 5 air changes per hour?	No	Proceed to Item C12 and C8.
		Yes	Proceed to Item C12 and C13.
C8	Are room specific portable air filtration units on hand, and do they have adequate power?	No	Perform a space evaluation and purchase portable air filtration units and/or ensure there is adequate power available for the spaces served for the portable filtration units. Proceed to C13.
		Yes	Deploy portable filtration units. Proceed to Item C13.

COVID-19 READINESS CHECKLIST CONTINUED

Item	Question	Response	Action
C9	Was the increase to outside air greater than 10% compared to the original airflow?	No	Monitor space temperatures during hot and cold days for capacity shortcomings. Should capacity shortcomings present, proceed to Items C10 and C11. Otherwise, proceed to Item C13.
		Yes	Proceed to Items C10 and C11.
C10	Is there adequate heating capacity?	No	Implement supplemental heating strategies either at the zone level, central air handling units, and/or central plant as applicable. Permanent improvements are recommended since COVID-19 is not an acute event day. Proceed to Item C13.
		Yes	Proceed to Item C13.
C11	Is there adequate cooling capacity?	No	Implement supplemental cooling strategies either at the zone level, central air handling units, and/or central plant as applicable. Permanent improvements are recommended since COVID-19 is not an acute event day. Proceed to Item C13.
		Yes	Proceed to Item C13.
C12	Can UV systems be added to the ductwork or room safely without exposing occupants or damaging architectural finishes?	No	Proceed to Item C13.
		Yes	Consider implementing UV filtration as an additional measure. Provide associated electrical to support the UV system. Proceed to Item C13.
C13	Continue implementing non-HVAC COVID-19 mitigation strategies, keeping up with the latest direction on COVID-19 mitigation measures from health agencies, as well as ensuring equipment is regularly maintained to ensure proper operation.		

SMOKE DAY READINESS CHECKLIST

Item	Question	Response	Action
S1	Does the system need to consider Smoke Days as a Design Condition?	No	Ensure risk profile of site is assessed against poor air quality days such as smoke days. Should the site be exposed to smoky conditions or poor air quality conditions, consider developing Smoke Readiness Plan.
		Yes	Proceed to Item S2.
S2	Is the equipment up to date on maintenance?	No	Provide adequate maintenance and/or repair to the equipment. Consider providing an updated test and balance and recommissioning. Proceed to Item S3.
		Yes	Proceed to Item S3.
S3	Is the system able to operate with MERV 13 Filters?	No	Provide MERV 11 where possible as a partial solution. Ensure filters are properly installed with no gaps. Proceed to Items S4 and S5.
		Yes	Install MERV 13 Filters and ensure filters are clean and properly installed with no gaps. Provide any necessary modifications to the equipment or ductwork to accommodate the additional filtration. Proceed to Item S4.
S4	Is the system able to operate with carbon filters?	No	Proceed to Item S5.
		Yes	Purchase carbon filters and install when there is active smoke day and/or smoke is forecasted for additional days. Provide any necessary modifications to the equipment or ductwork to accommodate the carbon filter. Proceed to Item S5.
S5	Can the fans be modified to increase static pressure performance to accommodate the additional filtration?	No	Proceed to Item S6 and S8.
		Yes	Proceed to Item S3 and S4.
S6	Are the current filters clean?	No	Replace the filters and ensure they are properly installed such to not have any unnecessary gaps around the filters. Proceed to Item S7.
		Yes	Ensure they are properly installed so that there are no gaps around the filters. Proceed to Item S7.
S7	Is the building positively pressurized?	No	Provide Test and Balance to balance outside air rates with exhaust air rates to achieve neutral and/or positive building pressure. Ensure that there are no cracks in the building envelope. Proceed to Items S8.
		Yes	Proceed to Item S9

SMOKE DAY READINESS CHECKLIST CONTINUED

Item	Question	Response	Action
S8	Are room-specific portable air filtration units on hand, and do they have adequate power?	No	Perform a space evaluation and purchase portable air filtration units and/or ensure there is adequate power available for the spaces served for the portable filtration units. Proceed to Item S9.
		Yes	Deploy portable filtration units when there is an active smoke day and/or smoke is forecasted for additional days. Proceed to Item S9.
S9	Is any of the equipment air cooled and exposed to the smoke/poor air quality?	No	Proceed to Item S11.
		Yes	Ensure that heat transfer surfaces and coils are clean. Ensure that maintenance is scheduled and performed for additional cleaning at the end of the smoke day event. Proceed to Item S11.
S10	Can the outside air dampers/systems modulate or be set at code minimum outside air conditions without compromising occupant exposure to airborne infectious aerosols?	No	Proceed to Item S11.
		Yes	Ensure a setpoint and/or manual position are recorded for normal operation and smoke day operation for the outside air. Set outside air dampers/systems to code minimum outside air conditions when there is an active smoke day and/or smoke is forecasted for additional days. Reset the outside air dampers/systems to normal operation setpoints and/or manual positions following a smoke day event.
S11	Continue monitoring smoke day forecasts as well as ensuring equipment is regularly maintained to ensure proper operation. Procure and deploy indoor air monitoring devices and monitor indoor air quality and system performance during smoke day events.		

