Keeping Buildings Safe and Healthy During Wildfire Events

A Guide To Evaluating Systems and Strategies To Mitigate Air Quality Threats in New and Existing HVAC Systems.

ABSTRACT

This document presents useful information regarding the significance of the growing threat of wildfire events and its impact on indoor air quality (IAQ). This advisory offers proactive solutions that building owners and operators and design professionals can implement to protect the occupants in their commercial buildings.

An in-depth review of systems and solutions and recommended solutions and products is presented in the Addenda.

> *Due to the effects of climate change, more frequent and intense wildfires are likely to become the new norm. Recurrent droughts and drier forests create conditions that are more conducive to the spread of severe wildfires.*
>
> *– Department of Ecology, State of Washington*

THE CHALLENGE – UNDERSTANDING THE NATURE OF WILDFIRE EVENTS

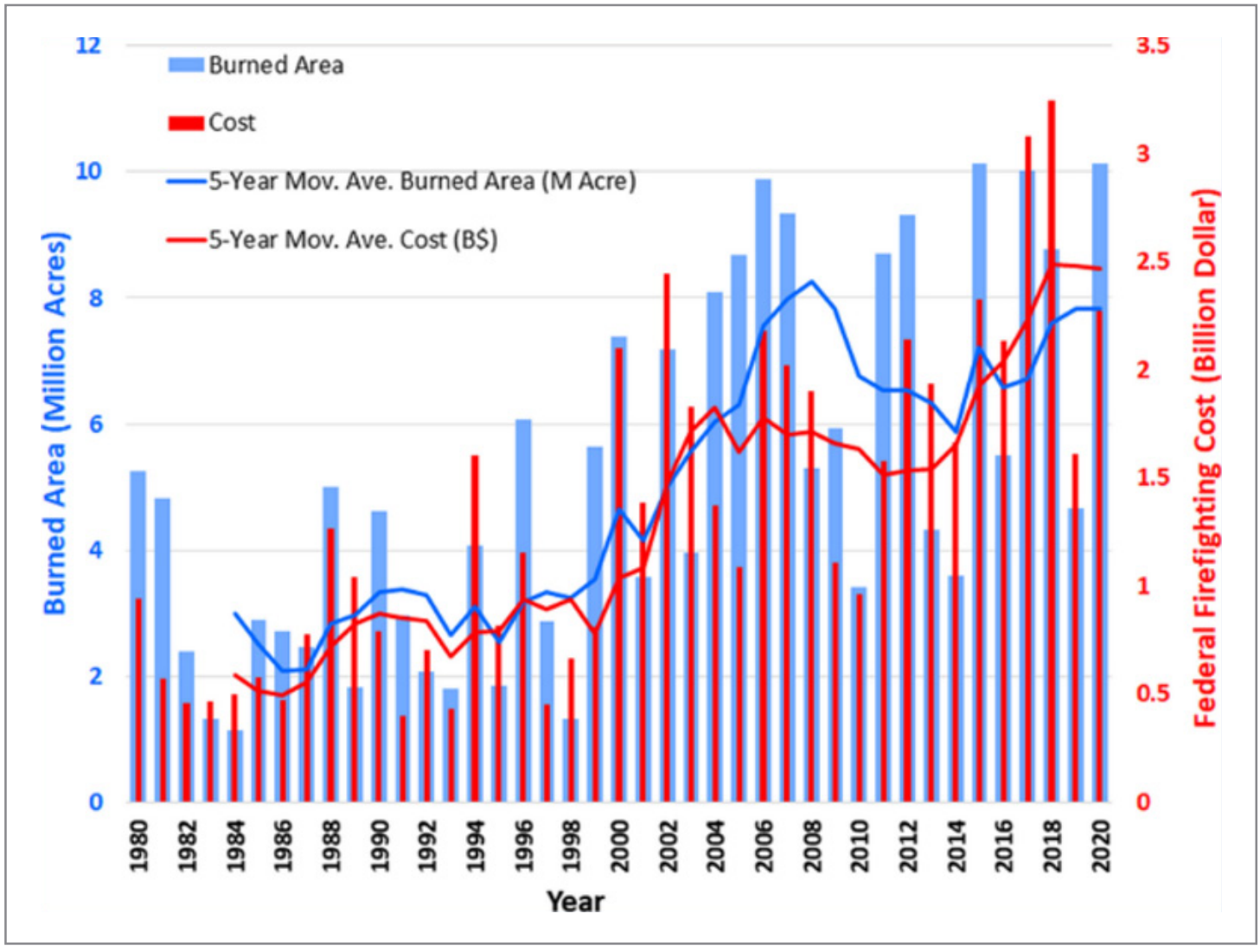
Wildfires have the potential to drastically lower IAQ within buildings. This can have a substantial negative impact on the comfort, health and safety of building occupants.

