

©ASHRAE www.ashrae.org. Used with permission from ASHRAE Journal at www.epa.gov. This article may not be copied nor distributed in either paper or digital form without ASHRAE's permission. For more information about ASHRAE, visit www.ashrae.org.

Protecting Building Occupants From Smoke During Wildfire and Prescribed Burn Events

BY TOM JAVINS, P.E. LIFE MEMBER ASHRAE; GAIL ROBARGE; EMILY GIBB SNYDER, PH.D.; GREGORY NILSSON; STEVEN J. EMMERICH, FELLOW ASHRAE

ASHRAE Guideline 44P, *Protecting Building Occupants from Smoke During Wildfire and Prescribed Burn Events*, will provide HVAC and building measures to minimize occupant exposures and health impacts from smoke during wildfire and prescribed burn smoke events. This column summarizes the planning framework for Guideline 44P, which is being shared by the guideline committee to provide immediate information on this pressing issue while the committee continues work on the complete guideline.

The planning framework includes information for building managers on developing their Smoke Readiness Plan, preparing for smoke events by having supplies on hand and testing procedures in advance, and knowing when and how to implement measures in their plans. The document, "Planning Framework for Protecting Commercial Building Occupants from Smoke During Wildfire Events," can be found at <https://tinyurl.com/yxyuqh72>.

What is the Concern and Who is at Risk?

In 2020, in the U.S. alone, over 58,000 wildfires

occurred, burning more than 10 million acres (4 million ha).¹ Increasing numbers of wildfires and large numbers of people living at wildland-urban interfaces makes protecting building occupants from smoke critically important. Wildfire smoke is composed of fine particulate matter (PM_{2.5}, particles less than 2.5 μm in diameter) and gases. Although wildfire smoke contains multiple contaminants, this document focuses on controlling exposure to PM_{2.5}. Breathing high concentrations of these pollutants can cause respiratory and cardiovascular health effects, especially for those

Tom Javins, P.E., is a mechanical engineer at the University of Montana in Missoula, Mont. Gail Robarge is a physical scientist and Emily Gibb Snyder, Ph.D., is a chemist at the U.S. Environmental Protection Agency, Office of Research and Development in Washington, D.C. Gregory Nilsson is a technical officer at National Research Council Canada in Ottawa, ON, Canada. Steven J. Emmerich is Indoor Air Quality and Ventilation Group Leader at the National Institute of Standards and Technology in Gaithersburg, Md.

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

with preexisting 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 also at greater risk of health effects, including pregnant women, infants, children and older adults.²

When Do Building Managers Need to Take Action?

Knowing when to implement building measures is critical for building managers. State and local health departments may issue air quality notifications when actions are needed to protect the public, and these notifications help building managers know when to initiate smoke mitigation efforts, outlined in their “Smoke Readiness Plan.” *Table 1* provides an easy to use decision matrix to help managers know when to implement the plan. The planning framework suggests that building managers consider implementing the plan when smoky conditions are likely to affect vulnerable populations.*

