Reducing Indoor Exposure to Particle Pollution from Outdoor Sources

Policies and Programs for Improving Air Quality in Homes

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Reducing Indoor Exposure to Particle Pollution from Outdoor Sources: Policies and Programs for Improving Air Quality in Homes

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Executive Summary

Particle Pollution is an Important Public Health Issue in the United States

Communities throughout the United States are affected by ambient air pollution from a variety of sources, including industrial facilities and power plants, cars and trucks, wildfires, and residential wood burning. One of the most significant air pollutants in terms of health risks is particulate matter (PM) – a mixture of small, solid particles and liquid droplets that may be emitted from a source directly or formed in the atmosphere as a result of complex reactions of other chemicals. Once inhaled, some of these particles can pass the nasal defenses, penetrate deep into the lungs, and even enter the bloodstream.

The health effects from exposure to particulate matter – especially fine particles, or PM2.5 – have been studied for years, and scientific evidence of the risks continues to mount. Exposure to particle pollution is associated with a range of respiratory and cardiovascular symptoms and diseases, as well as premature death. Older adults, children, and people with heart or lung diseases are especially vulnerable to the harmful effects of breathing particulate matter.

The U.S. has achieved substantial progress in reducing ambient air pollution over the past several decades, thanks in large measure to passage and implementation of the federal Clean Air Act. Nonetheless, research has found that harmful health effects can occur at PM levels below the limits set by federal law, and no threshold value has been identified. Moreover, many communities are impacted by pollution from local sources, such as high-volume roads, which may not be reflected in state and local air monitoring. While areas throughout the country are affected by particle pollution, studies have documented disproportionate air pollution exposures in communities of color and low-income communities.

A key to improving public health and mitigating climate change is to reduce air pollution at the source, e.g., by transitioning to cleaner power and cleaner vehicles. In the meantime, millions of people will continue to be at risk of serious health effects from particle pollution. As we work toward a future of greatly reduced emissions, action is needed now to minimize exposures.

The large majority of PM exposures in the U.S. occur *indoors*, where people spend most of their time. States, tribes, and local governments have an important role to play in advancing building design, construction, operation, and maintenance practices that reduce indoor exposure to outdoor particle pollution. This report highlights opportunities for developing policies and programs that can help improve public health and increase the resilience and adaptive capacity of individuals and buildings in the years ahead.

Well-Established Building Practices can Reduce Indoor Exposure to Outdoor Particle Pollution

Particles in outdoor air enter buildings through cracks and gaps in the building envelope and through natural or mechanical ventilation. Fortunately, building science provides solutions that can help reduce indoor exposure to outdoor pollutants by:

- Reducing *infiltration* of outdoor air – e.g., through sealing of the building envelope, important for reducing entry of outdoor pollutants and also a central strategy for improving energy efficiency;

- Providing adequate outside air for *ventilation* – important for avoiding the buildup of pollutants from indoor sources that can occur with a tight building envelope; and
- Ensuring adequate air *filtration* – important for filtering pollutants when outside air is brought in through ventilation systems and when air recirculates within the building.

Building design and construction practices for applying these principles to reduce indoor PM exposures are well established and readily available. In particular, there is now broad consensus among building science experts that *high-efficiency filtration* can be very effective at removing particles indoors. New and renovated mechanical systems can be designed to accommodate high-efficiency filters, facilitate regular filter replacement, and run efficiently to help minimize the cost of operating the system.

Existing homes vary widely in the protection they provide against outdoor particle pollution. In situations where it is not possible to provide higher-efficiency filters in a home's mechanical system, portable air cleaners have been shown to be effective at reducing indoor PM levels if the proper size and type of device is used. People can reduce their indoor exposure during periods when outdoor air quality is poor by following steps recommended by the U.S. Environmental Protection Agency in its guidance for wildfire smoke events: stay indoors with doors and windows closed; reduce indoor sources of air pollution; turn off ventilation systems that bring in outside air; use air conditioners and mechanical systems in recirculate mode; and use high-efficiency filters or portable air cleaners.

Policies and Programs are Needed to Reduce Residential Exposure to Outdoor Particle Pollution

This report provides information to assist states, tribes, and local governments in taking action to protect people from PM exposure in new and existing *residential* buildings, because people spend most of their time at home. The report also highlights some of the approaches that have been used to reduce exposures in school buildings, where millions of children spend a good part of their days.

While the report focuses on strategies for reducing indoor exposure to particulate matter generated *outdoors*, people are also exposed to particles from indoor sources – e.g., combustion activities such as smoking, cooking, burning wood, and lighting candles, and reactions of chemicals in the indoor environment. Some of the air filtration strategies discussed here can help reduce exposure to particles generated both outdoors and indoors. Strategies tailored to specific indoor sources – e.g., enhanced exhaust ventilation in kitchens or restrictions on wood-burning devices – are also needed and will be addressed in future ELI reports.

Reducing Exposures in New Residential Construction. Incorporating high-efficiency filtration and related practices in new residential construction can help prevent future indoor exposures to outdoor-generated particle pollution**.**

Building Codes. Most communities are covered by a building code that sets minimum standards for new home construction and renovation. These codes are the key policy vehicle for ensuring that homes built in the future are equipped to provide good protection from particulate matter generated outdoors. Yet for the most part, existing residential building codes – and the model codes and standards upon which they are based – do not require best practices such as high-efficiency filtration.

A notable exception is California's 2019 Energy Code, which provides a leading example for consideration by other jurisdictions. Among other things, California's new code requires high efficiency ("MERV 13") filtration in mechanical ventilation and space conditioning systems in new residential

construction. The state also took the notable step of requiring more detailed labeling of the filter and of the mechanical equipment to help ensure proper operation and maintenance following construction.

Green Building Policies. Many jurisdictions have adopted green building policies that go beyond minimum building code standards to require or encourage enhanced health and environmental features. Mandatory green building policies most often apply to government-funded construction, providing an opportunity for reducing exposures in new affordable housing developments. As is the case with building codes, however, existing green building policies – and the third-party standards they commonly reference – typically do not *require* projects to include high-efficiency filtration. Policymakers can strengthen these policies to include high-efficiency filtration as a required green building element.

Land Use Planning and other Policies to Address Local Pollution Sources. Within the framework established under state law, local policies can help reduce exposure to priority local air pollution sources in the siting of new residential buildings. For example, concentrations of particulate matter and other traffic-related air pollutants are frequently elevated next to high-volume roads, creating hotspots that may not be reflected in air monitoring. People who live near those roads are more highly exposed to pollutants from vehicle emissions and from re-suspended road dust, tire wear, and brake wear. In California, a number of local jurisdictions have revised their building codes, health codes, land use planning ordinances, and other policies to incorporate building setbacks, air filtration, and other design features for reducing near-road exposures in new residential construction.

Reducing Exposures in Existing Homes. Reducing exposure to outdoor particle pollution in existing homes involves similar technical practices, but different practical challenges. For example, even if buildings are equipped to provide protection from outdoor particle pollution, building owners, managers, and occupants may not be aware of when and how to use filtration and ventilation equipment effectively. Education and outreach can be important components of a strategy for reducing indoor exposures in existing homes.

Another significant challenge for many households is cost – e.g., the cost of retrofitting a mechanical system or purchasing equipment to provide higher-efficiency filtration. The cost of a portable air cleaner or air conditioning unit is generally reasonable, but still may be prohibitive for lower-income households. In addition, mechanical systems or portable air cleaners need to be running in order to effectively filter particles, and filters need to be replaced regularly. The associated costs may discourage people from using and maintaining the equipment as recommended.

Reducing indoor exposures for people who are at greatest risk from particle pollution thus warrants consideration of financial assistance programs as well as policies to improve housing standards. An inclusive public participation process is important in making decisions about allocating limited public resources and in balancing the twin goals of protecting public health and preserving the supply of affordable housing.

*Laws and Regulations Addressing Health and Safety in Existing Housing***.** States, tribes, and local governments establish housing codes, landlord-tenant laws, nuisance laws, and other policies to address indoor environmental quality conditions in housing. Housing codes (also referred to as property maintenance or sanitary codes) are the primary regulatory vehicle for setting the minimum habitability standards that must be maintained in rental properties. Some states have adopted statewide housing codes, though they are more commonly adopted and enforced locally.

Housing codes generally do not include requirements for high-efficiency filtration. Most also do not require air conditioning, which can be essential not only for preventing heat-related illness, but for keeping windows and doors closed during high-pollution episodes. Most housing codes *do* include general requirements for maintenance and habitability that could potentially be applied in situations where local PM sources or high-PM episodes pose a significant health threat. Periodic inspections to enforce compliance with those standards could prioritize the homes of medically-vulnerable tenants, and additional inspections could be undertaken in anticipation of or at the onset of wildfires or other high-pollution events.

In addition to broader application and enforcement of existing requirements, housing codes could be strengthened to include standards to help reduce indoor PM exposures. The National Heathy Housing Standard, which has been adopted in part by the city of Tukwila, Washington, is a model for incorporating housing code provisions aimed at reducing indoor pollutants, including express requirements for air filtration and filter replacement.

*Financial and In-Kind Assistance Programs to Reduce Risk for Vulnerable Individuals***.** Financial assistance programs are especially important for addressing priority air pollution sources, such as high-volume roads or wildfires, and for assisting people who are at greatest risk due to age or medical condition.

Some federal funding programs that are already in place in many jurisdictions could be adapted for this purpose. For example, the Weatherization Assistance Program, which provides energy-efficiency retrofits for around 35,000 low-income households each year, is a possible funding source for improving ventilation, filtration, and air conditioning. Another federal program, the Low Income Home Energy Assistance Program, subsidizes utility costs for running air conditioners and helps with the purchase or repair of an air conditioning unit. The largest source of federal funding for housing repair and rehabilitation, the Community Development Block Grant program, is a potential vehicle for incorporating filtration and related practices into local housing improvement programs.

States, tribes, and local governments have also established their own financial assistance programs that could be tapped to improve indoor air quality in the homes of vulnerable individuals. For example, programs that fund healthy homes interventions to reduce asthma triggers or that assist with general home repairs could be implemented to cover improved air filtration and air conditioning. A number of jurisdictions have developed initiatives focused specifically on providing air filtration to vulnerable populations that live near local pollution sources, such as roadways or industrial facilities, or that are at risk from wildfires and other severe pollution events. One notable example is Missoula, Montana, where the local health department and a non-profit organization have leveraged multiple public and private funding sources to implement a comprehensive wildfire smoke initiative, with an express focus on providing resources to help reduce exposures for vulnerable and underserved populations.

Chapter One

Introduction

Industries, households, cars and trucks emit complex mixtures of air pollutants,
many of which are harmful to health.
Of all of these pollutants, fine particulate matter has the greatest effect on human health.