> *Wildfire smoke is a mix of gases and fine particles from burning vegetation, building materials and other materials. Wildfire smoke can make anyone sick. Even someone who is healthy can get sick if there is enough smoke in the air.*
>
> *– Centers for Disease Control & Prevention*

> *As wildfire events increase in the U.S., public health and emergency response professionals in areas prone to wildfires or routine prescribed burning can help reduce exposure to smoke, whether outdoors or indoors, within the community during wildfire or prescribed burn events. Breathing in smoke is harmful to health, and fine particulate matter ($PM_{2.5}$) is the greatest health concern. Exposure to fine particles in smoke can cause respiratory and cardiovascular health effects, especially for those with preexisting conditions like asthma and heart disease. When smoke from fires becomes a health hazard, state and local health departments may advise people to stay indoors and avoid outside activity when possible. Smoke events can last for days and weeks, which is why it is important for building owners and managers to have information on best practices for reducing exposure to smoke that may enter schools, commercial buildings or multi-unit housing.*
>
> *– United States Environmental Protection Agency*

THE RISKS

Wildfires present a multi-faceted IAQ challenge that few installed HVAC systems are capable of handling.



Conceptualizing a probabilistic risk and loss assessment framework for wildfires.
Source: Natural Hazards 114, 1153–1169 (2022)

THE RISKS (CONTINUED)

Source: IQAir, iqair.com/us/lp/blog/wildfire/how-to-protect-yourself-from-wildfire-smoke?utm_source=taboola

The contaminants of concern are twofold:

a. **Particulates.** Smoke from a wildfire event consists of extremely small smoke and dust particles that standard air filters will not adequately capture. Approximately 90% of the total particle mass is comprised of $PM_{2.5}$, which refers to particulate matter that is generally 2.5 microns in size or smaller. This also includes ultrafine particles, those having diameters less than or equal to 0.3 microns. By comparison, the diameter of an average human hair is about 50 to 70 microns, approximately 50 times as large. Particulate matter up to 10 microns can collect deep in lungs and may enter the bloodstream (EPA: Particulate Matter Basics). Particulate matter 2.5 microns and larger are category particles are therefore potentially dangerous with extended exposure. Standard air filters are not effective for addressing this IAQ challenge, and most HVAC systems are ill-equipped.

b. **Gaseous compounds.** The wide variety of pollutants released by wildfires also includes gas-phase pollutants, including greenhouse gases — carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) — and photochemically reactive compounds — e.g., carbon monoxide (CO), nonmethane volatile organic carbon (NMVOC) and nitrogen oxides (NO_x). Wildfires influence the local climate both directly, through the emission of greenhouse gases and aerosols, and indirectly, via secondary effects on atmospheric chemistry — e.g., ozone (O3) formation — and a host of oxygenated VOC (OVOC), including methanol, acetic acid, acetone, 1,3-butadiene, furan and 2-furaldehyde. Some of these compounds are odorless, making them difficult to detect, and all of them are considered irritants with the potential to trigger severe health effects, especially for those with preexisting risk factors, pregnant women and the very young or elderly.

> *"The odds of all-ages non-traumatic mortality with same-day exposure was 1% greater on wildfire smoke days compared to non-wildfire smoke days, and the previous day's exposure was associated with a 2% increase. When stratified by cause of mortality, odds of same-day respiratory mortality increased by 9%, while the odds of same-day COPD mortality increased by 14%. In subgroup analyses, we observed a 35% increase in the odds of same-day respiratory mortality for adults ages 45–64."*
>
> – Source: Environmental Health Study of Mortality Tied to Wildfire Smoke in Washington State, 2006-2017

THE RISKS (CONTINUED)

Recognizing the potential severity of wildfire events and the impact they can have on buildings and their occupants, it is important to assess the filtration capabilities of a facility's HVAC system. In most cases, upgrades or supplemental systems will be required to adequately mitigate both particulate and gaseous contaminants. Depending on location, it is recommended that a proactive audit of all buildings be performed so that managers can develop targeted plans for improving the filtration effectiveness of their equipment.