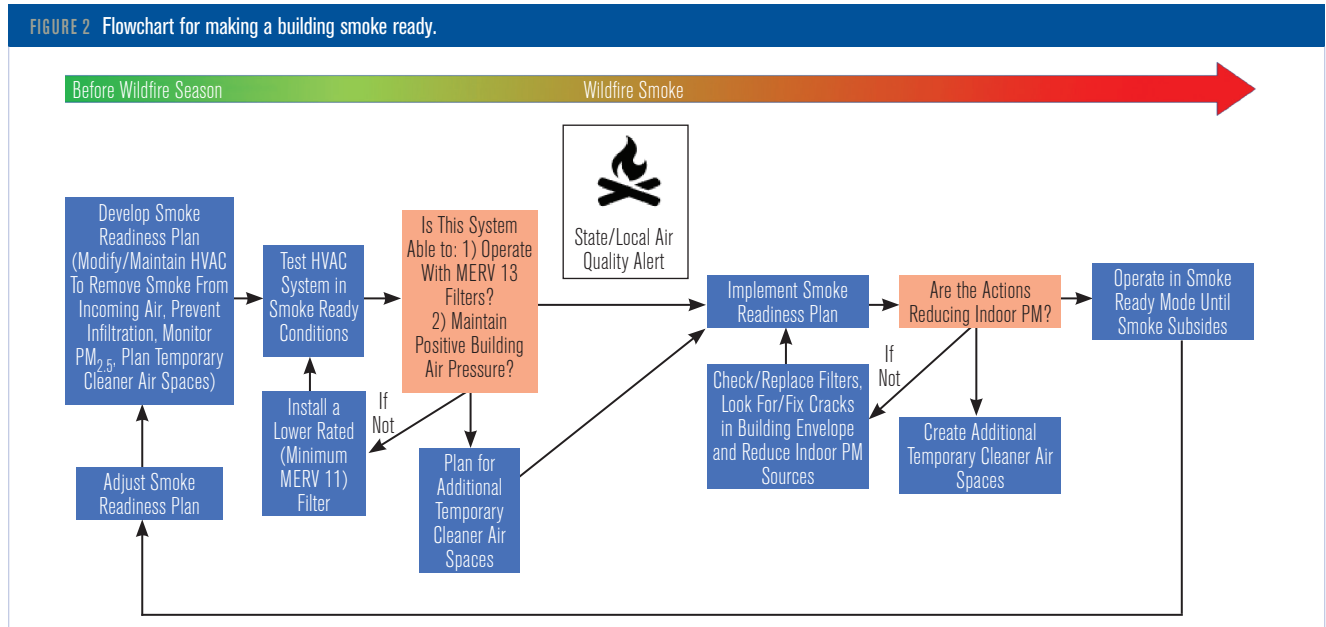
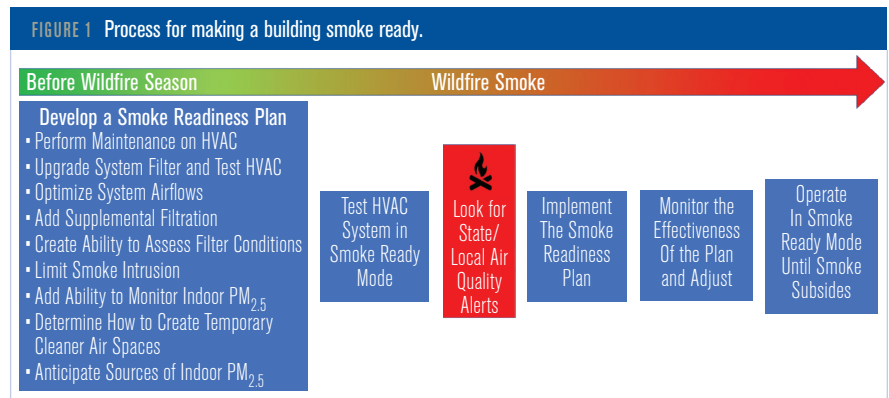
What is the Scope of the Framework?

This planning framework primarily focuses on reducing exposure to particulate matter and applies to most commercial buildings (e.g., retail, office space), schools, multiunit residential buildings and similar buildings that use air-handling units to

provide HVAC. These recommendations are not intended for single-family homes or individual dwelling units. Health-care facilities and other specialized buildings

SMOKE CONDITIONS ^a	ANSWERS	ACTION
Currently smoky? Forecast to be smoky in the coming days?	No No	Carry on with normal operations, and have your Smoke Readiness Plan prepared and ready.
Currently smoky? Forecast to be smoky in the coming days?	Yes No	Consider implementing Smoke Readiness Plan.
Currently smoky? Forecast to be smoky in the coming days?	No Yes	Consider implementing Smoke Readiness Plan.
Currently smoky? Forecast to be smoky tomorrow?	Yes Yes	Implement Smoke Readiness Plan.