– World Health Organization[1]

Particulate matter (PM), also referred to as particles or particle pollution, is a complex mixture of small, solid particles and liquid droplets found in air. Particles may be emitted from a source directly, though most form in the atmosphere as a result of complex reactions of other chemicals emitted into the air. Thus, particulate matter may be composed of many different individual substances, including acids (e.g., nitrates and sulfates), organic chemicals, metals, soil or dust particles, and allergens (e.g., mold spores or pollen).[2]

Particulate matter is formed by both human activities and natural processes. While some PM emissions are highly visible and dramatic, others are less obvious. Outdoors, particulate matter is a constituent of wildfire smoke that can drift hundreds of miles, as well as smoke wafting through neighborhoods from backyard fires and fireplaces. It is a result of pollutant emissions from the stacks of industrial and power plants and from the tailpipes of cars and trucks. Particulate matter is also generated indoors, primarily by combustion activities such as smoking, cooking, burning wood, and lighting candles, and by reactions of chemicals.[3]

Regardless of the source, most of our exposure to particle pollution happens when we are ***indoors.*** A recent study estimated that 90 percent of total exposure to fine particulate matter in the U.S. occurs inside buildings.[4] This is not surprising in light of an earlier study showing that people spend 87 percent of their time in buildings, on average.[5]

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[1] World Health Organization (WHO), Ambient Air Pollution, https://www.who.int/gho/phe/outdoor_air_pollution/en/ (accessed 12/18/19).

[2] U.S. Environmental Protection Agency (EPA), Particle Pollution and Your Health (2003), https://www3.epa.gov/airnow/particle/pm-color.pdf. When outdoor particles move indoors, "the chemical content can change substantially, acquiring substances such as phthalates, organophosphates, and perfluorinated surfactants from the indoor air. Natl. Acad. of Sciences, Health Risks of Indoor Exposure to Particulate Matter: Workshop Summary at 34-37 (2016), available at http://nationalacademies.org/hmd/Activities/PublicHealth/Health-Risks-Indoor-Exposure-ParticulateMatter/2016-FEB-10.aspx (summarizing remarks of Charles Weschler).

[3] U.S. EPA, Indoor Particulate Matter, https://www.epa.gov/indoor-air-quality-iaq/indoor-particulate-matter; Cal. Air Resources Board, Reduce your Exposure to Particle Pollutants, https://ww2.arb.ca.gov/resources/fact-sheets/reduce-your-exposure-particle-pollution.

[4] P. Azimi & B. Stephens, A Framework for Estimating the U.S. Mortality Burden of Fine Particulate Matter Exposure Attributable to Indoor and Outdoor Microenvironments, *.J. Expo. Sci. Environ. Epidemiol.* at Table 2 (12/05/18), https://www.nature.com/articles/s41370-018-0103-4 [hereinafter "Azimi & Stephens"](estimating the mean fraction of total PM2.5 exposure).

[5] N. Klepeis, The National Human Activity Pattern Survey (NHAPS): A Resource for Assessing Exposure to Environmental Pollutants (2001), https://indoor.lbl.gov/sites/all/files/lbnl-47713.pdf.

While we are exposed to many different pollutants indoors, particulate matter is one of the most significant in terms of health risks. Indeed, a study by scientists at Lawrence Berkeley National Laboratory modeled the health impacts of non-biological air pollutants in U.S. homes and found that fine particulate matter was responsible for the largest number of lost years of productive life.[6] Responding to heightened attention to indoor PM exposure over the last several years, the National Academies of Science, Engineering and Medicine convened a workshop of scientific experts in 2016 to review the health risks and possible intervention strategies and to identify key research questions.[7]

Governments at all levels have an important role to play in changing how we construct, operate, and maintain buildings to protect people from being exposed to particle pollution. This report discusses some of the ways that states, tribes, and local governments can improve public health and save lives by developing policies and programs to reduce indoor exposure to *particulate matter generated* ***outdoors*** (referred to here as "outdoor PM"), which enters buildings and comprises a large portion of indoor PM exposure.[8] Indoor activities and products also contribute significantly to PM exposures inside the home, and policies aimed specifically at reducing exposure to key indoor PM sources will be addressed in future ELI reports.

Health Effects of Particulate Matter

A great deal is known about the health effects of breathing particulate matter, thanks to a large body of scientific research conducted over decades. Breathing particles not only causes respiratory and other illnesses, but shortens lives as well.[9] Globally, these health effects "occur at levels of exposure currently being experienced by many people both in urban and rural areas and in developed and developing countries – although exposures in many fast-developing cities today are often far higher than in developed cities of comparable size."[10] In the United States, where great strides have been made to improve ambient air quality, exposure to particulate matter remains a serious public health problem. Recent estimates of premature deaths associated with particulate matter range from tens to hundreds of thousands each year.[11]

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[6] J. Logue, et al., A Method to Estimate the Chronic Health Impact of Air Pollutants in U.S. Residences, *Envtl. Health Persp.*, v. 120, no. 2 at 216 (2012), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3279453/.

[7] *See* Natl. Acad. of Sciences, Health Risks of Indoor Exposure to Particulate Matter: Workshop Summary (2016), available at http://nationalacademies.org/hmd/Activities/PublicHealth/Health-Risks-Indoor-Exposure-ParticulateMatter/2016-FEB-10.aspx.

[8] *See* Azimi & Stephens, supra, at 1 (noting that "indoor exposure to [fine particulate matter] of outdoor origin is typically the largest total exposure, accounting for ~40-60% of total mortality"); R. Allen, Indoor Particulate Matter Pollution and Cardiovascular Health (presentation at the Workshop on the Health Risks of Indoor Exposure to Particulate Matter) (2/11/16), available at: http://nationalacademies.org/hmd/Activities/PublicHealth/Health-Risks-Indoor-Exposure-ParticulateMatter/2016-FEB-10.aspx (discussing study finding that outdoor PM2.5 accounted for 80% of indoor PM2.5 in non-smoking U.S. homes).

[9] *See generally*, WHO, Air Pollution, https://bit.ly/2pxYITb ("There is a close, quantitative relationship between exposure to high concentrations of [PM] and increased mortality or morbidity, both daily and over time.").

[10] WHO, Air Pollution, https://bit.ly/2pxYITb (noting also that in 2016, around 90% of the world's urban population living in cities was exposed to particulate matter in concentrations exceeding the WHO air quality guidelines).

[11] *See, e.g.*, A. Goodkind, et al., Fine-Scale Damage Estimates of Particulate Matter Air Pollution Reveal Opportunities for Location-Specific Mitigation of Emissions, *Proceedings of the Natl. Acad. of Sciences,* 116 (18) 8775-8780 (2019), https://www.pnas.org/content/116/18/8775 (estimating that in the U.S. "anthropogenic $PM_{2.5}$ was responsible for 107,000 premature deaths in 2011, at a cost to society of $886 billion"); Azimi & Stephens, supra, at 1 (2019 study estimating 230,000-300,000 total deaths associated with PM2.5 exposure in 2012, including both outdoor and indoor sources); A. Cohen, et al., Estimates and 25-year Trends of the Global Burden of Disease Attributable to Ambient Air Pollution: An Analysis of Data from the Global Burden of Disease Study: 2015, *The Lancet*, v. 389, no. 10082 1907-1918 (5/13/17) (estimating over 88,000 deaths in the U.S. attributable to ambient PM pollution in 2015); N. Fann, et al., Estimating the National Public Health Burden Associated

Most research in this area has focused on the *size* of particles as an important factor in how they affect health.[12] Particle size (mass median aerodynamic diameter) is measured in microns; one micron (µm) equals one millionth of a meter. Particles under 10 µm are of special concern and are broken down into three categories:

- PM10 – "coarse" particles equal to or less than 10 µm;
- PM2.5 – "fine" particles equal to or less than 2.5 µm; and
- Ultrafine particles, or UFP – particles less than 0.1 µm, or 100 nanometers.

These particles are a health concern because when inhaled, they can pass the nasal defenses and penetrate deep into the lungs, and some can even enter the bloodstream. We know the most about the risks of inhaling particles less than 2.5 µm (30 times smaller than the diameter of the average human hair), which have been the focus of much of the public health research.[13]

Although many people think of respiratory problems as the main health effects from air pollution, there is broad consensus that exposure to particle pollution affects not only the respiratory system, but the cardiovascular system as well.[14] In fact, the "global public health burden of PM is primarily due to its cardiovascular effects."[15] A decade ago, EPA's 2009 Integrated Science Assessment of Particulate Matter found that the scientific evidence was sufficient to conclude that a causal relationship exists between short-term and long-term exposure to PM2.5 and cardiovascular effects as well as overall mortality, and that a causal relationship likely exists with respiratory effects.[16]

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with Exposure to Ambient PM2.5 and Ozone, *Risk Anal.V* 32(1):81-95 (2012), available at https://www.ncbi.nlm.nih.gov/pubmed/21627672 (estimating 130,000 PM2.5-related deaths in 2005).

[12] Particles vary considerably in their composition, however the public health research generally addresses the effects of PM as a general class of pollutant. *See* R. Allen, Indoor Particulate Matter Pollution and Cardiovascular Health (presentation at the NAS Workshop on the Health Risks of Indoor Exposure to Particulate Matter) (2/11/16), available at: http://nationalacademies.org/hmd/Activities/PublicHealth/Health-Risks-Indoor-Exposure-ParticulateMatter/2016-FEB-10.aspx (noting that one research gap is the relative toxicity of PM generated indoors versus outdoors); M. Bell and K. Ebisu, Environmental Inequality in Exposures to Airborne Particulate Matter Components in the United States at 1 (2012), *Envtl. Health Persp*., v. 120, no. 12, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3546368/ (noting toxicity of different parts of the PM mixture as a critical research need).

[13] *See generally* U.S. EPA, Particulate Matter Basics, https://www.epa.gov/pm-pollution/particulate-matter-pm-basics; Centers for Disease Control and Prevention (CDC), Particle Pollution, https://www.cdc.gov/air/particulate_matter.html.The Clean Air Act requires a national network of monitors to measure PM2.5, but not ultrafine particles. *See* U.S. EPA, Ambient Monitoring Technology Information Center, https://www.epa.gov/amtic/amtic-ambient-air-monitoring-networks. A recent EPA draft report highlighted the need for more research on the health effects of ultrafine particles, including "the potential for translocation of ultrafine particles from the respiratory tract into other compartments…and organs…" U.S. EPA, Policy Assessment for the Review of the National Ambient Air Quality Standards for Particulate Matter, External Review Draft at 3-114 (Sept. 2019), https://www.epa.gov/sites/production/files/2019-09/documents/draft_policy_assessment_for_pm_naaqs_09-05-2019.pdf.

[14] *See generally*, CDC, Health Impacts of Fine Particles in Air, https://ephtracking.cdc.gov/showAirHIA.action; Cal. Air Resources Board, Reduce Your Exposure to Particle Pollution, https://ww2.arb.ca.gov/resources/fact-sheets/reduce-your-exposure-particle-pollution; U.S. EPA, Indoor Particulate Matter, https://www.epa.gov/indoor-air-quality-iaq/indoor-particulate-matter.

[15] R. Allen, Indoor Particulate Matter Pollution and Cardiovascular Health (presentation at the Workshop on the Health Risks of Indoor Exposure to Particulate Matter) (2/11/16), available at: http://nationalacademies.org/hmd/Activities/PublicHealth/Health-Risks-Indoor-Exposure-ParticulateMatter/2016-FEB-10.aspx.