EXISTING SYSTEM CAPABILITY – A REVIEW OF CONVENTIONAL HVAC FILTRATION AND ITS ABILITY TO PROTECT BUILDINGS AND OCCUPANTS

Most commercial HVAC systems have rooftop units or air handlers that include some level of air filtration. These systems also provide a level of minimum ventilation to meet building code requirements and for best practice building pressurization. These systems draw in air from outside the building that during times of wildfires will be laden with the contaminants mentioned previously.

Except for certain process or medical applications, the filters used in these systems have typically been limited to a basic particulate filter designed to protect the HVAC system, *not* for indoor air quality. Recently, with the increased severity of wildfires, along with challenges resulting from the COVID-19 pandemic, more emphasis has been placed on increasing air filtration efficiency to focus on protecting occupants as well as keeping air conditioning units and ductwork clean. ASHRAE recommends minimum MERV 13 filtration efficiency (up to 97% arrestance for 1.0 micron particles) as a part of its guidelines for infectious disease control. This is consistent with the *minimum* level of filtration efficiency needed to arrest fine particles contained in wildfire smoke.

The air filters used in most commercial buildings typically do not meet these recommendations. They usually consist of a single bank of at most 2" deep panel or pleated filters. The efficiency of these filters is at best MERV 8 (up to 90% arrestance of particles 3 to 10 microns). *For filtering smoke particles that are one-tenth that size, these filters are not adequate.*

So, simply upgrade the filters to MERV 13 or better? Unfortunately, it is not that simple.

To avoid higher equipment costs and be the most energy efficient, rooftop or fan coil units have blower capabilities designed to meet original equipment and system requirements. This covers the air pressure drop load for the basic filters. When it comes to upgrading to higher efficiency filters, these HVAC units do not have the room or the fan power to accommodate them, as they impart a higher resistance to airflow. If used, the system airflow, and, consequently, heating cooling and ventilation capabilities, could be substantially reduced. Therefore, it is important to consider HVAC systems as a whole when considering upgrades to meet the IAQ challenges of wildfire events.

NEW DESIGN/NEW EQUIPMENT

When renovating facilities, or in the case of new constructions, there is an opportunity to proactively and cost-effectively design systems for a wildfire event. Physical size, blower capacity and serviceability can be implemented with upgraded, new equipment selections.

GOOD

Include an air filter section that accommodates at least MERV 13, high dust holding capacity filters.

This is the minimum step that should be integrated where the outside air enters the system. Consider two stages with a higher efficiency filter following a prefilter that can extend the time between filter changes.

Also, note that the ASHRAE Position Paper on Infectious Aerosols states "Improve central air and other HVAC filtration to MERV 13 or the highest level achievable." This is consistent with the GOOD recommendation and is an additional incentive for providing this minimum level of filtration. Adding air cleaners *indoors* is not an effective strategy because, at that point, the pollutants are already in the occupied space and in the breathing zone. It is imperative to arrest the pollutants *before* they enter the building.

BETTER

MERV 15 is substantially better for the removal of smaller particles and delivers a clear performance improvement for $PM_{2.5}$ and $PM_{1.0}$. MERV 13 traps more than 50% of the particles from 0.3 to 1.0 microns.

By comparison, MERV 15 captures more than 85%, approximately a 35% improvement. As previously stated, the contaminants of concern from wildfire smoke also includes gaseous compounds that the particulate filters will not remove. Therefore, in addition to the higher efficiency filters, a stage of gas-phase filters (aka "carbon" filters) should be added as the next downstream component in the HVAC system.

There are various kinds of chemical media, so be sure to specify the appropriate type for the intended service. As with particulate filters, there are options with respect to the performance of the chemical media. Contact your solutions provider for more application-specific information.

Note that the gas-phase filter may naturally release its own carbon dust. For this reason, a simple final filter should be included. Using a duplicate of the prefilter is a practical choice as it will keep filter inventory and procurement as simple as possible.

NEW DESIGN/ NEW EQUIPMENT (CONTINUED)

BEST

Some building occupants may be particularly sensitive to the negative effect of smoke. This includes medical facilities, retirement communities, daycare centers or facilities that have other IAQ concerns, such as manufacturing plants or casinos.

