

Protecting Building Occupants from Smoke during Wildfire and Prescribed Burn Events

Guideline 44 is in development to provide building measures to minimize occupant health impacts during wildfire and prescribed burn smoke events. In 2020, over 58,000 wildfires occurred in the U.S. alone, burning more than 10 million acres (1). With the increasing number of fires and the large numbers of people living at wildland-urban interfaces, protecting building occupants from smoke has become critically important. Wildfire smoke is composed of fine particulate matter (PM_{2.5}, less than 2.5 µm in diameter) and gases. Breathing high concentrations of these pollutants can cause respiratory and cardiovascular health effects, especially for those with pre-existing conditions such as asthma or heart disease (2). While most healthy people will recover quickly from exposure to smoke during a wildfire episode, some susceptible populations are at greater risk of health effects, including, pregnant women, infants, children and older adults (2). This article summarizes interim guidance developed by the guideline committee to provide immediate information on this pressing issue, while it continues to work on the complete guideline. The interim guidance can be found at [*note to reviewers, the correct link will be added when available*]

Knowing when to implement the building measures is critical for building managers. State and local health departments issue air quality notifications when actions are needed to protect the public. These notifications will help building managers know when to initiate smoke mitigation efforts, termed the “Smoke Readiness Plan”. Table 1 provides further guidance on when to implement the plan. The interim guidance suggests that building managers consider implementing the plan when vulnerable populations are anticipated to be impacted by smoky conditions.¹

¹ To find out more about local ambient air quality see AirNow.gov and state websites (3, 4). The US Air Quality Index, shown on AirNow.gov, has six categories indicating levels of health concern as a function of PM_{2.5} concentrations (5).

Table 1. Decision framework for implementation of Smoke Readiness Plan.

Smoke Conditions ¹	Answers	Action
Currently smoky? Forecasted to be smoky in the coming days?	No No	Carry on with normal operations. Have your Smoke Readiness Plan prepared and ready for execution.
Currently smoky? Forecasted to be smoky in the coming days?	Yes No	Consider implementing Smoke Readiness Plan.
Currently smoky? Forecasted to be smoky in the coming days?	No Yes	Consider implementing Smoke Readiness Plan.
Currently smoky? Forecasted to be smoky tomorrow?	Yes Yes	Implement Smoke Readiness Plan.

¹To find out more about local ambient air quality see AirNow.gov and state websites (3, 4).

This interim guidance primarily focuses on reducing exposure to particulate matter and applies to most commercial buildings, schools, multi-unit residential buildings and similar buildings that use air handling units to provide heating, ventilation and air conditioning (HVAC) to protect occupants from ?. Healthcare facilities and other specialized buildings should rely on qualified HVAC staff and consultants. Ideally, quick implementation of temporary measures will clean the air coming into the building and limit infiltration of wildfire smoke. Some buildings and HVAC systems are not designed and/or maintained to accommodate the modifications recommended in the interim guidance. Appropriately sized portable high-efficiency particulate air (HEPA) air cleaners can help to create temporary cleaner air spaces, however building managers will need to assess whether these measures are sufficiently reducing the levels of particulate matter. **The guidance emphasizes that assistance from an HVAC professional is generally required to assess existing HVAC equipment capabilities and implement portions of these recommendations.**

Indoor air needs to be cleaned whether ventilating with outside air or recirculating indoor air. To help building managers accomplish this, the interim guidance outlines a process (shown in Figure 1) for making a building Smoke Ready. Figure 2 provides a flow chart of actions within this process, including assessing whether these actions have been effective in reducing indoor PM_{2.5} levels. The interim guidance explains how and why these actions should be taken before and during wildfire smoke episodes.