[16] U.S. EPA, Integrated Science Assessment for Particulate Matter (2009), available at: https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter. The agency's more recent Assessment affirmed this finding. U.S. EPA, Integrated Science Assessment for Particulate Matter (2019), available at: https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=347534.

In 2019, the American Lung Association summarized the scientific literature that linked exposure to particulate matter with a variety of health effects, including:

- Short-term exposure: premature death from respiratory and cardiovascular causes, including strokes; increased hospitalization for cardiovascular and respiratory problems; increased emergency room visits for asthma and increased severity of asthma attacks among children; increased asthma symptoms; inflammation of lung tissue in young, healthy adults; and

- Long-term exposure: increased risk of death from cardiovascular disease; increased risk of lung cancer; slowed lung function growth in children and teenagers; development of asthma in children; significant damage to the small airways of the lungs; and increased risk of lower birth weight and infant mortality.[17]

In 2013, the International Agency for Research on Cancer concluded that outdoor particle pollution causes lung cancer.[18] Studies have also examined the impacts of particulate matter on neurological and psychiatric disorders, finding evidence linking PM2.5 and UFP exposure to, e.g., dementia, Parkinson's disease, and Alzheimer's disease.[19] In its 2019 *Integrated Science Assessment for Particulate Matter*, EPA concluded that the evidence supports a "likely to be causal relationship" between long-term PM2.5 exposure and both cancer and nervous system effects.[20]

Many people in the U.S. are at higher risk of suffering the adverse health consequences of PM exposure. Vulnerable individuals include children, older adults, and people with heart or lung diseases.[21] People of color and low-income children and adults "bear a disproportionate burden of asthma and other respiratory diseases and therefore they may be at increased risk of health effects due to exposure to particle pollution."[22] Socio-economic status, which encompasses a variety of community-level indicators such as education and income, may also increase exposure to particulate matter and the mortality risk from PM exposure.[23]

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[17] Amer. Lung Assoc., Particle Pollution (citations omitted) (updated 4/18/19), https://www.lung.org/our-initiatives/healthy-air/outdoor/air-pollution/particle-pollution.html. *See also* U.S. EPA, Wildfire Smoke: A Guide for Public Health Officials at 1 (rev. 2019), https://www3.epa.gov/airnow/wildfire-smoke/wildfire-smoke-guide-revised-2019.pdf [hereinafter EPA Wildfire Smoke Guide] (describing health effects ranging from "eye and respiratory tract irritation to more serious effects, including reduced lung function, pulmonary inflammation, bronchitis, exacerbation of asthma and other lung diseases, exacerbation of cardiovascular diseases, such as heart failure, and even premature death").

[18] *See* D. Loomis, et al., The International Agency for Research on Cancer (IARC) Evaluation of the Carcinogenicity of Outdoor Air Pollution: Focus on China (2014), available at https://www.ncbi.nlm.nih.gov/pubmed/24694836; WHO., Air Pollution, https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health ("A 2013 assessment by WHO's International Agency for Research on Cancer…concluded that outdoor air pollution is carcinogenic to humans, with…particulate matter…most closely associated with increased cancer incidence, especially lung cancer.").

[19] Natl. Acad. of Sciences, Health Risks of Indoor Exposure to Particulate Matter: Workshop Summary at 87 (2016), available at http://nationalacademies.org/hmd/Activities/PublicHealth/Health-Risks-Indoor-Exposure-ParticulateMatter/2016-FEB-10.aspx (summarizing remarks of Marc Weisskopf); Amer. Lung Assoc., Particle Pollution (citations omitted) (updated 4/18/19), https://www.lung.org/our-initiatives/healthy-air/outdoor/air-pollution/particle-pollution.html.

[20] U.S. EPA, Integrated Science Assessment for Particulate Matter at ES-15 (2019), available at: https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=347534.

[21] CDC, Outdoor Air: Particulate Matter, https://ephtracking.cdc.gov/showAirHealth.action#ParticulateMatter; U.S. EPA, Indoor Particulate Matter, https://www.epa.gov/indoor-air-quality-iaq/indoor-particulate-matter.

[22] EPA Wildfire Smoke Guide, supra, at 9.

[23] Id. at 9. *See also* CDC, Outdoor Air: Health Impacts of Fine Particles in Air, https://ephtracking.cdc.gov/showAirHIA.

Ambient Particulate Matter in the United States

Thanks in large part to the implementation of a nationwide regulatory framework for reducing air pollutant emissions, ambient particulate matter in the U.S. has decreased substantially over the past several decades. Nonetheless, many communities throughout the country still experience levels of particle pollution that pose health risks.

Progress under the Clean Air Act. The federal Clean Air Act establishes the nation's principal legal framework for protecting air quality. Among other things, the Act requires the U.S. Environmental Protection Agency (EPA) to set primary (public health) and secondary (public welfare) national ambient air quality standards (NAAQS).[24] The primary standards must be set at levels which, "allowing an adequate margin of safety, are requisite to protect the public health."[25] The current 24-hour primary standard for PM2.5 is 35 $\mu g/m^3$ and the annual standard is 12 $\mu g/m^3$; the 24-hour standard for PM10 is 150 $\mu g/m^3$.[26] The NAAQS apply to geographic units known as air quality control regions, which are designated by EPA.[27]

The Clean Air Act is implemented jointly by the federal government and the states. States have "primary responsibility for assuring air quality within the entire geographic area," and they must submit to EPA a State Implementation Plan that specifies "the manner in which national primary and secondary ambient air quality standards will be achieved and maintained within each air quality control region" in the state.[28] The Act requires ambient air monitoring for NAAQS pollutants, and EPA designates air districts as having either attainment or nonattainment status for a pollutant, depending on whether the district meets the federal standard.[29]

The Clean Air Act has been one of the country's most notable environmental success stories. In 2019, EPA reported that emissions of criteria pollutants had fallen by 74 percent since 1970, alongside significant population and economic growth. Since 1990, PM10 levels have fallen 26 percent, and since 2000, PM2.5 levels have fallen 39 percent (annual standard) and 34 percent (24-hour standard).[30] The American Lung Association's *State of the Air 2019* report found that many cities with the highest PM levels have experienced decreases in recent years.[31] These reductions in PM levels have brought corresponding public health benefits.[32]

But there remains work to be done in reducing outdoor PM levels. The *State of the Air 2019* report found that PM levels had increased in many cities, and that more cities had days of elevated short-term

[24] 42 U.S.C. § 7409. EPA has set NAAQS for PM2.5 and PM10, along with five other "criteria" pollutants (carbon monoxide, nitrogen dioxide, lead, ozone, and sulfur dioxide) that cause adverse health effects.
[25] 42 U.S.C. § 7409(b).
[26] *See* U.S. EPA, NAAQS Table, https://www.epa.gov/criteria-air-pollutants/naaqs-table.
[27] 42 U.S.C. § 7407
[28] 42 U.S.C. § 7407 (a).
[29] *See* 40 C.F.R. Pt. 58; 42 U.S.C. § 7407(c),(d). EPA also designates some area as "maintenance" – those that previously were in nonattainment, but now meet the standard and must continue steps to meet the standard. A district may also be designated as unclassifiable for a particular criteria pollutant if it lacks the information needed to determine attainment status.
[30] U.S. EPA, Our Nation's Air, https://gispub.epa.gov/air/trendsreport/2019/#introduction.
[31] Amer. Lung Assoc., Year-Round Particle Pollution, https://www.lung.org/our-initiatives/healthy-air/sota/key-findings/year-round-particle-pollution.html
[32] U.S. EPA, Clean Air Act Overview: Progress Cleaning the Air and Improving People's Health, https://www.epa.gov/clean-air-act-overview/progress-cleaning-air-and-improving-peoples-health#pollution.

PM levels during the period 2015-2017 than they had during 2014-2016.[33] A recent analysis of EPA monitoring data determined that, while overall levels of fine particulate matter decreased by 24 percent between 2009 and 2016, PM2.5 levels *increased* 5.5 percent between 2016 and 2018.[34]

Ambient Particle Pollution is a Problem that Affects Many States. Many of the areas with the highest PM levels are located in California, but the problem extends beyond one state. The *State of the Air 2019* report, which ranks cities based on PM2.5 monitoring data from 2015-2017, noted that while California continued to dominate the list of the 25 most polluted cities, other states and regions also showed elevated levels:

- For Year-round PM2.5 levels, California had six cities on the list, while Pennsylvania had five. Ohio and Texas each had two cities on the list, and 10 other states were represented. The list reflects cities in all regions of the country.

- For 24-hour PM2.5 levels, there was less geographic diversity. California had nine cities on the list, while Oregon and Washington had four and three respectively. Of the nine other states represented, only Pennsylvania and North Dakota are east of the Rocky Mountains.[35]

Areas in Attainment with Federal Standards May Nonetheless Have PM Levels that Pose Health Risks. At the close of 2019, six areas of the country (representing 16 counties over three states) were in nonattainment with federal PM2.5 standards.[36] While the small number of nonattainment areas represents important progress in meeting the goals of the Clean Air Act, these areas are home to approximately 21 million people.

Moreover, exposure to particulate matter at levels *below* current NAAQS standards may also be harmful to health, and research has not identified a threshold value below which PM2.5 does not affect health.[37] The Clean Air Act requires EPA to reevaluate the NAAQS every five years, and EPA began its current review of the PM NAAQS in December 2014.[38] Current World Health Organization (WHO) guideline levels

[33] Amer. Lung Assoc., State of the Air 2019: Key Findings, https://www.lung.org/our-initiatives/healthy-air/sota/key-findings/.
[34] C. Klay & N. Muller, Recent Increases in Air Pollution: Evidence and Implications for Mortality (2019), available at: https://www.nber.org/papers/w26381 (reflecting increases in the West and Midwest regions, while levels in other regions remained mainly flat).
[35] Amer. Lung Assoc., 2019 State of the Air: Most Polluted Cities, https://www.lung.org/our-initiatives/healthy-air/sota/city-rankings/most-polluted-cities.html.
[36] U.S. EPA, PM-2.5 (2012) Designated Area/State Information (accessed 1/8/20), https://www3.epa.gov/airquality/greenbook/kbtc.html
[37] *See. e.g.,* U.S. EPA, Integrated Science Assessment for Particulate Matter at ES-23 (2019), available at: https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=347534; F. Dominici, et al., (Health Effects Inst.), Assessing Adverse Health Effects of Long-Term Exposure to Low Levels of Ambient Air Pollution: Phase 1 at 24 (Nov. 2019), https://www.healtheffects.org/system/files/dominici-rr-200-report.pdf ; U.S. EPA, Policy Assessment for the Review of the National Ambient Air Quality Standards for Particulate Matter, External Review Draft at 3-96, 98 (Sept. 2019), https://www.epa.gov/sites/production/files/2019-09/documents/draft_policy_assessment_for_pm_naaqs_09-05-2019.pdf; WHO, Air Pollution, https://bit.ly/2pxYITb; Natl. Acad. of Sciences, Health Risks of Indoor Exposure to Particulate Matter: Workshop Summary at 78 (2016), available at http://nationalacademies.org/hmd/Activities/PublicHealth/Health-Risks-Indoor-Exposure-ParticulateMatter/2016-FEB-10.aspx (summarizing remarks of Ryan Allen); Amer. Lung Assoc., Year-Round Particle Pollution, https://www.lung.org/our-initiatives/healthy-air/sota/key-findings/year-round-particle-pollution.html.
[38] 42 U.S.C. § 7409(d)(l); U.S. EPA, Particulate Matter (PM) Air Quality Standard, https://www.epa.gov/naaqs/particulate-matter-pm-air-quality-standards.

for PM2.5 are lower than U.S. levels, and WHO is currently considering further revisions to the guideline with an expected publication date in 2020.[39]

PM Monitoring Does Not Tell the Local Story. Air quality monitoring under the Clean Air Act provides continuous (hourly) PM data from over 1,200 PM2.5 monitors and 500 PM10 monitors.[40] Because many communities lack monitors, the existing network may not reflect pollution hotspots created by local PM sources, such as high-volume roads. Moreover, the ultrafine particles that are a key component of vehicle exhaust are not subject to federal monitoring or regulation.