In these cases, it is recommended to use MERV 13 prefilters with a high dust holding capacity (deeper filters as a rule will hold more particles and reduce the frequency of filter replacements), followed by high-efficiency particulate arrestance (HEPA) filtration – the gold standard for removing the small particles associated with wildfire smoke. As previously stated, gas-phase filters with a post-filter should also be used. Adding dielectric barrier discharge bi-polar ionization tubes as a final component in the HVAC units provides an additional measure of protection.

Ionization technology provides a cost-effective, further mitigation of the gases before they enter the conditioned space, as well as an active process in the space that can break down VOC gases and agglomerate smaller particles, dropping them rapidly from the breathing zone. Bi-polar ionization can provide a back up if the filters become overloaded.

In a study by Fresno State University, sponsored by ASHRAE, bi-polar ionization when used in combination with a MERV 13 filter yielded HEPA performance. This is significant since the majority of buildings cannot withstand the static pressure drop caused by a HEPA filter, but where an upgrade to MERV 13 is very feasible.

There are pros, cons and tradeoffs with all the available options. As more filtration is added for much improved protection of the occupied zone air quality, the extra components take up more space and impart a higher pressure drop on the system air-moving device. These are not insignificant impacts and must be considered as decisions are made to protect people from the harmful effects of wildfire smoke particles and gases. However, with new equipment, the HVAC system can be designed optimally to address this severe wildfire challenge.

RETROFIT

For existing equipment, the facilities engineer or building owner faces a much different situation. While the good, better and best choices previously described still apply, there are several issues that may complicate implementation. First, there may be insufficient space for adding upgraded filtration components. Second, the system blowers may not be able to handle the additional restriction to airflow imparted by upgraded filtration. Despite these challenges, there are some work-arounds.

GOOD

Consider the system filtration. If it includes at least a 2" deep track for the filters initially specified, at a minimum, be prepared to install MERV 13 filters. Recognize this may result in some reduction of airflow if the original filters are rated with a lower MERV value.

The resulting reduction that could occur in the system cooling capacity likely will not outweigh the better protection provided for building occupants during an acute event.

The higher MERV value filters will reduce the infiltration of larger smoke particles (and the odor these particles carry) but will not have any impact on the gaseous compounds that are a large contributor to poor IAQ during a wildfire event. Indoor portable air purifiers may also be purchased and held on hand to deploy as needed (see addendum A4).

BETTER

In addition to the above, but also in recognition that the building's HVAC system may be constrained by its original design, there are other equipment enhancements that can assist with mitigating the worst of a wildfire event.

Ionization, a technology proven for its capability to reduce both particle and gas pollutants, may easily be added to the equipment, specifically in two locations:

1. Place in the supply or discharge duct to allow for ions to saturate into the occupied space. This will help to add a layer of protection in the occupant breathing zone for the particulate and VOC gases that may increase during wildfire events. Bi-polar ionization will agglomerate particles and displace them from the breathing zone rapidly and break down VOCs into carbon dioxide and water vapor.
2. Where space allows, provide ionizers *upstream* of the air filters. This is because ions are effective at agglomerating small particles, therefore the downstream filters become more effective. (This location for ion generators is usually not recommended since these devices may become dirty and because the best use of ions for cleaning air in the space should be generated close to the supply air discharge in the occupied zone. However, in this case, the immediate concern is to improve air cleaning during the time period when the need for aggressive air purification is acute [service of these devices can occur post-event].) Consult with the ionizer solutions supplier for installation instructions and recommendations.

As an added note of interest, the ion generators in the supply air could be left in service continuously, not just during a wildfire event. They draw very little power and will continue to provide an IAQ benefit at all times.

BEST

For buildings where there is a significant threat of wildfire events and for any facility where there are either vulnerable occupants (medical centers, hospitals or retirement or assisted living facilities) or a high concentration of people (airports, corrections facilities, casinos or schools), the measures described previously may need to be enhanced.

To truly attack the problem at the source without fully replacing the existing HVAC equipment, filtration sections can be added. For both particulate and gas pollutant control, these sections can be produced and installed well in advance of their need with options built in for existing equipment and specific building requirements.

The concept is to provide the solution *without imposing higher energy costs or maintenance costs or demanding specialized professional service technicians.*

Instead, managers would gain an at-the-ready ability to remove pollutants before being allowed to enter the building. A supplemental filtration section would be connected to the existing OA inlets (at the existing units or outdoor air inlet openings).