HEAT WAVE READINESS CHECKLIST

Item	Question	Response	Action
H1	Does the system need to consider Heat Wave Days as a Design Condition?	No	Ensure risk profile of site is assessed against heat wave and high temperature days such as heat domes. Should the site be exposed to heat wave conditions, consider developing Heat Wave Readiness Plan.
		Yes	Proceed to Item H2.
H2	Is the equipment up to date on maintenance?	No	Provide adequate maintenance and/or repair to the equipment. Consider providing an updated test and balance and recommissioning. Proceed to Item H3.
		Yes	Proceed to Item H3.
H3	Is there air conditioning equipment?	No	Proceed to Item H10.
		Yes	Proceed to Item H4.
H4	Is the maximum operating temperature limit of equipment known?	No	Compile a list of maximum operating conditions for equipment. Proceed to Item H5.
		Yes	Proceed to Item H5.
H5	Is the equipment maximum operating temperature above the basis of design condition including heat island effects?	No	Proceed to Item H6.
		Yes	Proceed to Item H7.
H6	Can the equipment be retrofit with high ambient kits to operate at temperatures above the basis of design condition including heat island effects?	No	Proceed to Item H8.
		Yes	Retrofit equipment with high ambient kits. Proceed to Item H7.
H7	Is the cooling capacity adequate for the basis of design condition?	No	Proceed to Items H8 and H10.
		Yes	Proceed to Item H8.
H8	Can the fans be modified to increase airflow performance to accommodate additional supply air?	No	Proceed to Items H9 and H10.
		Yes	Proceed to Items H7 and H9.

HEAT WAVE READINESS CHECKLIST CONTINUED

Item	Question	Response	Action
H9	Can the chilled water and/or condenser water pumps be modified to increase chilled water and/or condenser water flow performance?	No	Proceed to Item H10.
		Yes	Proceed to Items H7 and H9.
H10	Can proactive comfort strategies be deployed?	No	Proceed to Item H11.
		Yes	Configure sequences of operation or operation routines to perform proactive comfort strategies prior to and during heat wave days. Proceed to Item H11.
H11	Are the spaces comfortable during a heat wave event based on the actions taken above?	No	Develop a long-term improvement plan for adding air conditioning. Proceed to Item H12.
		Yes	Proceed to Item H12
H12	Is power reliability a concern for the HVAC equipment?	No	Proceed to Item H13.
		Yes	Develop a standby power plan to support HVAC equipment either by a permanent standby power source or a temporary standby power source. Should the standby power source by temporary, ensure logistics are planned for to procure and/or deploy temporary emergency power. Proceed to Item H13.
H13	Continue monitoring heat wave forecasts as well as indoor air temperatures ensuring equipment is regularly maintained to ensure proper operation.		

EDUCATION AND OUTREACH

As schools prepare physical buildings to be safe during extreme heat and wildfire smoke events, school staff may need to share information with families and students to explain the risks and ways to stay safe, both in school and at home.

The following resources are organized for different audiences: kids, caregivers, schools, or the general public. Information is constantly being updated and translated into more languages. Some key websites to check for the latest information include www.heat.gov and https://www.airnow.gov/wildfires/

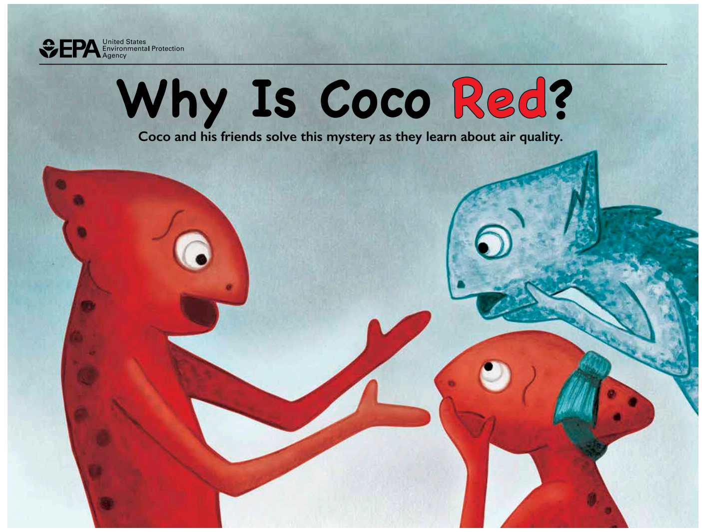


Figure 25: Picture book, Why is Coco Red?, *provides information to children about wildfire smoke and air quality.*

FOR CHILDREN: WILDFIRES AND AIR QUALITY

AirNow
Air Quality Flag Program for students
En español
Includes resources to teach children about the environment, clean air, and wildfires

Why is Coco Orange?
En español
Children's book on air quality and staying healthy during poor air quality events

Why is Coco Red?
En español
Children's book on how wildfires can affect air quality and health

Piplo Productions, Trinka and Sam: The Big Fire
Available in multiple languages
Story on recovery after a fire

Ready.gov Ready Kids
En español
Tools, games, and information on preparing for disasters for kids, teens, parents, and people who work with kids

FOR CHILDREN: EXTREME HEAT

CDC: Ready Wrigley Books
Available in English and Spanish
Children's books on preparing for wildfires and smoke and one on extreme heat with dog Ready Wrigley

Ready.gov Ready Kids
En español
Tools, games, and information on preparing for disasters for kids, teens, parents, and people who work with kids

The following resources can help teachers, health workers, and other community members understand the risks from wildfire smoke and extreme heat to children and ways to protect them from a variety of impacts.