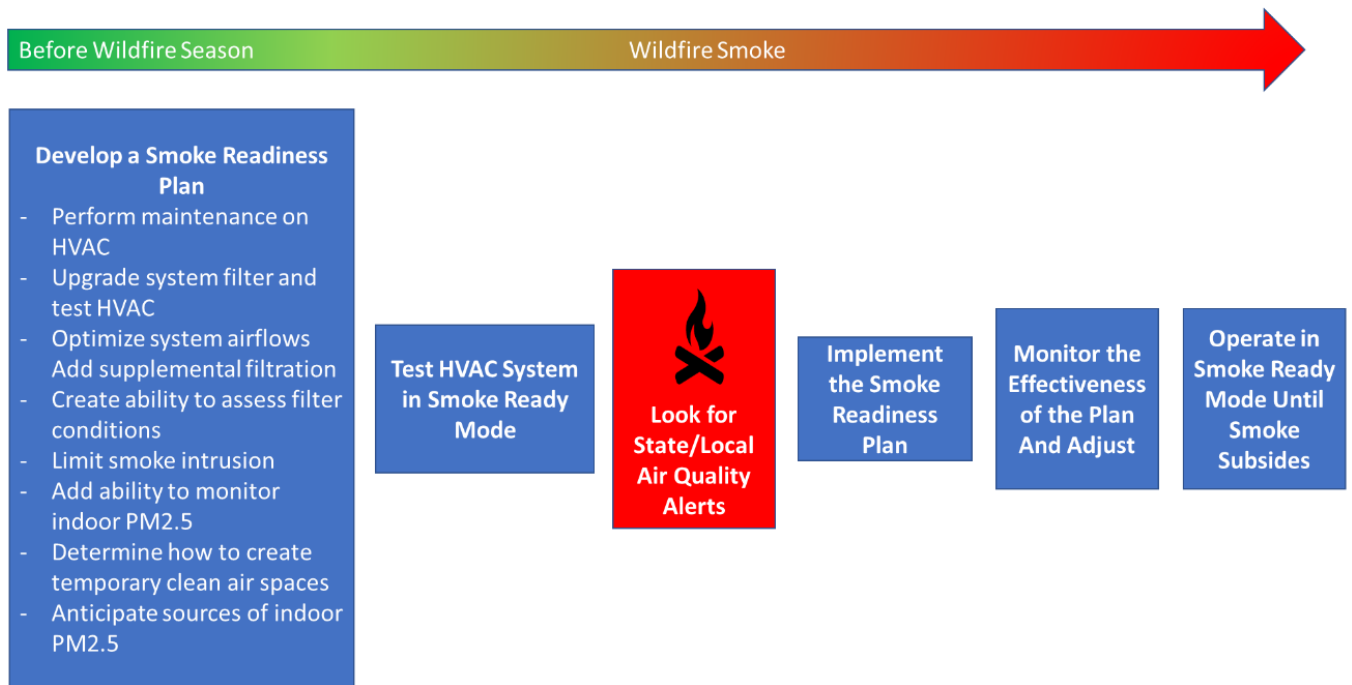


Figure 1. Process for making a building Smoke Ready.

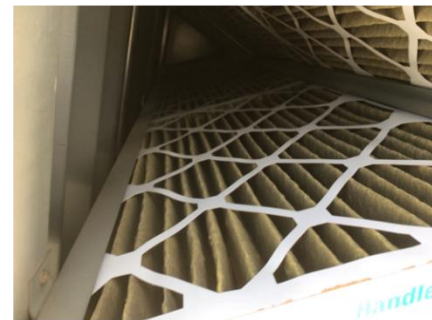
The interim guidance emphasizes that a Smoke Readiness Plan needs to be specific to each building and should address the following elements:

1. **Smoke Preparation Supplies.** Before wildfire season, purchase materials and supplies needed for the plan. For example, purchase portable air cleaners and extra filters in advance, as they may become difficult to find during a smoke event. Wildfire smoke can quickly load filters (see Figure 3) and they may need to be changed as frequently as daily.



Clean filter

2. **Upgrade System Filter. Minimum Efficiency Reporting Value? (MERV) 13 filters** are recommended during smoke events as they ?. However, prior to wildfire season, HVAC systems must be assessed for ability to function properly with the upgraded filters.