Include:

- Full housing with its own OA inlet hood or grille as necessary.
- Prefilter: a high-capacity (deeper) filter (minimum MERV 11, preferably MERV 13).
- Post-filter: high-capacity filter (MERV 14 or 15), bag filter or V-bank filter.
- Gas-phase filtration: This is the "carbon" filter designed and selected specifically for the gas compounds associated with wildfires. Reminder, gas compounds that may not be seen can severely impact IAQ and cause temporary or more permanent health issues.
- Bi-polar ionization tubes: To allow the delivered air to be enriched with air ions to further enhance all filtration and ventilation methods, add an active method of air cleaning to the passive methods described previously.

Concerned about an added pressure drop that the existing HVAC unit blowers might not be able to handle? As part of the evaluation of the currently in-place equipment, the supplemental filter sections should be sized for reduced velocity, low pressure drop filters as practical. The loss of some airflow during an event may be an acceptable compromise. For an application where the air purification and full airflow is necessary, booster fans can also be included (recognizing that the section size and cost will increase). Consult with the solutions provider for installation instructions and recommendations (see addendum A4).

AIR MONITORING

Information is always critical when making decisions regarding indoor air quality. IoT-capable IAQ sensors are now being used by many facilities to make more informed decisions. These systems give an indoor/outdoor comparison and will alert the user to adverse outdoor air quality (www.airnow.gov/aqi/aqi-basics/) that will ultimately impact indoor air quality. Monitors can be integrated into building functions to adjust operational sequences such as overriding economizer operation to revert back to minimum ventilation, outdoor and indoor air quality changes. Also, for space occupants, public displays can be incorporated to reassure them that they are breathing clean indoor air.

PRACTICAL CONSIDERATIONS

Stage filters

It is important to avoid consuming fan power unnecessarily and to prematurely load up the supplemental filters by having them installed full time. The goal is to treat wildfire smoke. So, when it is not present, supplemental filters should be left staged and clean in a nearby storage area. The filter section should remain empty until an event approaches. This should be included in the planning, so the system is most effective when called on to deliver clean air.

Spare filters

This advisory's purpose is to provide practical recommendations for functional results. What is a likely weak link? The filters, irrespective of their capacity to remove contaminants, may become quickly overloaded by the magnitude of the pollution challenge. The filters could rapidly load up, causing the system effectiveness to drop off. Practically, to reorder replacement filters during an event will likely result in an "out of stock" response from a local filter supplier. *Consider stocking a second set of filters as a backup.*