^aTo find out more about local ambient air quality see AirNow.gov and state websites.^{3,4}



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 planning framework. Appropriately sized portable air cleaners can help create temporary cleaner air spaces. However, building managers will need to assess whether these measures are sufficiently reducing the levels of particulate matter. The planning framework emphasizes 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 outdoor air or recirculating indoor air. To help building managers accomplish this, the planning framework outlines a process for making a building smoke ready (Figure 1). Figure 2 provides a flowchart of actions within this process, including assessing whether these actions have been effective in reducing indoor $PM_{2.5}$ levels. The planning framework explains how and why they should be taken before and during wildfire smoke episodes.

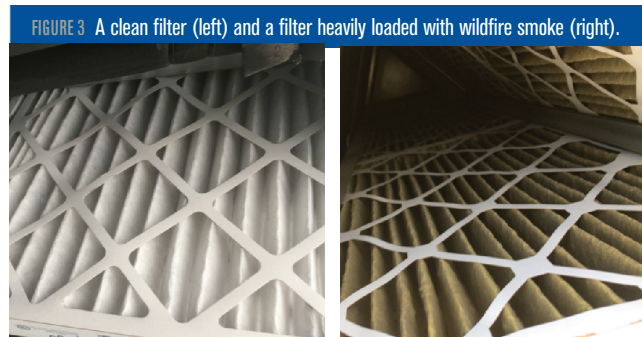
The planning framework emphasizes a Smoke Readiness Plan needs to be building-specific and address the following:

1. Purchase 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 (Figure 3) and they may need to be changed as frequently as daily.

2. Upgrade HVAC System Recirculation Filter. MERV 13 filters are recommended during smoke events. However, prior to wildfire season, HVAC systems must be assessed for the ability to function properly with the upgraded filters.

3. Maintain the HVAC System. Repair broken dampers, actuators and HVAC controls prior to fire season. Pay special attention to the economizer because they can be complex and may not be installed correctly. The economizer will need to be temporarily disabled.

4. Optimize 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 outdoor 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. Prepare to Add 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 outdoor 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.

6. Assess Filter Conditions. Prior to wildfire 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.

8. Prepare to Monitor Indoor $PM_{2.5}$. Prior to wildfire season, purchase one or more low-cost air monitors 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. Determine How to Create 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 (or other high efficiency 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 verify that the air is in fact cleaner in the cleaner air space relative to other spaces in the building. Avoid models of air cleaners that produce ozone or generate ions (see list on California Air Resources Board website).⁷

10. Anticipate Sources of Indoor PM_{2.5}. Cooking, vacuum cleaning, use of printers or copiers and smoking are examples of activities that increase indoor PM_{2.5} levels.⁸ Understanding potential sources in the building can assist in the reduction of these sources during wildfire or prescribed burn events.

The planning framework includes a full checklist to determine whether the building HVAC system is ready for smoke. A few issues include: Are outdoor dampers working correctly? Is the outdoor air economizer working and can it be shut off? Can the HVAC system use MERV 13 filters?

Pay Special Attention to Economizers

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

Numerous manufacturers and control schemes exist

for economizers. Finding effective work-arounds to temporarily limit the economizer damper operation in response to wildfires is challenging. This framework 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 outdoor air damper in manual control and setting the position to allow the minimum air required for ventilation.

SARS-CoV-2

The planning framework 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 comparable respirable particle sizes, a low ventilation rate may be desirable for smoke control⁹ and, in contrast, a high ventilation rate may be needed to remove SARS-CoV-2 virus particles.¹⁰ The building manager's challenge is to monitor system components and indoor conditions and change system settings as outdoor air quality changes to balance potential trade-offs between smoke and SARS-CoV-2 exposure. Portable air cleaners with a HEPA filter may be helpful in removing virus as well as smoke particles.