Heavily loaded filter

3. **Maintenance of the HVAC system.** Repair broken dampers, actuators and HVAC controls prior to fire season. Pay special attention to the economizer because they are complex and may not be installed correctly. The economizer will need to be temporarily disabled why ?.

4. **Optimization of System Airflows.** Assess and maintain adequate airflows that are protective of human health and equipment health during smoke events. Prior to wildfire season, determine an outside air intake level that controls odor, temperature, indoor contaminant levels, and maintains a positive building pressure consistent with the building and HVAC system design.

5. **Supplemental Filtration.** During a smoke event, add additional filtration at the intake air vent where possible (Figure 4). A minimum of a MERV 13 filter on the outside air intakes will capture a large fraction of the PM_{2.5}. Prior to fire season, inspect the air intake and make a list of filters, tape, temporary ducting materials and other items needed to mount filters to the air intake with minimal bypass around the filter.

Figure 3. Picture comparing a clean (HEPA OR MERV) filter to a filter heavily loaded with wildfire smoke.

6. **Assessing Filter Conditions.** Prior to fire season, add a port or pressure gauge to measure the filter pressure drop on at least one air handling unit. This will simplify determining when to change filters.
7. **Limit Smoke Intrusion.** Prior to wildfire season, weatherize the building envelope, including doors and windows to reduce infiltration by sealing and caulking cracks. Keep doors and windows closed to limit smoke intrusion.



Figure 4. Picture of a MERV 13 filter installed on an intake air vent

8. **Indoor PM_{2.5} Monitoring.** Prior to wildfire season, purchase one or more low-cost air monitors (example) equipped with a PM_{2.5} sensor and install it in the facility (6). These monitors will not be as accurate as regulatory monitors but can show whether your interventions are reducing indoor PM_{2.5}. For example, upward trends in PM_{2.5} levels can indicate that doors or windows are open, air filters are degrading or HEPA room air purifiers should be turned on. Make a plan for how the data from the monitor will be accessed and the actions that will be taken during a smoke event.
9. **Temporary Cleaner Air Spaces.** Determine how to create temporary cleaner air spaces within the building prior to fire season. Use portable room air cleaners of the appropriate size for the room with HEPA filters and other methods to clean the air (see discussion below). Some portable air cleaners come with indicators that change color as the air quality improves. If the cleaner does not come with an indicator function, it may be helpful to purchase a low-cost air monitor to determine whether the air is being cleaned. A low-cost air monitor may also help to verify that the air is in fact cleaner in the cleaner air space relative to other spaces in the building. Beware and avoid the models of air cleaners that produce ozone or are generate ions generators (see list on California Air Resources Board website (7)).
10. **Anticipate Sources of Indoor PM_{2.5}.** Cooking, vacuum cleaning, incense, smoking and similar activities increase indoor PM_{2.5} levels. Understanding potential sources in the building can assist in the reduction of these sources during wildfire or prescribed burn events.

The interim guidance includes a full checklist for use in determining whether the building HVAC system is ready for smoke. A few of the issues outlined in the checklist include: Are the outside dampers working correctly? Is the outside air economizer is working and can it be shut off? Can the HVAC system use MERV 13 filters?

The interim guidance urges special attention to economizers. Most roof top units and larger HVAC systems are equipped with an outside air economizer. To save energy, the economizer uses outside air to replace the mechanical cooling system when temperatures allow. This can bring in large amounts of smoke and particulate matter into a building during wildfire season. The economizer control also maintains a minimum outside air damper position for ventilation, controls relief fans and may close the outside damper when the building is unoccupied. Care and regular maintenance are recommended to ensure the economizer operates as intended.

There are numerous manufacturers and control schemes for economizers. Finding effective workarounds to temporarily limit the economizer damper operation in response to wildfires is challenging. The guidance recommends investigating what actions are needed to limit operations; this may include adding switches and control relays. Other work arounds may also be required, such as placing the outside air damper in manual control and set the position to allow the minimum air required for ventilation.