Figure 26: Picture book, Ready Wrigley Prepares for Extreme Heat*, provides information to children about extreme heat.*

FOR PARENTS/CAREGIVERS: WILDFIRES AND AIR QUALITY

Ready.gov Ready Kids
En español

EPA webinar with experts on wildfire smoke, mental health, and green cleaning
Available in English and Spanish

CDC: Protecting children from wildfire smoke
Available in English and Spanish

Western States Pediatric Environmental Health Specialty Unit (WSPEHSU)
Some information available in English and Spanish
Wildfires and children's health
A Story of Health

National Child Traumatic Stress Network (NCTSN)
Available in multiple languages
Wildfire Resources

FOR PARENTS/CAREGIVERS: EXTREME HEAT

CDC: Heat and Infants and Children
Available in English and Spanish

National Child Traumatic Stress Network (NCTSN)
Information available in multiple languages
Extreme Heat Resources

Sunwise
Available in English and Spanish

FOR SCHOOLS/EDUCATORS: WILDFIRES AND CLEAN AIR

AirNow
Air Quality Flag Program for Teachers
En español

American Public Health Association Fact Sheet on Climate Change: Wildfires and Children's Health

Ready.gov Resources for Educators & Organizations
Available in English and Spanish

Smokey Bear: For Educators
Some information available in Spanish

EPA: Sensible Guide for Healthier School Renovations

EPA: Sensible Steps to Healthier School Environments

EPA: Best Practices for Reducing Near-Road Pollution Exposure at Schools
Available in English and Spanish

Department of Education Readiness and Emergency Management for School Technical Assistance Center
Wildfire Preparedness for K-12 Schools and Institutions of Higher Education

EPA Indoor Air Quality Tools for Schools

EPA Wildfires and Indoor Air Quality for Schools and Commercial Buildings

FOR SCHOOLS/EDUCATORS: EXTREME HEAT

Sunwise
Available in English and Spanish
Education on sun safety for children

American Public Health Association Fact Sheet on Climate Change
Extreme Heat and Children's Health in Early Care and Education

GENERAL INFORMATION AND RESOURCES: WILDFIRES AND AIR QUALITY

EPA Wildfire Smoke Resources
Some information available in English and Spanish

AirNow
Available in English and Spanish
Be Smoke Ready

Living with smoke: How to be prepared for smoke exposure
From University of Nevada, Reno

Tribal Indoor Air Quality Training and Resource Directory

Air Quality Sensors and Low-Cost Monitors
Air Sensor Technology and Indoor Air Quality
Low–Cost Air Pollution Monitors and Indoor Air Quality

GENERAL INFORMATION AND RESOURCES: EXTREME HEAT

EPA Extreme Heat Resources

Heat Islands and Equity

EPA Let's Talk About Heat Challenge
Includes example public service announcements, social media toolkits, and comics used by communities around the U.S.

BEYOND THE HVAC EQUIPMENT

This Playbook presents technical assistance around strategic upgrades to or the installation of new air handling systems to reduce heat-related and smoke-related threats to communities, especially those that have been traditionally underrepresented. These systems are the focus of the Playbook—and represent the primary scope of this study.

Beyond these equipment upgrades, however, there are a host of other measures that benefit the overall goal of keeping people cool and breathing clean air. As temperatures get hotter, and smoke events more frequent, a holistic approach is needed to maximize the efficiency of the cooling and air quality systems in a building.

Building a holistic approach involves looking beyond the building equipment to the areas on the roof, the larger campus landscape, best practices in the classroom, and even how people get to and from the cooling and clean air centers. Interventions in each of these different focus areas can help support the central cooling and clean air systems in the building —by reducing the loads on the HVAC systems, and keeping people safe throughout a hazardous event. Some of these additional recommendations for improvements that support the overall system include the following strategies:

COOLING THE EQUIPMENT

Most AC intake systems are located on the roofs of buildings or on concrete pads located adjacent to the buildings. The areas around these units can produce significant heat, especially if the areas are a dark color that absorbs heat from the sun, or made of conductive materials like concrete that will absorb heat during the day and release it well into the nighttime hours.

Cooling these areas with green roofs, or using lighter color roofing materials—such as a white roofs that are more reflective—can prevent heat buildup in the areas near the AC intake systems, which can lower the air temperature coming into the building, reducing the burden on the AC systems.

Find out about cooling roofs and surfaces around AC intake systems here:

Heat Island Cooling
https://www.epa.gov/heatislands/heat-island-cooling-strategies

Heat Island Compendium
https://www.epa.gov/heatislands/heat-island-compendium

COOLING THE BUILDING

Heat gained through the roof, walls, and windows of a building, regardless of where the AC system is located, adds significant burden to the AC system. Shade from tree planting along facades of a building that receives direct sunlight—and especially in areas that reduce the amount of direct sunlight shining through windows into the interior spaces of the building—can reduce the internal temperatures in the building significantly. White or light-colored roofing materials, as well as green roofs, will reduce the heat gained as well.

Find out about cooling a building through materials and shading here:

Landscaping Shade
https://www.energy.gov/energysaver/landscaping-shade

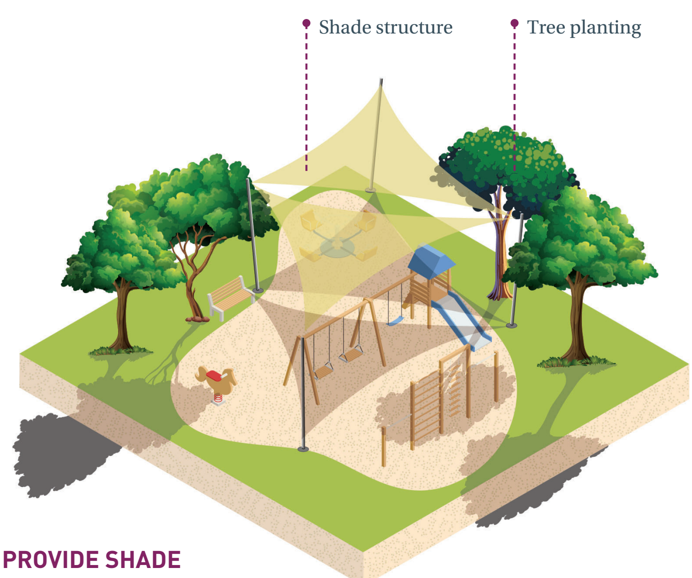
Extreme Heat Guidebook
https://www.epa.gov/sites/default/files/2016-10/documents/extreme-heat-guidebook.pdf

Windows are the key facilitator of daylight and ventilation in a building. This brings benefits of access to natural light and well-ventilated rooms, but also can be a major source of unwanted heat absorption and increase the burden on the AC system. Window Glazing Systems utilize new technologies to reduce heat transfer, resulting in a more stable interior temperature. Glazing options can be selected based on various factors such as window orientation, building design and climate.