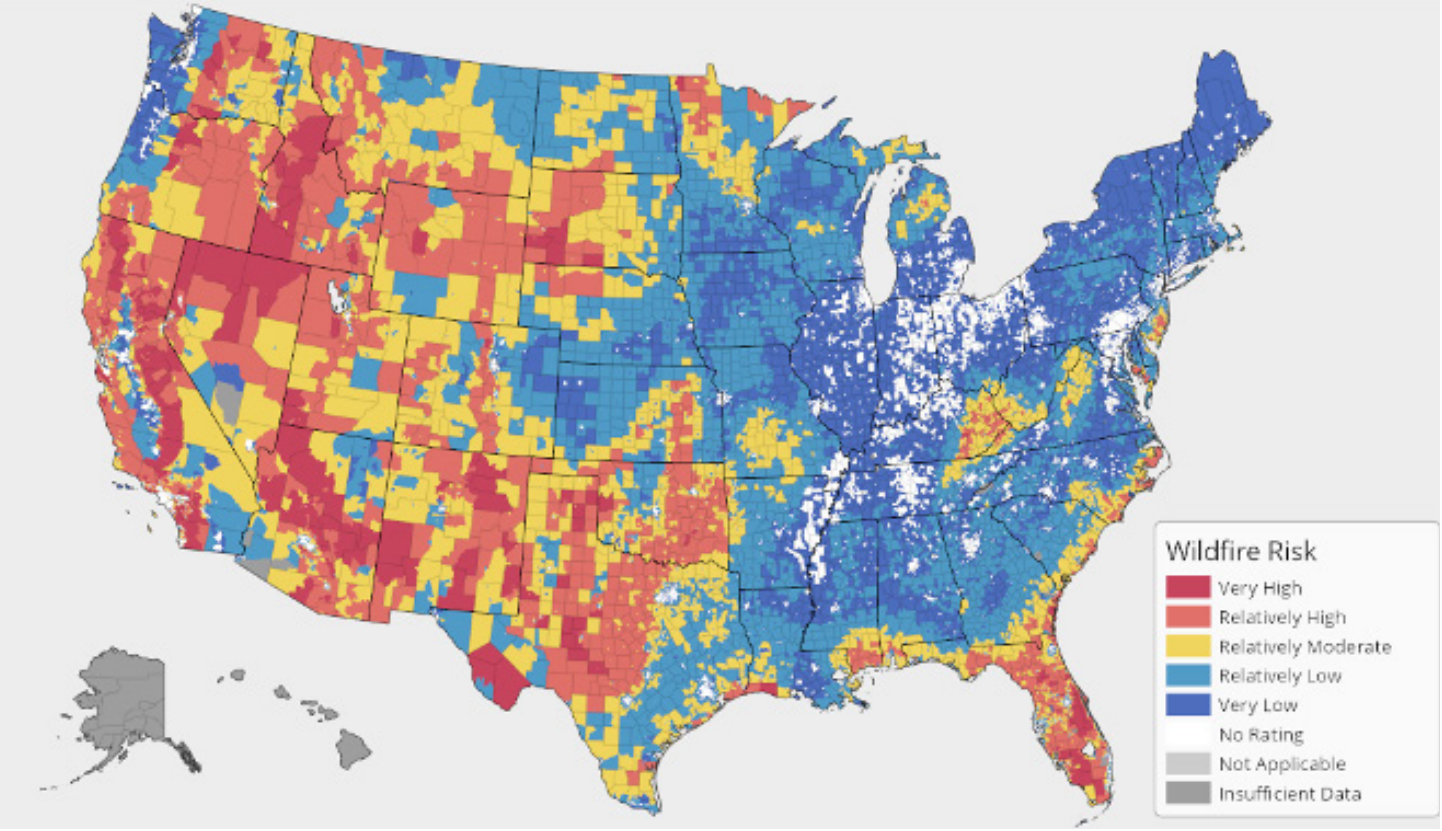
Use of existing unit filters

Contact your solutions provider for advice on how best to utilize the existing filters. Depending on the solution design chosen for a given facility, these filters can be used to maximum effect.

Consider setting HVAC system controls to minimize outside air intake during a wildfire event, but do not set them to zero. Temporarily disable the economizer function. Understanding that the IAQ challenge is in the outside air, it is nonetheless best to maintain some positive pressurization within the building to reduce infiltration at the building entrances or openings.

SUMMARY

Anticipation of profound and serious risk to the health and safety of building occupants during a wildfire event places tough demands on the building owner and facility's engineer. But with a plan developed and ready to be implemented in advance of the need, commercial buildings can be prepared to maintain adequate air quality using options that align with both budget and practical installation considerations. See the Addenda for more specific product solutions in support of this advisory.



Source: FEMA National Risk Assessment

ADDENDA

A1. Preparation:

Readiness. All building managers should have a plan prepared in advance of any potential disaster, and wildfire events are no exception. Suggested plans are available. It is strongly recommended that a plan best suited for a specific property be selected and implemented. Examples:

https://www.fema.gov/disaster/wildfire-actions
https://www.dnr.wa.gov/publications/rp_fire_how_to_prepare_wildfire.pdf

An itemized example from The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE):

1. *Purchase smoke preparation supplies, such as portable air cleaners and extra filters.*
2. *Evaluate the ability of the HVAC system to handle a higher efficiency filter. (The planning framework recommends MERV 13 or higher filters during smoke events.)*
3. *Conduct a full maintenance check on the HVAC system and make repairs if needed.*
4. *Assess and maintain adequate air flows to protect occupant health and equipment during smoke events.*
5. *Prepare to add supplemental filtration at the intake air vent where possible.*
6. *Assess filter conditions by adding a port or pressure gauge to measure the filter pressure drop on at least one air-handling unit.*
7. *Weatherize the building to limit smoke intrusion. Consider measures such as limiting allowable entrances to reduce smoke entry.*
8. *Prepare to monitor indoor $PM_{2.5}$ by purchasing one or more low-cost air sensors designed to measure the pollutant. These low-cost sensors can be used to show trends in $PM_{2.5}$ levels (i.e., whether $PM_{2.5}$ is increasing or decreasing). These low-cost sensors will not be as accurate as regulatory monitors but can show whether your interventions are reducing indoor $PM_{2.5}$.*
9. *Determine how to create temporary cleaner air spaces within the building.*
10. *Anticipate sources of indoor $PM_{2.5}$, such as cooking, vacuum cleaning, use of printers or copiers and smoking, which can increase levels of $PM_{2.5}$ within the building.*