The interim guidance recognizes that SARS-CoV-2 raises additional challenges. While HVAC filtration and air cleaning recommendations for smoke and SARS-CoV-2 are similar due to similar respirable particle sizes, a low ventilation rate is desirable for smoke control and, in contrast, a high ventilation rate is needed for removal of SARS-CoV-2 virus particles. The building manager's challenge is to monitor system components and indoor conditions and change system settings as outside air quality changes to balance potential tradeoffs between smoke and SARS-CoV-2 exposure. Portable air cleaners with a HEPA filter can be helpful in removing virus particles as well as smoke particles.

If the HVAC system is not able to reduce the PM_{2.5} concentrations throughout the building or tradeoffs are made to reduce potential SARS-CoV-2 exposures, a cleaner air space is needed. A portable air cleaner with a HEPA filter, appropriately sized for the space, is recommended. Multiple devices may be needed for larger rooms. The Association of Home Appliance Manufacturers has developed a rating system and room size recommendations for portable air cleaners. The smoke clean air delivery rate (CADR) is the rating for 0.09 to 1.0-micron particles and represents the amount of clean air delivered on the high-speed setting. Units with HEPA filters and low noise ratings are recommended (8). While do-it-yourself room air cleaners using a box fan and a MERV 13 furnace filter provide air cleaning similar to a small room (100 ft²) air cleaner, they are noisier and should not be left unattended or placed near water (9).

When the Smoke Readiness Plan is prepared and before the start of wildfire season, the interim guidance suggests testing the HVAC system with the additional filtration and adjusted flow settings. There may be several non-functioning items that will take more time to fix than emergency conditions allow. This test run along with the additional preparations outlined in the interim guidance, should facilitate implementation of the Smoke Readiness Plan when smoke occurs. For optimal results, this guidance suggests monitoring the effectiveness of the plan over the course of the smoke event. At the end of the wildfire season, any adjustments and lessons learned should be incorporated into the Smoke Readiness Plan to be better prepared

for future smoke events. The full guideline will build upon this interim guidance further fleshing out topics like design, installation and commissioning of the components of a smoke ready building and system performance testing.

REFERENCES

- 1) <https://www.nifc.gov/fireInfo/nfn.htm>
- 2) California Air Resources Board; California Office of Environmental Health Hazard Assessment; U.S. Centers for Disease Control and Prevention; U.S. Forest Service; and U.S. Environmental Protection Agency. [2019] *Wildfire Smoke: A Guide for Public Health Officials*. Retrieved from <https://www.airnow.gov/wildfire-smoke-guide-publications/>
- 3) U.S. Environmental Protection Agency. [2020] *AirNow website*. Retrieved from <https://www.airnow.gov/>
- 4) U.S. Environmental Protection Agency. [2020] *State Smoke Advisory Websites*. Retrieved from <https://www.airnow.gov/air-quality-and-health/fires/smoke-advisories/>
- 5) U.S. Environmental Protection Agency. [2015] *Air Quality Guide for Particle Pollution*. Retrieved from https://www.airnow.gov/sites/default/files/2020-03/air-quality-guide_pm_2015.pdf
- 6) Berkeley Lab. [2020] *Low-Cost Home Air Quality Monitors Prove Useful for Wildfire Smoke [news article with links to relevant publications]*. Retrieved from <https://newscenter.lbl.gov/2020/08/18/low-cost-home-air-quality-monitors-prove-useful-for-wildfire-smoke>
- 7) California Air Resources Board. [2020] *Hazardous Ozone-Generating Air Purifiers*. Retrieved from <https://ww2.arb.ca.gov/our-work/programs/air-cleaners-ozone-products/hazardous-ozone-generating-air-purifiers>
- 8) Association of Home Appliance Manufacturers [2019] *Find a Certified Room Air Cleaner*. Retrieved from <https://ahamverifide.org/directory-of-air-cleaners/>
- 9) Puget Sound Clean Air Agency. [2020] *DIY Air Filter*. <https://www.pscleanair.gov/525/DIY-Air-Filter>