Some Communities are Disproportionately Affected by Ambient PM. While there are elevated PM areas throughout the U.S., racial/ethnic disparities in pollution exposure are well documented. According to a 2011 Centers for Disease Control (CDC) analysis: "Minority groups, including Asians and Hispanics, were more likely to reside in [nonattainment] counties in comparison with non-Hispanic whites."[41] Moreover, numerous studies dating back decades have shown that communities of color and lower-income communities are disproportionately located near and affected by pollution from local sources such as hazardous waste sites, landfills, and other polluting facilities.[42] As discussed in Chapter Two, particle pollution from high-volume roads affects many people in many parts of the country, but lower-income communities and communities of color are more likely to live near busy roadways.[43]

Reducing Indoor Exposure to Particulate Matter from Outdoor Sources

Source reduction is a crucial strategy for limiting exposure to indoor air pollutants. For pollutants that are prevalent mainly *indoors*, such as radon, lead, and tobacco smoke, source reduction can be achieved by remediating the building or changing personal behavior. For air pollutants generated outdoors, significant source reduction requires broader societal action to speed the transition to cleaner vehicles, industries, and power generation. Reducing PM and other pollutant emissions from these sources of ambient pollution will yield the twin benefits of improving public health and mitigating the impacts of climate change.[44]

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[39] WHO, WHO Air Quality Guidelines – Global Update 2005, https://www.who.int/airpollution/publications/aqg2005/en/ (PM2.5 standards of 10 µg/m^3 [annual] and 25 µg/m^3 [daily], compared to 12 µg/m^3 and 35 µg/m^3, respectively, in the U.S.); WHO, Ambient (Outdoor) Air Pollution, https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health.

[40] EPA Wildfire Smoke Guide, supra, at 33.

[41] CDC, Fact Sheet: Health Disparities in Unhealthy Air Quality (2011), https://www.cdc.gov/minorityhealth/chdir/2011/factsheets/AirQuality.pdf.

[42] See, e.g., United Church of Christ, Toxic Wastes and Race in the United States (1987), http://d3n8a8pro7vhmx.cloudfront.net/unitedchurchofchrist/legacy_url/13567/toxwrace87.pdf?1418439935; U.S. EPA, Environmental Equity: Reducing Risk for All Communities (1992). *See also* C. Tessum et al., Inequity in Consumption of Goods and Services Adds to Racial–Ethnic Disparities in Air Pollution Exposure, Proc Natl. Acad. Sci. USA, 116(13):6001–6 (2019), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6442600/ (study finding that Blacks are exposed to 21% more PM2.5, and Hispanics 12% more, than the overall population average exposure in the U.S.); M. Miranda, et al., Making the Environmental Justice Grade: The Relative Burden of Air Pollution Exposure in the United States (2011), Intl. J. Environ. Res. Public Health, 8(6): 1755–177 (2011), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3137995/ (study suggesting that "among areas where monitoring data are available, low income and minority communities tend to experience higher ambient pollution levels").

[43] *See generally* T. Boehmer et al., "Residential Proximity to Major Highways -- United States 2010," CDC Morbidity and Mortality Weekly Report Supplement, Vol. 62, No. 3 at 46-47 (2013) (citations omitted), available at: https://www.cdc.gov/mmwr/pdf/other/su6203.pdf.

[44] *See generally* U.S. Global Change Research Program, Fourth National Climate Assessment, Ch. 13 (Air Quality) (2018), https://nca2018.globalchange.gov/chapter/13/; Intergovernmental Panel on Climate Change, Global Warming of 1.5°C (2019), https://www.ipcc.ch/sr15/.

Even with accelerated action to reduce outdoor emissions of particulate matter and other pollutants, millions of people across the U.S. will continue to be exposed to particle pollution in the coming decades, and many will become sick or die prematurely as a result. It is important to take steps now to protect people where they are most exposed – in their own homes.[45]

Buildings can provide good protection from outdoor air pollution. In practice, though, existing homes vary widely in the level of protection provided from the fine particles that are strongly associated with health impacts.[46] In general, buildings with envelopes and mechanical systems that are leaky or poorly maintained will provide less protection from outdoor particulate matter. Fortunately, building science provides technical solutions that can be integrated into policy and practice. These solutions include not only reducing infiltration of outdoor air through the building envelope, but also ensuring adequate ventilation and filtering the air inside the building.[47]

Integrating these technical solutions into policies and programs poses a number of challenges. Perhaps the most important challenge is ensuring that the benefits of public policies reach those who are most susceptible to the impacts of air pollution and who cannot afford the cost of implementing recommended measures to reduce their exposure. In developing financial assistance programs to help underserved communities that are heavily impacted by pollution, jurisdictions often must allocate limited funding among a wide array of housing and social service needs. In addition, while considering stronger building and housing standards to protect occupants, policymakers must also work to preserve and expand the availability of affordable housing units. These multiple, related goals underscore the importance of consulting with affected communities in developing strategies for reducing indoor PM exposure.

Scope and Organization of the Report

The purpose of this report is to assist states, tribes and local governments in developing policy and program strategies to reduce indoor PM exposure. The information provided in the following chapters focuses on (1) *outdoor* (ambient) PM sources, which represent a significant amount of the indoor exposure to PM., and (2) *homes*, because that is where people spend most of their time and where most exposure to PM occurs. Though not the focus here, examples of policies and programs for reducing exposures in schools – where millions of children spend their days – are highlighted throughout the report.[48]

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[45] *See* Azimi & Stephens, supra, at Table 2 (estimating that around 70% (mean fraction) of total PM2.5 exposure in the U.S. occurs inside homes and that the majority of this exposure is due to PM2.5 of outdoor origin). On average, 69% of our time is spent in our homes. N. Klepeis, et al., The National Human Activity Pattern Survey (NHAPS): A Resource for Assessing Exposure to Environmental Pollutants (2001), https://indoor.lbl.gov/sites/all/files/lbnl-47713.pdf.

[46] *See* Natl. Acad. of Sciences, Health Risks of Indoor Exposure to Particulate Matter: Workshop Summary at 73 (2016), available at http://nationalacademies.org/hmd/Activities/PublicHealth/Health-Risks-Indoor-Exposure-ParticulateMatter/2016-FEB-10.aspx.

[47] Measures for reducing exposure to PM inside a building may not be as effective in reducing exposure to other air pollutants generated by outdoor sources. *See* Cal. Air Resources Board., Technical Advisory: Strategies to Reduce Air Pollution Exposure near High-Volume Roadways at 36, https://ww3.arb.ca.gov/ch/rd_technical_advisory_final.pdf [hereinafter CARB 2017 Technical Advisory]; U.S. EPA, Residential Air Cleaners, A Technical Summary (3d ed.) at 7 (2018), https://www.epa.gov/sites/production/files/2018-07/documents/residential_air_cleaners_-_a_technical_summary_3rd_edition.pdf [hereinafter EPA Residential Air Cleaners Technical Summary].

[48] For additional information on state policies addressing indoor air quality in schools, see Envtl. Law Inst., Indoor Environments and Green Buildings Program, https://www.eli.org/buildings.

The remainder of the report is divided into two chapters:

- Chapter Two (New Construction). This chapter discusses the types of policies that can advance key technical practices for reducing outdoor PM in new homes, focusing mainly on establishing standards for higher-efficiency air filtration. The chapter addresses new construction generally, as well as the siting of new homes near local pollution sources such as major roadways.

- Chapter Three (Existing Homes). Existing buildings pose greater challenges for reducing indoor exposures. This chapter discusses policies and programs for reducing PM exposures in existing homes, including financial assistance programs that may be available to assist vulnerable households. The focus of this chapter is on reducing PM exposures generally and on addressing extreme PM events, such as wildfires.

This report does not address all residential environments. For example, it does not cover regulated environments such as assisted living, long-term care, foster homes, or group homes, whose residents may be more vulnerable to particle pollution. State and local policies regulating or licensing these facilities may provide another mechanism for reducing risk. Similarly, while child care that is provided in homes may benefit from the policies discussed here, the report does not cover child care licensing laws and regulations, which apply to in-home and center-based child care in all 50 states.[49]

While the report cannot cover all existing and potential approaches to reducing indoor PM, the following chapters describe policy and program frameworks that exist in many jurisdictions and provide examples of how states and local governments have used those frameworks for addressing the problem of exposure to outdoor sources of particulate matter. Policies and programs to address *indoor* sources that also contribute significantly to PM exposure (e.g., smoking, cooking, and wood burning) will be the subject of future ELI reports.

[49] *See generally* Envtl. Law Inst., Reducing Environmental Exposures in Child Care: A Review of State Policy (2015), https://www.eli.org/buildings/reducing-environmental-exposures-child-care-facilities.

Chapter Two

Reducing Exposure to Outdoor Particulate Matter in New Homes

Building codes, which govern housing construction in most jurisdictions in the United States, are an important and viable policy opportunity for addressing indoor exposure to particulate matter generated outdoors.

Part I of this chapter describes how air filtration and related practices are incorporated into model construction codes and standards and into current state and local building codes. This part also discusses a related area of policy – laws and regulations governing state-funded construction, including affordable housing development, that establish requirements beyond minimum building code provisions.

Part II of the chapter explores how policies and programs for new home construction can address *local sources* of outdoor PM. This section focuses specifically on vehicle emissions from high-volume roadways, a problem affecting many communities throughout the country, especially urban areas. Many of the strategies for mitigating traffic-related pollution are potentially applicable to other local air pollution sources, such as industrial facilities.

Part I
Strengthening Standards for New Residential Construction

Building design and construction practices for reducing indoor exposure to outdoor-generated particles are well established and readily available. In particular, there is now broad consensus among building science experts that high-efficiency air filtration can be very effective at removing particles indoors. Strengthening building standards to provide enhanced filtration of outdoor air is an important and largely untapped policy opportunity for reducing risk and advancing public health.