Find out about Window Glazing here:

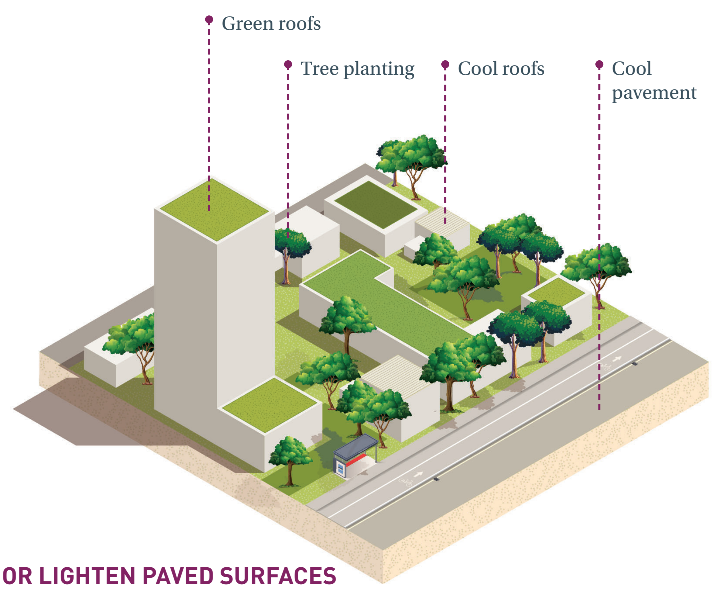
Windows and Glazing
https://www.wbdg.org/resources/windows-and-glazing

Window Types and Technologies
https://www.energy.gov/energysaver/window-types-and-technologies



PROVIDE SHADE OVER PLAYGROUND

Shading playgrounds and gathering areas offers heat reduction and improves quality of life.



REDUCE OR LIGHTEN PAVED SURFACES

Replacing paved surfaces with greenery or lighter coatings reduces the surrounding air temperature.

Figure 27: Design Strategies for Extreme Heat.

COOLING THE LANDSCAPE

Hot parking lots and other paved areas around a building can increase the air temperature before it reaches the building. On larger campuses, reducing paving and incorporating more trees and shade into the landscape will reduce the ambient air temperature surrounding the building, reducing the burden on the AC system.

Trees, landscaped areas, and lighter colored paving absorb less heat than materials like asphalt or dark paving. Solar panels over parking areas can provide shade while also producing electricity to offset electrical demand from the grid system.

Find out about reducing temperature through landscaping here:

Energy Efficient Landscaping
https://www.energy.gov/energysaver/energy-efficient-landscaping

Smart Growth and Heat Islands
https://www.epa.gov/heatislands/smart-growth-and-heat-islands

Cool Pavements
https://www.epa.gov/sites/default/files/2014-08/documents/coolpavescompendium_ch5.pdf

KEEPING THE CLASSROOM COMFORTABLE

Even inside the classroom there are measures that can benefit the overall cooling and air cleaning systems. Clear instructions for teachers on when to close windows during heat or smoke events, how to properly block sunlight and heat from coming into the building through the windows, and other best practices could be placed in each classroom.

Air sensors and thermometers in the classrooms could alert the teachers to threats that may be localized to a certain part of a building. Having a supply of filtering masks available for the most vulnerable students during a smoke event could help extend valuable time to relocate during an emergency. Ensuring proper fit for children is essential, otherwise masks may provide a false sense of reduced PM exposure.

Find more information about filtering masks for children here:

Protecting Children from Wildfire Smoke
https://wspehsu.ucsf.edu/projects/wildfires-and-childrens-health-2/.

Find out about best practices and techniques for maintaining a safe and comfortable classroom here:

Creating Healthy Indoor Air Quality in Schools
https://www.epa.gov/iaq-schools

Take Action to Improve Indoor Air Quality in Schools
https://www.epa.gov/iaq-schools/take-action-improve-indoor-air-quality-schools

Why Indoor Air Quality is Important to Schools
https://www.epa.gov/iaq-schools/why-indoor-air-quality-important-schools

Even instructions for how to assemble homemade filter box fans, or Corsi Rosenthal Boxes, could help prepare for events where portable filtration units are in short supply.

Find information and instructions for creating filter box fans here:

DIY Box Fan Filters – Corsi-Rosenthal Box
https://cleanaircrew.org/box-fan-filters/

COOLING THE RIDE

The route to the schools and cooling centers can be a danger point for children and people sensitive to heat and smoke during an event. Retrofitting buses with AC and clean air filters—or ensuring that new buses are capable of safely transporting people during these types of events—would make transportation between home and shelter safer.