Portable Air Cleaners

If the HVAC system is not able to reduce the PM_{2.5} concentrations sufficiently throughout the building or trade-offs are made to reduce potential SARS-CoV-2 exposures, a cleaner air space is needed. A portable air cleaner with a HEPA filter (or other high efficiency 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 (or other high efficiency filters) and low noise ratings are recommended.¹¹

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 [9 m²]) air cleaner, they are noisier and should not be left unattended or placed near water.¹² The framework also recommends reading and following the fan safety instructions.

Test the Smoke Readiness Plan Before Wildfire Season

When the Smoke Readiness Plan is prepared and before the start of wildfire season, the planning framework suggests testing the HVAC system with the additional filtration and adjusted flow settings. Several non-functioning items may exist that will take more time to fix than emergency conditions allow. This test run, along with the additional preparations outlined in the planning framework, should facilitate implementation of the Smoke Readiness Plan when smoke occurs. For optimal results, this framework 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 planning framework, further fleshing out topics like design, installation and commissioning of the components of a smoke-ready building and system performance testing.

Acknowledgments

The planning framework was prepared and reviewed by a Work Group of the GPC 44P committee including the following people: Tom Javins (Work Group Chair), University of Montana, Retired; Alison Clune, U.S. Environmental Protection Agency (EPA); Randall Cooper, Association of Home Appliance Manufacturers; Steven Emmerich, U.S. National Institute of Standards and Technology; Michael Gallagher, Western Allied Corporation; Duane Hammond, National Institute for Occupational Safety and Health; Dr. Sarah Henderson, B.C. Center of Disease Control, Canada; Stacey Katz, EPA; Ann Kosmal, U.S. General Services Administration; Gregory Nilsson, National Research Council Canada; Gail Robarge, EPA; Emily Gibb Snyder, Ph.D., EPA; Rebecca J. Schmidt, Ph.D., University of California, Davis School of Medicine; David Schaaf, AAF Flanders; Kevin Teichman, Ph.D., EPA, Retired; Amanda J. Wheeler, Ph.D., Australian Catholic University.

Disclaimer

The views expressed in this article are those of the authors and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency.

References

1. U.S. National Interagency Fire Center. 2021. "Fire Info."

<https://www.nifc.gov/fireInfo/nfn.htm>

2. EPA. 2019. "Wildfire Smoke: A Guide for Public Health Officials." U.S. Environmental Protection Agency, with California Air Resources Board, California Office of Environmental Health Hazard Assessment, U.S. Centers for Disease Control and Prevention and U.S. Forest Service. <https://tinyurl.com/14kztn7s>
3. EPA. 2021. AirNow website. U.S. Environmental Protection Agency. <https://www.airnow.gov/>
4. EPA. 2020. "Smoke Advisories." U.S. Environmental Protection Agency. <https://tinyurl.com/th2ksm8z>
5. EPA. 2015. "Air Quality Guide for Particle Pollution." U.S. Environmental Protection Agency. <https://tinyurl.com/y4dmkxnz>
6. LBNL. 2020. "Low-Cost Home Air Quality Monitors Prove Useful for Wildfire Smoke." Lawrence Berkeley National Laboratory. <https://tinyurl.com/y2tapla3>
7. CARB. 2020. "Hazardous Ozone-Generating Air Purifiers." California Air Resources Board. <https://tinyurl.com/y4aldpde>
8. EPA. 2018. "Residential Air Cleaners: A Technical Summary." U.S. Environmental Protection Agency. <https://tinyurl.com/52qctoyp>
9. EPA. 2020. "Wildfires and Indoor Air Quality (IAQ)." U.S. Environmental Protection Agency. <https://tinyurl.com/5yaxs6kr>
10. ASHRAE Epidemic Task Force. 2021. "Building Readiness." ASHRAE. <https://tinyurl.com/1mlbnl47>
11. AHAM. 2019. "Find a Certified Room Air Cleaner." Association of Home Appliance Manufacturers. <https://tinyurl.com/y5hfahlf>
12. Puget Sound Clean Air Agency. 2020. "DIY Air Filter." <https://tinyurl.com/y4do38zu> ■



Advertisement formerly in this space.