States, tribes, and localities can revise their building codes and other new construction policies to help ensure that future homes incorporate high-efficiency filtration and related best practices. The following sections of the report supports those efforts by:

- Reviewing technical practices that can be integrated into policies governing new residential construction;
- Describing current model building codes and standards, as well as existing state building code provisions;
- Highlighting recent building code changes in the state of California that offer a model for strengthening filtration requirements; and
- Summarizing state and local green building policies that go beyond minimum code to establish environmental and health-related requirements for certain types of new residential construction.

The section closes with a discussion of some of the key considerations in strengthening filtration standards for new homes.

High-Efficiency Filtration and Related Building Practices to Reduce Indoor Exposures

Building design and construction involves complex and interrelated practices that vary depending on factors such as the building type, size, and climate zone. The following overview of filtration and related practices is general in nature; it does not discuss the wide range of technical issues involved in optimizing ventilation and filtration in buildings. It also does not discuss emerging building technologies, but rather emphasizes well-established approaches that are widely considered to be effective based on research and experience to date.

Infiltration/Sealing. Buildings are responsible for around 40 percent of the energy consumption in the United States.[50] Heating and cooling account for 40-60 percent of the energy used in buildings, and in a typical home, air leakage alone can use 25 to 40 percent of heating/cooling energy.[51] Thus, energy efficiency is a cornerstone of sustainable building design and construction, and a core energy-efficiency practice is tightening the building envelope (windows, doors, walls, roof, and floors) to reduce air leakage.[52]

In addition to reducing energy use, a tight building shell can help reduce infiltration of PM2.5 and ultrafine particles from outside.[53] But sealing by itself can potentially *harm* indoor air quality (IAQ) by reducing ventilation rates, limiting air exchange, and allowing the buildup of indoor contaminants.[54] As EPA has noted, "Indoor concentrations of some pollutants have increased in recent decades due to such factors as energy-efficient building construction (when it lacks sufficient mechanical ventilation to ensure adequate air exchange) and increased use of synthetic building materials, furnishings, personal care products, pesticides, and household cleaners."[55]

To maintain good indoor air quality, attention to energy efficiency should be paired with steps to ensure adequate ventilation to bring in outdoor air. With the emergence of research showing the health and productivity benefits of increased ventilation rates, "build tight, ventilate right" has become a theme of advanced building practice.[56]

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[50] U.S. Energy Information Admin., FAQs (updated May 2019), https://www.eia.gov/tools/faqs/faq.php?id=86&t=1.
[51] Building Codes Assistance Project, Residential Ventilation, www.bcapcodes.org/tools/code-builder/residential/ventilation; U.S. EPA, Air Sealing (2005), https://www.energystar.gov/ia/home_improvement/home_sealing/AirSealingFS_2005.pdf.
[52] *See* id.; U.S. Dept. of Energy, Why Energy Efficiency Upgrades, http://energy.gov/eere/why-energy-efficiency-upgrades; J. Logue, et al., Energy Impacts of Envelope Tightening and Mechanical Ventilation for the US Residential Sector, *Energy and Buildings* 65: 281-291 (2013) (estimating the energy benefits of air sealing across the U.S.).
[53] *See, e.g.*, ASHRAE, Guideline 24-2105 (Ventilation and Indoor Air Quality in Low-Rise Residential Buildings) at 15, available at: https://www.techstreet.com/standards/guideline-24-2015-ventilation-and-indoor-air-quality-in-low-rise-residential-buildings?product_id=1898710; B. Singer, Indoor PM Exposure Mitigation in Low-SES Households (Presentation at Nat'l. Academies of Sciences Workshop on Health Risks of Indoor Exposure to Particulate Matter Workshop) (2/10/2016), available at: http://nationalacademies.org/hmd/Activities/PublicHealth/Health-Risks-Indoor-Exposure-ParticulateMatter/2016-FEB-10.aspx.
[54] *See* U.S. Dept. of Energy, Ventilation, https://www.energy.gov/energysaver/weatherize/ventilation.
[55] U.S. EPA, Report on the Environment (Indoor Air Quality), https://www.epa.gov/report-environment/indoor-air-quality.
[56] *See, e.g.,* Lawrence Berkeley Nat'l. Lab, IAQ Scientific Findings Resource Bank: Building Ventilation, https://iaqscience.lbl.gov/vent-summary ("Increased ventilation rates are, on average, associated with fewer adverse health effects and with superior work and school performance."). Lower ventilation rates may also lead to increased concentrations of carbon dioxide indoors, and an emerging body of research suggests that increased indoor levels of CO2 itself is associated with adverse impacts on occupants' health and performance. *See, e.g.,* U. Satish et al., Is CO2 an Indoor Pollutant? Direct Effects of Low-to-Moderate CO2 Concentrations on Human Decision-Making Performance*, Envtl. Health Persp.* v. 120, at 1671 (2012), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3548274/; J. Allen, et al., Associations of Cognitive Function Scores with

Mechanical Whole-Building Ventilation. Outside air can be introduced through natural ventilation (via the opening of windows and infiltration of air through the building envelope) or mechanical systems that bring in outside air. Most existing single-family homes rely on natural ventilation. Yet many people do not regularly open windows because they use central heating and cooling systems most of the year, and such systems in existing homes typically recirculate the air within the home.[57]

Mechanical ventilation systems make the introduction of outdoor air intentional and controllable, rather than incidental and variable. The use of such systems to provide specified quantities of outdoor air is standard practice in commercial construction, and in recent years has become a more widely-used practice for improving residential indoor air quality.

There are three main types of mechanical ventilation systems – exhaust only, supply only, or balanced. The type of system chosen will depend on the type of building, the climate zone, and other factors.[58] Exhaust systems do not allow for direct filtration of outdoor air that enters the building, though some particles are removed as air enters through the building envelope.[59] (Kitchen and bath exhaust ventilation are also very important for removing indoor air pollutants – e.g., particulate matter generated during cooking and moisture created in bathrooms.) Supply systems and balanced systems bring in outside air in a way that can be filtered directly.

Ensuring that the ventilation system brings in an adequate amount of outdoor air does not in itself ensure healthy conditions in a home. Regardless of the type of mechanical system used, "efficient filtration systems, at least for particles, should be employed" to reduce indoor exposure to outdoor air pollutants.[60]

Air Filtration. As one prominent building scientist recently noted, the filtration of incoming outdoor air and recirculated indoor air should be the first approach taken to mitigate individual exposure to particulate matter.[61] Studies show that mechanical systems with high-efficiency filtration can remove about 50-99 percent of the particles in the air inside a home, depending on particle size and

Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers: A Controlled Exposure Study of Green and Conventional Office Environments," *Envtl. Health Persp.,* v. 145(6), 805-812 (2016).

[57] U.S. Dept. of Energy, Ventilation, https://www.energy.gov/energysaver/weatherize/ventilation; U.S. EPA, Improving Indoor Air Quality, https://www.epa.gov/indoor-air-quality-iaq/improving-indoor-air-quality; Lawrence Berkeley Natl. Lab., California's Ventilation Requirements, https://homes.lbl.gov/ventilate-right/californias-ventilation-requirements.

[58] For a summary of the advantages and disadvantages of each type of system, see U.S. Dept. of Energy, Whole-House Ventilation, https://www.energy.gov/energysaver/weatherize/ventilation/whole-house-ventilation and Lawrence Berkeley National Lab., Whole Building Ventilation Type: System Pros and Cons, https://homes.lbl.gov/ventilate-right/system-pros-and-cons#hrverv. *See also* J. Lstiburek, Measure Guideline: Ventilation Guidance for Residential High Performance New Construction – Multifamily at 3 (2017), https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/67581.pdf (recommending balanced ventilation strategies for most multifamily construction).

[59] *See* B. Singer, et al., Reducing In-Home Exposure to Air Pollution (2016), https://ww3.arb.ca.gov/research/apr/past/11-311.pdf (testing portable air cleaners using HEPA filters in a home with exhaust-only ventilation).

[60] Lawrence Berkeley Natl. Lab., IAQ Scientific Findings Resource Bank: Ventilation Rates and Health in Homes, https://iaqscience.lbl.gov/vent-home.

[61] Nat'l. Academies of Sciences, Engineering, and Medicine – Health and Medicine Division, Health Risks of Indoor Exposure to Particulate Matter: Workshop Summary at 59 (2016), available at http://nationalacademies.org/hmd/Activities/PublicHealth/Health-Risks-Indoor-Exposure-ParticulateMatter/2016-FEB-10.aspx (summarizing comments of William Fisk).

other factors.[62] Studies also have "estimated that potential health benefits of using particle filtration to lower indoor exposures to PM of outdoor origin….are large, and the estimated financial benefits far exceed the estimated costs."[63]

While it is common for commercial buildings to have particle filtration, some homes lack central heating and air conditioning systems and thus do not have any filters at all. Existing homes and commercial buildings that are equipped with particle filters typically use filters with low efficiencies that help protect the mechanical equipment but do not remove the very small particles.[64] The technology exists to change this approach and to make higher-efficiency filtration standard practice in new and renovated homes.

The most common method for filtering particles originating from outdoor air is the use of fibrous filters.[65] This can be accomplished in two ways. First, mechanical ventilation and space conditioning systems can be equipped with in-duct filters. Filters in mechanical systems that provide supply air (a supply or balanced system) remove particles as outdoor air enters the building. Forced-air space conditioning systems, which are common in the U.S., recirculate the indoor air; they can filter both outdoor and indoor air, though the outdoor air is filtered after it has already entered the building. A second method for providing filtration is through portable air cleaners equipped with high-efficiency filters, discussed in Chapter Three of this report.

Filter Efficiency – MERV Ratings. A key factor affecting filtration is the efficiency of the filter in removing particles, which is rated using various scales and test methods. The most commonly used system in the U.S. is the minimum efficiency reporting value (MERV) rating system, which is calculated according to ASHRAE Standard 52.2. This scale evaluates the removal efficiency for particles 0.3-10 µm in diameter for filters ranging from MERV 1 to MERV 16.[66]

In general, the higher the MERV rating, the higher the removal efficiency.[67] However, a filter must meet a minimum percentage removal efficiency in order to be labeled with the specified MERV rating under the ASHRAE 52.2-2017 standard.