Find out about how to improve heat and smoke exposure during the bus ride here:

Heat Safety on the School Bus
https://sisc.kern.org/wp-content/uploads/2012/10/HeatSafety-BusDrivers1.pdf

Sensible Steps to Healthier School Environments
https://www.epa.gov/sites/default/files/2017-06/documents/sensible_steps_final_may2017_web.pdf

END NOTES

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FIGURES

Figure 1: Provided by Glumac, A Tetra Tech Company

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Figure 3: Provided by Glumac, A Tetra Tech Company

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Figure 13: (Top) Provided by CSU Long Beach & Gensler; (Bottom) Provided by CSU Long Beach & Glumac, A Tetra Tech Company

Figure 14: Provided by Glumac, A Tetra Tech Company

Figure 15: Provided by Glumac, A Tetra Tech Company

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APPENDIX

APPENDIX A: WORKSHOPS

MULTNOMAH COUNTY WORKSHOP PARTICIPANTS

The EPA and the design team held workshops over a 2-day period, Dec 6 & 7, 2022, to help Portland Public Schools create an action plan for retrofitting schools for cleaner air and cooling for students and staff. Over this period participants discussed a range of dynamic topics related to creating a successful plan including Experiences from Previous Cooling Centers, Lessons Learned, Technical Guidance for Retrofits, Operations and Policies & Procedures. The workshop participants include the following groups and organizations:

Multnomah County Health Department
Multnomah County Office of Sustainability
Multnomah County Department of County Human Services
Portland Public Schools
Portland Fire Bureau
Portland Bureau of Emergency Management
Cultivative Initiatives

APPENDIX B: ADDITIONAL RESOURCES

SMOKE

ASHRAE Smoke Guidance

"American Society of Heating, Refrigerating and Air-Conditioning Engineers"
The Smoke Guidance is a framework for safety measures and preparation in order to minimize smoke exposure for building occupants. The guide explains how to create and implement plans, test HVAC filtration and readiness, and how to incorporate adjustments based on the assessment.

https://www.ashrae.org/File%20Library/Technical%20Resources/COVID-19/Planning-Framework-for-Protecting-Commercial-Building-Occupants-from-Smoke-During-Wildfire-Events.pdf

Wildfire Study to Advance Science Partnerships for Indoor Reductions of Smoke Exposures

An EPA study in partnership with the University of Montana, the Hoopa Valley Tribe in California, and others to measure and compare smoke infiltration into buildings during non-smoke and smoke events. This research is being used to develop new strategies and plans as well as emphasize how working with local communities will develop more effective solutions for combating smoke infiltration inside buildings.

https://www.epa.gov/air-research/wf-aspire

EXTREME HEAT

Heat Islands and Equity

This page defines heat islands, their affects and consequences on communities, and the inequities linked to demographic factors and historic discrimination such as redlining. The page goes on to give examples of how cities have started to address heat island inequity and how to effectively more forward to combat future heat events.

https://www.epa.gov/heatislands/heat-islands-and-equity

Managing Extreme Heat Recommendations for Schools: Pilot Version

This document provides recommendations for schools serving grades K–12 on actions to mitigate the effect of extreme heat on students and reduce the frequency of heat-related illness among students.

https://www.azdhs.gov/documents/preparedness/epidemiology-disease-control/extreme-weather/heat/managing-extreme-heat-recommendations-for-schools.pdf

APPENDIX C: ASHRAE FILTER RETROFIT GUIDANCE

ASHRAE

APPENDIX:
USE CAUTION WHEN UPGRADING AIR FILTERS

Introduction

How can I tell If my system can safely use MERV 13 filters? When upgrading filters to ones with higher efficiency, there is concern that the additional pressure drop will stress or harm the fan motor or other HVAC components. Monitoring the fan motor operation and checking temperatures at a few key locations will provide information to determine safe operation or the inability to use higher MERV rated filters.

Overview

Air handlers and roof top package units are designed with a fan sized to provide air flow for adequate heating and cooling. To do this, the supply air fan provides static pressure to move the air though dampers, filters and heat exchangers as well as ductwork, registers and the conditioned space. The amount of air must be adequate to transfer heat in and out of the conditioned space within the design parameters of the equipment. Cleaning the fan and finned air coils will provide additional capacity for air filtration. These systems are dynamic: as filters load with dust and heat exchangers become fouled with dirt, the performance is affected and the potential for failure increases. To gain an understanding of important benchmark temperatures and pressures, reference the manufacturer's literature. Rule of thumb guidance is presented as a starting point.

Centrifugal fan surge

Surge is a natural phenomenon that occurs when the maximum head pressure and minimum flow is reached by a centrifugal fan. When the head pressure is greater than the outlet pressure the air will reverse and try to flow back into the fan inlet. This unstable pressure cycling creates pulsing noises and vibrations known as surge. If surge is created by the addition of MERV 13 filters the fan design has been exceeded. Another method should be used to clean the indoor air.

ECM fans

Electronically commutated motors (ECM) for fans are electronically speed controlled for constant torque. These motors will increase in speed and power usage to maintain a constant air flow. Up to a point this is a good thing. These motors should be monitored for amperage to verify they do not overload when upgraded filters are installed and whenever the filter loading is checked. Do this until there is adequate history that demonstrates the motors do not exceed their rated electrical capacity (full load amperage) during a wildfire smoke event. As the static pressure increases ECM fans may become noisy.

VFD controlled fans

Fan motors on a variable frequency drive (VFD), also known as a variable speed drive, typically are controlled to maintain a duct static pressure set point. These motors need to be monitored as well for overloading. Check the drive parameters to verify they match the motor name plate information. Most VFDs will provide adequate motor protection if these parameters are correct. If the drive display shows the motor operating continuously at 100% speed, the unit or filters may need additional corrective actions.

Other AC induction motors

Constant speed induction motors typically used with fans will decrease the power usage as the filters load with dirt and the air flow decreases. These motors will not overload with a greater pressure drop but lower air flow may harm other parts of the system. When increasing the fan speed do not exceed the maximum tip speed or the maximum motor power.