A2. Sources of Additional Information to Properly Prepare for and Protect Your Building and Its Occupants:

https://www.nfpa.org/wildfirepreparedness

https://www.fs.usda.gov/treesearch/pubs/33764

https://www.ashrae.org/file%20library/technical%20resources/covid-19/planning-framework-for-protecting-commercial-building-occupants-from-smoke-during-wildfire-events.pdf

https://www.epa.gov/system/files/documents/2021-07/flyer-recommendations-for-reducing-wildfire-smoke-in-commercial-buildings-and-schools.pdf

https://ehjournal.biomedcentral.com/track/pdf/10.1186/s12940-020-0559-2.pdf

https://www.cdc.gov/disasters/covid-19/reduce_exposure_to_wildfire_smoke_covid-19.html

https://gis-fema.hub.arcgis.com/pages/wildfires

https://www.fema.gov/data-visualization/fire-incidents-states-and-counties

https://www.airnow.gov/

https://toolkit.climate.gov/tool/planning-framework-protecting-commercial-building-occupants-smoke-during-wildfire-events

A3. Possible Sources of Funding:

https://www.fema.gov/disaster/wildfire-actions#fmag

https://www.fema.gov/sites/default/files/documents/fema_funded-wildfire-mitigation-activities.pdf

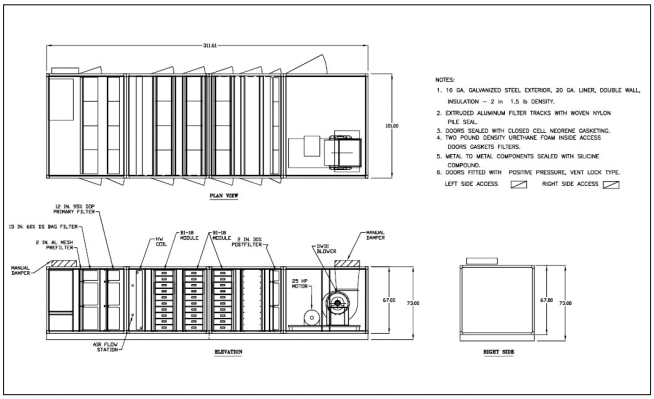
https://www.usda.gov/media/press-releases/2022/07/26/biden-harris-administration-announces-1-billion-community-wildfire

https://www.fema.gov/grants/mitigation/pre-disaster

- Consider local state grant and funding opportunities in addition to federal programs.

A4. Product Solutions:

New system options:

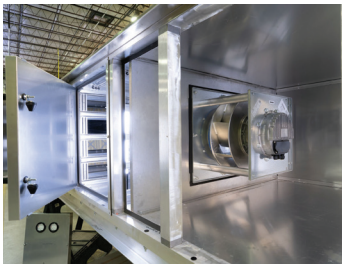


Bioclimatic Air Purification System - Horizontal

1. Particulate filtration only:
    a. Specify upgrade to MERV 13 through HEPA efficiency, with 4” to 28” filter depths; provided by HVAC equipment OEM.
    b. Add-on filter sections to accommodate upgrades (as available from OEM or through third party that specializes in providing IAQ solutions that match your system design; see example to the left). These supplemental units can be provided with or without blowers as required.
    c. Built-to-fit kits to install in existing equipment where space allows.
2. Gas-phase filtration:
    a. Addition of “carbon” type filters, with 1” to 18” deep media.
    b. Add-on sections to house media and pair with standard HVAC units.
3. Complete solutions – full, multistage sections or complete air handlers specifically geared for building ventilation airflow requirements and including all necessary filtration sections.

Retrofit options:

1. Particulate filtration only.
2. Gas-phase filtration.
3. Bi-polar ionization.
4. Complete solutions (including housed units manufactured to fit and coordinate with existing equipment).



Fully packaged air purification system for treating outside contaminants

AtmosAir 500 EC & FC

Bioclimatic unit filter rack for high-capacity, odor-removal

Portable options:

AtmosAir RIA SafeGuard

Applications Support:
Bioclimatic Air Systems | 856-334-4300 | bioclimatic.com