For particles in the 1.0 to 3.0 µm range, minimum percentage removal efficiencies are established only for MERV 9 and higher – e.g., MERV 9 (35%), MERV 11 (65%), MERV 13 (85%) and MERV 16 (95%). Removal efficiencies for smaller particles in the 0.3-1.0 µm range are provided only for MERV 11 and higher – e.g., MERV 11 (20%), MERV 13 (50%), and MERV 16 (95%).[68] Although the MERV rating system

[62] *See* CARB 2017 Technical Advisory, supra, at 36-38 (citations omitted). As discussed in Chapter Three, the effectiveness of the filter depends on a number of operational factors, including the run-time of the system and how frequently filters are replaced.
[63] EPA Residential Air Cleaners Technical Summary, supra, at 44 (citations omitted).
[64] Lawrence Berkeley Natl. Lab., IAQ Scientific Findings Resource Bank: National-Level Opportunities, https://iaqscience.lbl.gov/benefits-summary; EPA Residential Air Cleaners Technical Summary, supra, at 15, 21.
[65] For an overview of filtration technologies for particles and gasses, see EPA Residential Air Cleaners Technical Summary, supra, at 17.
[66] *See* ANSI/ASHRAE Standard 52.2-2017 (Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size), available at: https://www.techstreet.com/ashrae/standards/ashrae-52-2-2017?gateway_code=ashrae&product_id=1942059. Other proprietary test methods used include Microparticle Performance Rating (MPR) and Filter Performance Rating (FPR). *See* EPA Residential Air Cleaners Technical Summary, supra, at 7.
[67] According to ASHRAE, the "MERV designation progresses upward through this efficiency spectrum, allowing the designer to select the desired bracket of efficiency at the smallest particle size of concern." ASHRAE, Indoor Air Quality Guide: Best Practices for Design, Construction and Commissioning at 574, available at: https://www.ashrae.org/technical-resources/bookstore/indoor-air-quality-guide. *See also* EPA Residential Air Cleaners Technical Summary, supra, at 7.
[68] ANSI/ASHRAE 52.2-2017, table 12-1.

does not specify removal efficiencies for particles smaller than 0.3 µm in diameter, some studies have shown good removal efficiencies using MERV 16 rated filters.[69]

The California Air Resources Board has summarized the evidence on filter performance levels this way:

- "Flat, one-inch fiberglass filters are the most commonly used filters in residential heating and air systems. They remove only a portion of the largest particles in the airstream that passes through the filter and are typically rated no higher than MERV 4.
- MERV 5 to MERV 8 filters are medium efficiency filters that remove some additional types of particles such as mold spores and cat and dog dander, but they still do not remove the finer particles….
- MERV 9 to MERV 12 filters begin to remove particles in the smaller fraction of PM2.5.
- Higher efficiency MERV 13 to MERV 16 filters remove a portion of ultrafine and submicron particles….
- True HEPA (high efficiency particulate arrestance) filters—equivalent to MERV 17 to MERV 20—remove 99.97 percent to 99.999 percent of particles less than 0.3 microns (µm)…."[70]

Thus, MERV 9 filtration may begin to remove the smaller particles in the PM2.5 range, though MERV 13 or higher filtration is required to effectively remove a substantial portion of PM2.5 and is recommended in several best practice documents. ASHRAE's IAQ best practice guidance for multifamily and commercial buildings notes that MERV 13 "provides a good balance of efficiency, capacity, pressure drop, and both first and operating costs" and that if space or pressure drop limits restrict this selection, MERV 8-12 are good improvements over the minimal MERV 6.[71] ASHRAE's IAQ guidance for low-rise residences recommends MERV 10-13 or higher for removing PM2.5 and MERV 13 or higher for removing ultrafine particles.[72] EPA recommends that those who are concerned about small particles choose filters with at least a MERV 13 rating or as high a MERV rating as the system can accommodate.[73]

Additional Filtration Considerations. Filter efficiency is not the only technical factor affecting whether a system will provide good filtration. Other important considerations include the fit of the filter

[69] CARB 2017 Technical Advisory, supra, at 37.

[70] Id. at 36-38. *See also,* EPA Residential Air Cleaners Technical Summary, supra, at 7; B. Stephens, Selecting Ventilation Air Filters to Reduce PM2.5 of Outdoor Origen at 14 (2016); S. Bell, et al., Avoiding the TRAP: Traffic-Related Air Pollution in Toronto and Options for Reducing Exposure at 23 (2017), available at: https://www.toronto.ca/legdocs/mmis/2017/hl/bgrd/backgroundfile-108070.pdf.

[71] ASHRAE, Indoor Air Quality Guide: Best Practices for Design, Construction and Commissioning at 563, available at: https://www.ashrae.org/technical-resources/bookstore/indoor-air-quality-guide.

[72] ASHRAE, Guideline 24-2105 (Ventilation and Indoor Air Quality in Low-Rise Residential Buildings) at 16-17, available at: https://www.techstreet.com/standards/guideline-24-2015-ventilation-and-indoor-air-quality-in-low-rise-residential-buildings?product_id=1898710.

[73] EPA Residential Air Cleaners Technical Summary, supra, at 9. *See also* U.S. EPA Indoor airPLUS Construction Specifications at 9, https://www.epa.gov/sites/production/files/2018-03/documents/indoor_airplus_construction_specifications.pdf (requiring MERV 8 as a minimum standard, but recommending MERV 13 or higher to reduce exposure to fine particles, and further noting that the filter rack holding a filter should have flexible, air-tight gasket material on the downstream side of the filter, as well as "friction fit or spring clips installed on the upstream side of the filter to hold it firmly in place.").
A study that tested several combinations of ventilation and filtration equipment to test their effectiveness in reducing in-home PM exposure recommended using MERV16 or equivalent filtration on a supply ventilation system, which could be provided with a "relatively low incremental energy cost;" the study also noted that using the central forced air system to provide filtration and air cleaning can be very effective in reducing both outdoor and indoor-generated air pollutants if operated either on a minimum runtime or continuously at a low speed setting. B. Singer, et al., Reducing In-Home Exposure to Air Pollution at 126-128 (2016), https://ww3.arb.ca.gov/research/apr/past/11-311.pdf.

in the filter slot or holder and whether there are adequate seals around the filter cabinet to prevent air from bypassing the filter. Filter efficiency depends heavily on regular replacement, so filters should be located and labeled to make replacement convenient. And because in-duct air filters do not work if the mechanical system is turned off, it is also important that forced-air thermal systems are capable of operating intermittently or continuously at low speed when not providing heating or cooling; an efficient blower motor can help reduce the power use associated with increased operation of the system. A user-friendly thermostat can help ensure that people will operate the system efficiently in recirculation mode.[74]

Other Practices. Other design and construction features can affect indoor exposure to outdoor-generated particulate matter. For example, air intakes can be located so as to avoid bringing in outdoor pollutants from sources near the building. Walk-off mats can be installed to prevent tracking in outdoor particles, particularly in multifamily buildings.

In addition, space cooling – important for growing numbers of people as average temperatures rise and heat waves become more common – may be necessary to effectively reduce exposure during high-pollution events, such as wildfires. Residents are advised to keep windows closed during such episodes, but that may not be feasible if outdoor temperatures are high and the home lacks air conditioning. The design and construction of new residential buildings to ensure adequate space cooling is an important issue, but is not addressed this report.[75] Policies and programs for providing air conditioning in existing buildings are described in Chapter Three.

Building Codes: Strengthening Minimum Residential Construction Requirements

Building codes are the central policymaking tool for establishing design and construction requirements. Most states have adopted a mandatory statewide building code that sets minimum requirements throughout the state for new residential and/or commercial construction and renovation.[76] A minority of these states have adopted a statewide building code for commercial and/or public buildings, but not a separate code for low-rise residences. State building codes are generally enforced at the local level, and state law may give localities authority to amend the state code; typically local amendments must be at least as stringent as the state requirements.[77]

Building codes in the United States have expanded greatly since their early adoption as a means of preventing loss of life and property. Current building codes cover a wide scope of design and construction practices, addressing evolving societal priorities ranging from accessibility and resilience to

[74] *See generally* EPA Residential Air Cleaners Technical Summary, supra, at 39 (2018); B. Singer, Measured Performance of Filtration and Ventilation Systems for Fine and Ultrafine Particles and Ozone in an Unoccupied Modern California House (2016), http://eta-publications.lbl.gov/sites/default/files/lbnl-1006961_2.pdf.

[75] The ICC and ASHRAE model building codes and standards described here do not require new residential construction to include mechanical air conditioning systems, though jurisdictions can add such requirements. For example, Phoenix' IRC-based code requires that every dwelling unit" shall be provided with…cooling facilities capable of maintaining room temperatures between 68° F…and 90° F" and that the "installation of one or more… portable space coolers shall not be used to achieve compliance with this section." Phoenix Building Construction Code, R303.10.

[76] The information about current building code provisions presented in this section is based primarily on an ELI review of state building codes in mid-2019.

[77] *See generally* U.S. Dept. of Energy, How are Building Codes Adopted, https://www.energy.gov/eere/buildings/articles/how-are-building-codes-adopted; ICC, Code Adoption Process by State, https://www.iccsafe.org/gr/Documents/AdoptionToolkit/HowStatesAdopt_I-Codes.pdf.

energy efficiency and indoor air quality. Because of the technical and financial resources required to develop buildings codes, state and local codes draw largely on model codes and standards developed by third-party organizations.

This section begins with a short description of widely-referenced model codes and standards. As noted earlier, mechanical ventilation systems bring in outdoor air, which helps reduce levels of particulate matter and other pollutants from indoor sources, but also brings in more particles from outdoors. Thus, the focus here is on provisions in the model codes related to filtration of outdoor and recirculated air. It is beyond the scope of this report to discuss the variety of technical issues relevant to determining how best to ensure adequate ventilation – e.g., how much outside air is needed and how that air flow is controlled and distributed throughout a building or dwelling unit – while achieving energy efficiency goals.[78]

As discussed below, the model residential construction codes and standards most commonly incorporated into state and local policies either establish no filtration requirements or require filtration efficiencies that are not effective for removing PM2.5 or ultrafine particles. While most state and local building codes follow these models, this section ends by describing a notable exception – California's recent adoption of a high-efficiency filtration requirement for residential and other buildings.

Model Building Codes and Standards. A prominent industry standard for ventilation and indoor air quality in new buildings is ASHRAE 62, which has been incorporated into some state and local building codes, as well as certain governmental and non-governmental high performance building programs.[79] California's Energy Code, for example, incorporates elements of ASHRAE 62, with amendments that strengthen the ventilation and filtration provisions of that standard.

Most jurisdictions with mandatory building codes have adopted one or more of the model codes of the International Code Council (ICC), with amendments. Most, but not all, of these states have adopted the ICC codes for both low-rise residential and large residential buildings.

In 2018, ICC and ASHRAE jointly produced the International Green Construction Code (IgCC), a model code designed to be fully compatible with the ICC family of codes and applicable to all occupancies *except* single-family homes, multifamily structures up to three stories, and other low-rise occupancies.[80] Section IC, below, includes a chart comparing the ventilation and filtration requirements of selected green building standards, including the IgCC.

ASHRAE. ASHRAE, a professional organization representing building system design and industrial process professionals, undertakes research, standards writing, publishing and continuing

[78] *See generally* U.S. Dept. of Energy, Whole House Ventilation, https://www.energy.gov/energysaver/weatherize/ventilation/whole-house-ventilation; ASHRAE, Indoor Air Quality Guide: Best Practices for Design, Construction and Commissioning at 117-137, available at: https://www.ashrae.org/technical-resources/bookstore/indoor-air-quality-guide.

[79] *See, e.g.,* Wa. Admin. Code § 51-51-1507 (adopting the 2015 Int'l Residential Code but allowing ASHRAE 62.2 as compliance path for meeting whole-house mechanical ventilation system design requirements); Vt. Residential Building Energy Code Handbook at 2 (2015), https://publicservice.vermont.gov/sites/dps/files/documents/2015_VT_Energy_Code_Handbook_V4%202.pdf (ASHRAE Standard 62.2 allowed as alternate method to meet mechanical ventilation requirements).