Direct expansion cooling

Low air flow can lead to loss of cooling and compressor failure. Air temperature measurements are a simple way to verify safe operation. The manufacturer's literature or the startup records will have a recommended air temperature difference (ΔT) across the evaporator coil. The rule of thumb is 20ºF (11ºC) ΔT with a minimum discharge temperature of 55ºF (13ºC) measured after 20 minutes of continuous running. If the discharge temperature is below 55ºF (13ºC), visually check for frost or ice on the evaporator coil. Frost is an indication that there is inadequate air flow and the filters, or the level of dust loading are too restrictive. Some fan motors may have the ability to increase speed by changing electrical connections or VFD settings. After adjusting the fan speed, re-check the temperatures.

As the filters load with dust the air flow may fall below the acceptable rate. Piston (reciprocating) compressors are most likely to be damaged by low air flow; scroll compressors are a little more resilient. Units with compressor staging may require additional observation and testing. It is up to the operator to determine that conditions for safe operation are in place.

Heat pumps

While cooling, follow the guidelines above. While heating, low air flow may cause the unit to shut down when the high-pressure safety trips. Review the manufacturer's instructions to determine the appropriate limits for the maximum discharge temperature and ΔT.

Electric Resistance Heating

Electric heating elements must have sufficient air flow to operate. Review the manufacturer's instructions to determine the appropriate discharge temperature limit.

Combustion appliances

Roof top units and air handlers with natural gas or propane heat need adequate supply air flow for heat transfer and to prevent damage to the heat exchanger. The unit label or manufacturer's literature will list a maximum discharge air temperature and a range of temperature differences that indicate acceptable operation. Rule of thumb is 160ºF (71ºC) maximum discharge temperature and 40 to 60ºF ∆T (22 to 33ºC) across the heat exchanger. Direct fired units and oil-fired units have similar parameter. Always use the manufacturers recommended settings to determine that safe operations are being met.

APPENDIX D: HEAT DAY CHECKLIST

BEST PRACTICES FOR TEACHERS

- ☐ Use window coverings such as closing the blinds or using shading devices/materials (such as foil) to reflect the sun out of the building.
- ☐ Dim the lights or use fewer lights.
- ☐ Use ceiling fans or room fans to increase airspeeds in the classroom.
- ☐ Encourage students to wear appropriate clothing for forecasted hot days in the classroom.
- ☐ Increase the frequency of water breaks and/or encourage students to bring water bottles.
- ☐ Reduce the heat producing equipment use such as projectors.
- ☐ Maintain low energy activities such as stretching and recovery in lieu of strenuous exercise.
- ☐ Check air outlets with a flashlight to ensure that there are no major obstructions that could inadvertently limit airflow. If you see something, notify maintenance before taking corrective action.
- ☐ Check with the maintenance department before a forecasted heat wave day to see if you need to make any thermostat adjustments. There may be special initiatives by the maintenance department that involve the thermostat as noted below:
    - Pre-Cooling: Setting the thermostat to a lower temperature to start at a lower temperature at the beginning of the day.
    - Load Shedding: Setting the thermostat to a slightly higher temperature to reduce the electrical strain and cooling capacity strain on the building's systems.
- ☐ If there is air conditioning, ensure windows and exterior doors are closed.
    - If the air conditioning system isn't keeping the room cool, check with maintenance before opening the windows as it could bring in more hot air that the system cannot handle and it could also turn off the air conditioning system if there are automatic HVAC shut off sensors on the windows.

APPENDIX E: SMOKE DAY CHECKLIST

BEST PRACTICES FOR TEACHERS

- ☐ Ensure windows and exterior doors remain closed.

- ☐ Check for any cracks or openings in the walls/windows/doors and notify maintenance.

- ☐ Check with the maintenance department if portable filtration units should be used.

    - ☐ Consider the use of a do it yourself air cleaner similar to one here: https://www.epa.gov/indoor-air-quality-iaq/wildfires-and-indoor-air-quality-iaq

- ☐ Continue the use of the air conditioning and ventilation systems.

- ☐ Avoid activities that create more fine particles indoors such as:

    - Spraying aerosol products
    - Frying or broiling food
    - Burning candles or incense
    - Vacuuming, unless the vacuum has a HEPA filter
    - Dust producing activities such as woodworking, laser cutting, additive printing, etc. without source capture exhaust with appropriate filtration

- ☐ Avoid strenuous activities to limit smoke inhalation.

- ☐ If there are concerns about smoke within the classroom, encourage the use of particulate respirators have "NIOSH" and either "N95" or "P100" printed on it that are right sized and include two (2) straps that go around your head such as those found here: https://www.airnow.gov/sites/default/files/2020-06/the-right-respirator-and%20proper-fit-508_0.png

APPENDIX F: PPS SCHOOL CLOSURE PLAN

School Closure Plan

Portland Public Schools

School Year 2022-2023

I. Purpose of the School Closure Plan

This document is intended to provide guidance to the School Closure Decision Team for events when school closure is anticipated (EG: forecasted snow or known poor air quality). As climate change exacerbates the frequency and severity of extreme weather events, this plan expands the methodology for school closures to keep our community safe. Schools may also be closed or impacted for emergencies and unanticipated events; for those situations reference:

- Emergency Operations Plan; or
- Utility Outages Standard Operating Procedure

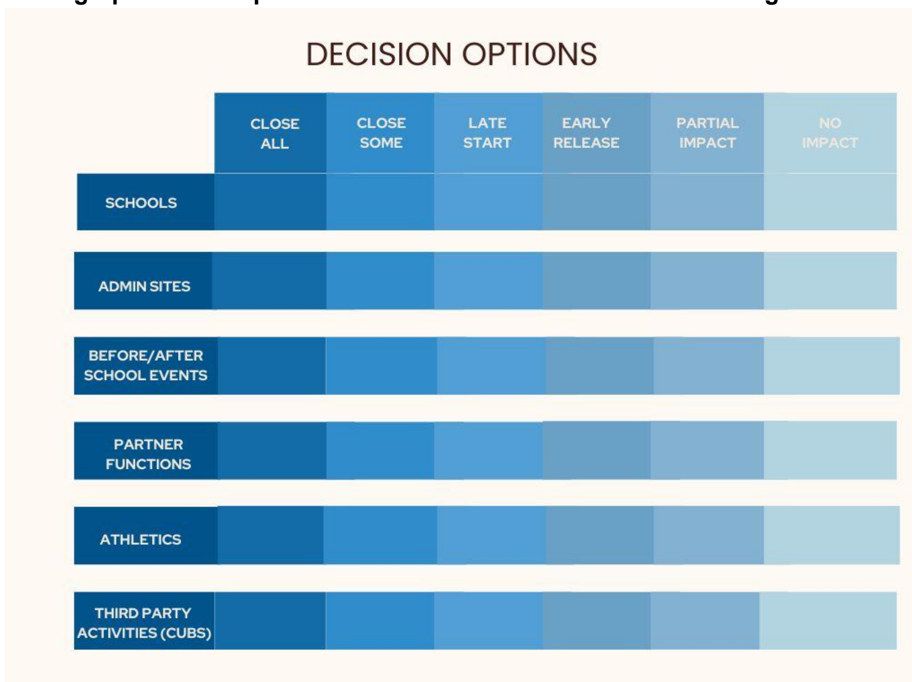
II. School Closure Decision Team

This section is omitted for individuals' privacy

III. School Closure Decision Team Meeting Protocols

When the need to convene the School Closure Decision Team is identified, the Director of Security (or designee) will send a Google meeting link to the School Closure decision making team prior to 5 a.m. or the evening prior to the event. In the event that Google meeting is unavailable, the PPS Zoom Link will be used as a back-up.

The graph below depicts a matrix for consideration when making decisions.



IV. Common School Closure Scenarios

Extreme Heat

High temperatures can cause conditions in schools that may require school closure or alterations. The heat index is what the temperature feels like to the human body when relative humidity is combined with the air temperature. When outside conditions exceed heat index thresholds, the School Closure Decision Team will meet to review conditions and determine if schools need to be closed or otherwise impacted.

1. **Thresholds**

   The School Closure Decision Team will meet when:
   - Heat index for the day expected to be >80° beginning at 10 a.m. or earlier
   - Heat index for the day expected to be >95° while school activities are in session
   - Heat advisory warning is sent out by the county
   - Other excessive heat concerns

2. **Responsibility**

   Risk Management has primary responsibility for monitoring potential extreme heat conditions and initiating a School Closure Decision Team meeting.

3. **Decision Considerations**

   No school closure:
   - Schools with mechanical cooling systems do not have to close
   - Heat index is not expected to be >80° after 10 a.m.
   - Pre-cooling of school buildings remains in effect per the OSHA heat illness prevention rule

   Early release:
   - Heat index is expected to be ≥95° after 10 a.m., or
   - Heat index is expected to be ≥100° before school day ends
   - Pre-cooling of school buildings remains in effect per the OSHA heat illness prevention rule

   School closure considerations:
   - Heat index of at least 105 degrees F for more than three hours per day for two consecutive days, or

- Heat index of between 91-103 for three consecutive days or more

4. **Notes**
   - The decision to close will be based upon the determination of whether the environment is deemed safe based on the temperatures within the classrooms and after steps have been taken to alleviate the excessive heat conditions.
     The District will NOT make decisions to close all schools (or all schools without A/C) due to heat conditions. The primary reasons for this are:
     Air-conditioned schools can function comfortably in high external heat conditions
     Amongst schools without A/C, the temperatures can vary greatly building by building (and within buildings). Some schools may be somewhat uncomfortable, while others may be extremely uncomfortable.
     Individual schools have and can develop different mechanisms for coping with heat.
   - Outdoor activities and sports can be moved indoors or canceled.
   - Buildings with air conditioning: Prophet Center, Clarendon, Columbia, Faubion, Franklin, Grant, Holiday Annex, Kellogg, McDaniel, Roosevelt, Rosa Parks, Tubman, Lincoln
   - Programs/Services Impacted by Extreme Heat: Schools, Evening Scholars, SPED, Athletics, Construction/Maintenance Projects-PPS, Childcare, Partner Programs, CUB's, Transportation

5. Resources
- OR-OSHA Heat Rule: LINK
- Heat index tracking app: LINK
- PPS Extreme heat plan: LINK
- NWS Weather Ready Nation "Beat the Heat" Resources: URL: http://www.nws.noaa.gov/os/heat/index.shtml
- CDC Tips for Preventing Heat-Related Illness: URL: http://emergency.cdc.gov/disasters/extremeheat/heattips.asp
- CDC Info for Specific "Heat Sensitive" Groups: URL: http://emergency.cdc.gov/disasters/extremeheat/specificgroups.asp
- American Red Cross Heat Wave Safety: URL: http://www.redcross.org/prepare/disaster/heat-wave
- Ready.gov Extreme Heat Resource: URL: http://www.ready.gov/heat
- OSHA Heat Educational Resources: URL: https://www.osha.gov/SLTC/heatillness/edresources.html
- PPS:Weather, Disasters, School Emergencies

Snow/Ice

Snow and ice accumulation can cause unsafe road conditions and impact school operations. When snow and/or ice is forecast to accumulate and potentially impact schools, the School Closure Decision Team will meet to review conditions and determine if schools need to be closed or otherwise impacted.