[80] ICC, et al., International Green Construction Code (2018), available at: https://www.iccsafe.org/products-and-services/i-codes/2018-i-codes/igcc/. The IgCC is the product of a partnership between the ICC and ASHRAE, as well as the U.S. Green Building Council, the American Institute of Architects, and the Illuminating Engineering Society.

education.[81] ASHRAE 62.2, *Ventilation and Acceptable Indoor Air Quality in Residential Buildings*, is a consensus standard of practice for dwelling units in non-transient residential occupancies. This section describes the most recent update, ASHRAE 62.2-2019.[82] Prior to 2016, residential units in buildings four stories or higher were covered by a separate standard, ASHRAE 62.1, *Ventilation for Acceptable Indoor Air Quality*; that standard now applies only to commercial buildings and to common areas and spaces other than dwelling units in high-rise residential buildings.[83] ASHRAE 62.2 and 62.1 provisions are framed as enforceable requirements that can be incorporated into building codes.

ASHRAE 62.2 sets a "minimum standard" for ventilation.[84] ASHRAE has published a guideline (24-2015) to accompany Standard 62.2, which "goes beyond Standard 62.2's baseline objective of acceptable IAQ in providing information aimed at helping to achieve better IAQ" and addresses issues such as higher efficiency air filtration, which were not addressed in Standard 62.2 "due to a lack of consensus or other reasons."[85]

Providing Ventilation. ASHRAE 62.2, Section 4.1, requires mechanical ventilation via a "mechanical exhaust system, supply system, or combination thereof…installed to operate for each dwelling unit to provide continuous dwelling-unit ventilation…."[86] Sections 4.1 through 4.6 set forth system requirements, including a minimum ventilation rate and alternative compliance pathways. Other ventilation provisions of ASHRAE 62.2 related to infiltration of outdoor pollutants include:

- A requirement that *air inlets* that are part of the ventilation design be located a minimum of 10 feet from "known sources of contamination such as a stack, vent, exhaust hood or vehicle exhaust," with limited exceptions. (Sec. 6.8.) ASHRAE 62.1, which would apply to common areas of residential buildings four stories or higher, establishes minimum distances from specific contaminant sources, which range from five to 30 feet depending on the source type.[87] For example, Table 5.5.1 requires that air intakes be located at least 25 feet from a "thoroughfare with high traffic volume" and from truck loading or bus parking/idling areas.

[81] ASHRAE, ASHRAE's Mission and Vision, https://www.ashrae.org/about/mission-and-vision. ASHRAE is a member of the American National Standards Institute (ANSI), which approved Standard 62.2 as an American National Standard. *See* ASHRAE Standard 62.2 at Special Note (front matter).

[82] *See* ANSI/ASHRAE Standard 62.2-2019, Ventilation and Acceptable Indoor Air Quality in Residential Buildings, available at: https://www.ashrae.org/technical-resources/standards-and-guidelines/read-only-versions-of-ashrae-standards. The 2019 version incorporates 16 addenda to the 2016 edition.

[83] *See* ANSI/ASHRAE Standard 62.1-2019, Ventilation and Acceptable for Indoor Air Quality, available at https://www.ashrae.org/technical-resources/standards-and-guidelines.

[84] Lawrence Berkeley Nat'l. Lab., ASHRAE Standard 62.2, https://homes.lbl.gov/ventilate-right/ashrae-standard-622.

[85] ASHRAE Guideline 24-2015 (Ventilation and Indoor Air Quality in Low-Rise Residential Buildings) (2015), available at: https://www.techstreet.com/standards/guideline-24-2015-ventilation-and-indoor-air-quality-in-low-rise-residential-buildings?product_id=1898710. ASHRAE also collaborated with several organizations in 2009 to publish the Indoor Air Quality Guide: Best Practices for Design, Construction and Commissioning (https://www.ashrae.org/technical-resources/bookstore/indoor-air-quality-guide), which applies to commercial and large, multi-unit residential buildings.

[86] An exception is made where the local authority determines window operation is a permissible method of providing ventilation and either 1) the building is in a specified climate zone and has no mechanical cooling, or 2) the building is thermally conditioned for human occupancy less than 876 hours/year. ASHRAE 62.2, § 4.1.1.

[87] ASHRAE 62.1, § 5.5.1 provides: "Outdoor air intakes….shall be located such that the shortest distance from the intake to any specific potential outdoor contaminant source shall be equal to or greater than the separation distance listed in Table 5-1" or an alternative calculation method. The potential contaminant sources listed in Table 5-1 include air exhaust outlets; vents, chimneys/flues from combustion appliances; and plumbing vents.

- Required *sound rating limits for fans,* which can help ensure that systems will not be turned off due to noise concerns. The standard sets a 1.0 sone maximum for whole-house ventilation or continuous local exhaust fans (except HVAC air handlers and remote mounted fans). (Sec. 7.2.)

- *Information and labeling requirements,* which can help ensure the system will be used properly. Information about the ventilation systems installed, instructions on their proper operation, and instructions detailing any required maintenance must be provided to the owner and the occupant of the dwelling unit, and controls must be labeled as to their function. (Sec. 6.2.)

Providing Air Filtration. As ASHRAE 62.2 Section 2.2 states: "While acceptable IAQ is the goal of this standard, it will not necessarily be achieved even if all requirements are met….if the ambient air is unacceptable and this air is brought into the building without first being cleaned (ambient outdoor air cleaning is not required by this standard)….[or] when high-polluting events occur."

ASHRAE 62.2 does require minimum filtration on the recirculating airstream. At a minimum, a filter rated MERV 6 or higher must be provided in mechanical systems supplying air to an occupiable space through ductwork exceeding 10 feet in length and through a thermal conditioning component.[88] The system must be "designed such that all recirculated and mechanically supplied outdoor air is filtered before passing through the thermal conditioning components," and the filter must be located and installed to "facilitate access and regular service by the owner." Filter locations in new mechanical and distribution systems must be labeled with the maximum allowable clean-filter pressure drop in a manner visible to the person replacing the filter. Section 4.1.4 ("Ventilation-rate Reduction for Particle Filtration") permits users to reduce the total ventilation rate by 20 percent when using a high-efficiency filter in a recirculated air distribution system as specified in the standard.[89]

ASHRAE 62.1 has somewhat more stringent filtration provisions, however only the non-residential areas in high-rise buildings – as well as non-residential buildings, including schools and child care centers – fall within the scope of that standard.[90]

International Code Council. The ICC publishes 15 different model codes intended to be adopted by states and other jurisdictions. The International Residential Code (IRC), which covers one- and two-family dwellings and townhouses three stories or less, is a comprehensive code that covers most construction requirements. The International Building Code (IBC) applies to all other building types, including larger multi-unit residential buildings, and is used in conjunction with a series of specialized codes, including the International Mechanical Code (IMC), which governs ventilation systems. The

[88] ASHRAE 62.2, § 6.7.This section allows use of an alternative filter efficiency standard, AHRI Standard 680, Performance Rating of Residential Air Filter Equipment. There is an exception for evaporative coolers.
[89] This compliance option was not adopted by California in the recent revision of its filtration standards, described below.
[90] ASHRAE 62.1, § 5.9 requires MERV 8 or higher filters "upstream of all cooling coils or other devices with wetted surfaces through which air is supplied to an occupiable space…."
The Standard provides a separate requirement for buildings located in areas of nonattainment for PM, requiring that "particle filters or air-cleaning devices shall be provided to clean the outdoor air at any location prior to its introduction to occupied spaces." In areas where *PM2.5* is exceeded, these filters must have a minimum MERV 11 rating; in areas where *PM10* is exceeded, MERV 8 is required (§§ 6.1.4.1--.2). In addition, outdoor air quality must be investigated before completing the ventilation system, including identifying "local contaminants from surrounding facilities that will be of concern if allowed to enter the building" (§§ 4.1, 4.2).

International Energy Conservation Code (IECC) also incorporates ventilation requirements for high-rise and low-rise residential buildings.

The purpose of the ICC codes is to establish minimum standards for protecting public health and safety.[91] Following is a short summary of how the IRC and IBC/IMC address key ventilation and filtration strategies for reducing indoor exposure to outdoor PM. The ICC updates its codes every three years; parenthetical citations below are to the 2018 codes, though the provisions discussed here were not changed substantially from the 2015 and 2012 versions of the codes, which are still in effect in many states.

Reducing Infiltration and Providing Ventilation. The IRC requires that the building/unit be tested and verified as having an air leakage of either five or three air changes per hour (ACH) or less, depending on the climate zone; whole-building mechanical ventilation is required if "the air infiltration rate of a dwelling unit is 5 air changes per hour or less…."(IRC N1102.4.1.2, R303.4.) The IMC requires whole-building mechanical ventilation if "the air infiltration rate of a dwelling unit is 5 air changes per hour or less…." (IMC M401.2.) The IECC also establishes air leakage provisions for residential construction and requires that buildings be provided with ventilation that complies with the IRC or IMC, as applicable. (IECC R402.4, R403.6, C402.5, C403.2.)

Both the IRC and the IMC include minimum requirements for design of the whole-building mechanical ventilation system. While the 2018 ICC codes do not reference ASHRAE 62.2 explicitly, their ventilation requirements build on ASHRAE standards.[92] An exhaust-only, supply-only, or balanced system is allowed for residential occupancies three stories or less; for other building types, the IMC requires both "supply air and return or exhaust air." (IRC Chap. 1505, IMC 403.1.) Outdoor air must be provided continuously at the minimum rate established in the codes, which allow the system to operate intermittently if controls enable operation for the minimum amount of time specified in the code. (IRC M1505.4.3; IMC M403.) Systems covered by the IRC must have controls that enable manual override; in larger, multifamily buildings, a system must be installed for each dwelling and must be provided with manual or automatic controls that will operate the systems whenever the spaces are occupied. (IRC M1505.4.2, IMC 405.1.)

Both the IRC and the IMC require that mechanical and gravity outdoor air intakes be located at least 10 feet horizontally from or three feet below hazardous or noxious contaminants such as vents, chimneys, streets, alleys and parking lots. (IRC 303.5; IMC 401.4.)

Providing Air Filtration. The IRC does not include an explicit requirement for filtration of outdoor air, nor does it establish a minimum efficiency standard if filtration is provided. The IMC mandates that heating and air-conditioning systems be provided with "approved filters" that are installed such that all return air, outdoor air, and makeup air is filtered upstream from any heat exchanger or coil. (IMC 605.1.) The IMC does not, however, establish a minimum required filter efficiency.

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[91] *See* ICC, International Mechanical Code § 101.3 ("The purpose of this code is to establish minimum standards to provide a *reasonable* level of safety, health, property protection and public welfare….") (italics added); ICC, International Residential Code, § R101.3 ("The purpose of this code is to establish minimum requirements to safeguard the public safety, health, and general welfare…").