1. **Thresholds**
   PPS uses the National Weather Service as the primary source for weather information, in addition to data from transportation in the field and our regional partners. This plan could be activated whenever snow, sleet, or ice is forecasted, or at any time deemed necessary by the Superintendent or their designee..

2. **Responsibility**
   Student Transportation has primary responsibility for monitoring potential snow or ice conditions and initiating a School Closure Decision Team meeting.

3. **Decision Considerations**
   Student Transportation team members will drive roads and assess the conditions overnight to assess:
   - Safety of the students walking to school, bus stops, and waiting for the bus.
   - Areas impacted by the event (district-wide, localized, single school).
   - Transportation's ability to respond effectively to this event.
   - The ability of school staff to arrive safely and on time.
   - The impact to the families in the unaffected areas.

   The Facilities and Operations team also provides site reports for school buildings.

4. **Notes:**
   -

5. **Resources**
   - Transportation Inclement Weather Plan

- National Weather Service: https://www.weather.gov/
- PPS school elevation chart: LINK
- Custodial Inclement Weather Inspection Checklist
- Inclement Weather Communications Plan (includes template messages)

Air Quality

Outdoor air quality can cause unsuitable conditions inside and outside schools that may require school closure or alterations. When outdoor air quality conditions exceed air quality index (AQI) thresholds, the School Closure Decision Team will meet to review conditions and determine if schools need to be closed or otherwise impacted.

1. **Thresholds**

   The School Closure Team will meet when:
   - AQI is ≥101 Outdoor activities and sports should be moved indoors
   - AQI is ≥250 All schools are closed; Outdoor activities and sports should be moved indoors or canceled

2. **Responsibility**

   Risk Management has primary responsibility for monitoring potential extreme heat conditions and AQI, and initiating a School Closure Team meeting.

3. **Decision Considerations**
   - PPS will work with external partners, including public health organizations, when making determinations on school closures or canceling any planned outdoor activities due to hazardous air quality.

4. **Notes**
   -

5. **Resources**
    - The Oregon Health Authority provides the following resource and guidance regarding outdoor activities during wildfire events: OHA Public Health Guidance: School Outdoor Activities During Wildfire Events
    - Inclement Weather Communications Plan (see plan for new messages)

Utility Outages

Planned utility outages can cause schools to be without power. When planned utility outages are known, the School Closure Team will meet to review conditions and determine if schools need to be closed or otherwise impacted.

1. **Thresholds**
   When planned utility outages are known, the School Closure Decision Team will meet to review conditions and determine if schools need to be closed or otherwise impacted.

2. **Responsibility**
   Utility companies do not follow a uniform procedure for notifying PPS of planned outages. However, either Emergency Management or Facilities are typically the first departments notified. When any School Closure Team member is made aware of a planned outage, they will initiate a School Closure Team meeting.

3. **Decision Considerations**
    - Duration of outage
    - Timing of outage
    - Impact to individual schools and/or surrounding neighborhoods

4. **Notes**
    -

5. **Resources**
    - Utility Outage EOP
    - PGE Outage Line **503-736-5585**

- Pacific Power Outage Line **1-877-508-5088**

V. School Closure Notification Protocol

Once a decision has been made by the School Closure Decision Team, quick and efficient communication to students, staff, partners, and the community is essential.

1. **Communication to community and families**
   Students, families, and community members will need to be notified of the School Closure Decision Team's decision (EG: if a portion of the district is closed, the students and families of these schools need to be notified). The Communications team will take the lead on communicating to the PPS community. Communications will:
   - Communicate directly to families via email, texts, and robocalls.
   - Share updates to local media via FlashAlert.
   - Post information on PPS.net homepage and social media accounts.
   - Monitor and respond to community questions throughout the school closure period.

2. **Communication to affected PPS staff**
   Staff impacted by the decision will need to be informed (EG: if a portion of the district is closed, staff of these schools will need to be informed). The Communications team will take the lead on providing communication to affected PPS staff. Communications will:
   - Communicate directly to staff via email using SchoolMessenger.

3. **Communication to implementation staff**
   Depending on the decision, various school operations will be impacted by the Team's decision (EG: if a portion of the district is closed, departments such as OSP, Nutrition Services, and OTIS, as well as community partners, will need to be notified and make appropriate operational modifications). Department leaders on the School Closure Decision Team will be responsible for communicating both "up and down" the chain of command to ensure all tiers of staff are informed. Department leaders will report back to the School Closure Decision Team any learned operational concerns or impacts.

Example Department Lead Communications:

Department Lead	**Required Notification**
Office of School Performance (Chief of Schools)	Deputy Superintendent, Instruction and School Communities Assistant Superintendents (if not on the Team call) Area Senior Directors Principals PIL ***Research, Assessment and Accountability*** ***Office of School Support Services*** ***Office of Teaching and Learning***
Chief of Staff	Communications (if not on the Team call) Community Engagement Government Relations ***School Board*** ***RESJ Partnerships***
Operations (Chief Operating Officer)	Deputy Superintendent, Business and Operations Nutrition Services Security and Emergency Management (if not on the Team call) Student Transportation (if not on the Team call) Maintenance and Operations (if not on the Team call) Planning and Real Estate Facilities Project Management and Construction Office of School Modernization ***Finance*** ***OTIS***
Risk Management	General Council
Human Resource	Union leaders

4. Notes

5. **Resources**
   - Inclement Weather Communications Plan (includes template messages)
   - Employee reporting & compensation expectations by employee group - HERE

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