[92] *See* Joseph Hill, New York State Dept. of State, ICC Committee Hearings at 27, https://media.iccsafe.org/codes/2018-2019/GroupA/CAH/IRC-M.pdf (noting that mechanical ventilation "was introduced into the 2012 IRC…a derivation of the requirements of ASHRAE 62.2 -2004….").

Air Filtration Requirements in ICC and ASHRAE Model Codes and Standards		
	Air Filtration	**Minimum Filter Efficiency (MERV)**
International Residential Code 2018	N/A	N/A
International Mechanical Code 2018	Heating and air-conditioning systems must be provided with "approved filters," installed so that all return, outdoor, and makeup air is filtered upstream from any heat exchanger or coil. (§605.1)	N/A
ASHRAE 62.2-2019 (Residential)	Mechanical systems that supply air to an occupiable space through ductwork exceeding 10 ft., through thermal conditioning component (except evaporative coolers), must be provided with a filter, designed so that all recirculated and mechanically-supplied outdoor air is filtered before passing through the thermal conditioning components. (§6.7)	MERV 6 (§6.7)
ASHRAE 62.1-2019	PM filters or air cleaners must be provided upstream of all cooling coils or other devices with wetted surfaces through which air is supplied to an occupiable space. (§5.9) In non-attainment areas for PM10 or PM2.5, particle filters or air cleaning devices required for each ventilation system that provides outdoor air. (§§6.1.4.1--2)	MERV 8 (§5.9) MERV 11 in areas where PM2.5 standard is exceeded. MERV 8 in areas where PM10 standard os exceeded. (§§6.1.4.1--2). Outdoor air quality must be investigated before completing building ventilation system, including (1) determining whether the area is in attainment, and (2) doing an "observational survey of the site and its immediate surrounding…..to identify local contaminants from surrounding facilities that will be of concern if allowed to enter the building." (§§ 4.1, 4.2).

State Building Codes. While the ICC codes promote uniformity and consistency, it is common for states and localities to amend the model codes to address their own circumstances and priorities. The same is true for states incorporating ASHRAE 62.2 into their codes. Nevertheless, few states have provisions for reducing indoor exposure to outdoor air pollutants more stringent than those in the model codes.[93]

The building codes in most states – and likely most local jurisdictions – incorporate the ventilation provisions in the IRC and IMC described above, including the requirement for mechanical ventilation to bring in outside air if the air infiltration rate of dwelling unit is five air changes/hour or less. A relatively small number of states have strengthened or weakened this requirement.[94] Even fewer states have altered the filtration requirements in the model codes.

Air Filtration Requirements. Nearly all state building codes adopt the minimum filtration provisions of the ICC codes – no filtration requirement in the IRC and a general IMC requirement that all return air, outdoor air, and makeup air is filtered upstream from any heat exchanger or coil. A small number of states adopting these codes have augmented the filtration provisions but have not established a requirement for high-efficiency filtration.[95] For the most part, states that have adopted ASHRAE standards in their building codes have not augmented the ASHRAE 62.2 requirement for MERV 6 filters. This report reviewed a small number of *local* building codes in jurisdictions with high ambient PM levels and found that, for the most part, those codes similarly do not include filtration requirements that go beyond the adopted model codes.[96]

One state, however, recently amended its mandatory, statewide building code to ensure that new residential construction will have high-efficiency filtration designed to remove fine particles. In 2018, the California Energy Commission (CEC) adopted a high-efficiency (MERV 13 or equivalent) filtration requirement as part of the state Energy Code, which was subsequently approved by the Building Standards Commission for inclusion in the statewide mandatory building code. California's new filtration requirement, which applies to mechanical ventilation and space conditioning systems, offer a model for consideration by other jurisdictions.

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[93] The 2012, 2015, and 2018 versions of the IRC and IMC are similar with respect to the provisions discussed in this report. As of late 2019, most states that had adopted ICC codes were using the 2015 version of one or more codes; only a handful of states had adopted a version of the IRC, IBC, or IMC earlier than 2015, and a few states had adopted 2018 versions of the codes. Many states are required to update their codes to follow the ICC cycle and a number of states will thus consider code revisions in the near term. *See* ICC, Code Adoption Process by State: Revised June 2019, https://www.iccsafe.org/wp-content/uploads/Code-Adoption-Process-by-State-June-2019.pdf.

[94] Virginia and Washington are examples of states that require mechanical ventilation regardless of the infiltration rate. Vermont's residential code, which is not based on the IRC, includes a similar provision. *See* 13 Va. Admin. Code 5-63-210 (310.11); Wa. Admin. Code 51-51-0303 (R303.4); Vt. Residential Building Energy Code Handbook at § 3.1a. At the same time, this report's review of state codes found that a few states have deleted the mechanical ventilation requirement or have set a lower air changes per hour threshold, thus potentially reducing the number of homes required to have mechanical ventilation.

[95] For example, Washington's residential code requires that where whole-house ventilation systems use a supply fan, the "outdoor air must be filtered before it is delivered to habitable spaces." Wa. Admin. Code ch. 51-51 (M1507.3.6.1). Minnesota amended the IMC filtration requirement for low-rise residential buildings: "All mechanically supplied outdoor air shall have a filter with a designated minimum efficiency of MERV 4 as defined by ASHRAE Standard 52.2." Minn. Rules Pt. 1322.0403.

[96] One limited exception is New York City's mechanical code for residential and commercial buildings, which requires: "Air-handling units of mechanical ventilation systems, any portion of which provide outdoor air ventilation, shall be equipped with a particulate matter filtration system in accordance with ASHRAE 62.1 or ASHRAE 62.2 and shall have [MERV 11] or greater…." An exception for air-handling units with a design capacity of less than 5,000 cfm limits the extent to which this would apply to systems in homes or within individual dwelling units. NYC Admin. Code MC 605.2.1, Local Law 72 of 2011; see Construction Codes Update #58 at 58a, available at: https://www1.nyc.gov/assets/buildings/building_code/cc_update_58-LL72-11.pdf.

Incorporating High-Efficiency Filtration in Residential Building Codes: California's 2019 Energy Code

California is known as a leader in building energy efficiency and recently adopted solar photovoltaic requirements for new homes. What is less widely recognized is the state's leading role in integrating energy efficiency and indoor air quality. This focus on indoor air quality is enshrined in state law, which requires the CEC "when assessing energy conservation standards for residential and nonresidential buildings…. [to] include in its deliberations the impact that those standards would have on indoor air pollution problems."[97]

As part of its regular code review process, the CEC "considered both proposed and existing building standards in light of new information about the effects of indoor particulate pollutants…noting that filters meeting current MERV 6 and 8 requirements are only moderately effective at filtering out airborne particulates (PM10) and are unable to capture or filter out fine particulates (PM2.5)."[98] The CEC developed the new MERV 13 standard "to ensure that filtration requirements were set at a level appropriate for our current understanding of human indoor air quality needs and the effects of particulate pollutants on human health."[99] The requirement, effective January 2020, applies to mechanical ventilation *and* space conditioning systems that supply air to habitable spaces in all new buildings.

A sister agency, the California Air Resources Board (CARB), has played a key role in advancing building science research and integrating IAQ best practices in new building construction. CARB provided formal comments in support of the CEC proposal to strengthen the filtration standard. Though CARB staff expressed a preference for a MERV 16 requirement for most applications, the agency acknowledged that "ease of implementation and enforceability are important criteria" and supported "a move to MERV 13 on a statewide basis at this time."[100] The CEC considered higher and lower MERV values, ultimately selecting MERV 13 "based on availability of filters and, in particular filters that would maximize filtration performance and capture of small particulates while having a minimal impact on pressure drop relative to current MERV 6 and MERV 8 filters."[101]

Key Elements of California's New High-Efficiency Filtration Standard

California's statewide Building Standards Code, Title 24 of the California Code of Regulations, covers residential and non-residential buildings and comprises plumbing, mechanical, energy, and other specific codes. These codes are based on model codes from the ICC and other model code organizations,

[97] Ca. Pub. Resources Code § 25402.8.
[98] Cal. Energy Comm., 2019 Energy Code Initial Statement of Reasons at 37-38 (1/18/2018), available at https://ww2.energy.ca.gov/title24/2019standards/rulemaking/documents/.
[99] Id. at 135.
[100] California Air Resources Board Staff Comments on Proposed 2019 Residential Standards at 1-2 (6/26/17), available at: https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=17-BSTD-01
[101] Cal. Energy Comm., 2019 Energy Code Initial Statement of Reasons at 135 (1/18/2018), available at https://ww2.energy.ca.gov/title24/2019standards/rulemaking/documents/.

with or without state-specific amendments, as well as elements that are not covered by model codes but have been authorized by the state legislature "to address particular California concerns."[102] The filtration requirements are adopted in the energy portion of the building code, the 2019 California Energy Code, which is revised every three years.[103] The Energy Code applies to residential and nonresidential new construction, additions, and alterations. It incorporates provisions of ASHRAE 62.2, but is not based directly on a model code. Until the 2019 revision, the CEC incorporated ASHRAE's MERV 6 air filtration requirement.

Effective January 1, 2020, the Energy Code requires filters with a MERV 13 or greater particle removal efficiency, when tested per ASHRAE 52.2, in all residential (low-rise and high-rise) and commercial construction subject to the code.[104]

- The requirement applies to mechanical ventilation *and* space conditioning systems that supply air to occupiable spaces through ductwork over 10 feet in length. All recirculated air or outdoor air supplied to the occupiable space must be filtered before passing through any system thermal conditioning component.[105]
- The systems must be designed to accommodate the rated *pressure drop* of the system air filter at the designed airflow rate.[106]
- The systems must use a *two-inch deep filter*, though a one-inch filter is allowed if the filter is sized according to design parameters specified in the regulations.[107] The CEC noted that these options would "help ensure that MERV 13 filters can be installed with little or no impact on overall system performance," but pointed out that "a 2" filter depth is valuable in allowing filters to have airflow characteristics that are superior to a 1" filter, and may facilitate use of even higher MERV filters (such as the MERV 16…) if chosen as replacement filters by system owners."[108]
- The Energy Code also strengthened requirements for *labeling of mechanical ventilation system controls* and operations in the recent code update cycle. The code now requires manual switches associated with dwelling unit ventilation systems to have a label clearly displaying the following or equivalent text: *This switch controls the indoor air quality ventilation for the home. Leave it on unless the outdoor air quality is very poor.*[109]
- Mechanical space conditioning systems must be equipped with air filters that have the air filter *manufacturer's performance label* affixed to the filter product stating both the efficiency and the pressure drop characteristics of the installed filter. Additionally, for all types of systems, the air filter

[102] Cal. Building Standards Comm., Building Standards Code, https://www.dgs.ca.gov/BSC/Codes.
[103] 24 Ca. Code Regs. Pt. 6. The code is also known as the Building Energy Efficiency Standards (BEES) Code.
[104] 24 Ca. Code Regs. Pt 6, §§ 150.0(m)(12)(C), 120.1(b)(1)(C). Alternatively, filters may have an equivalent or a particle size efficiency rating equal to or greater than 50 percent in the 0.30-1.0 µm range, and equal to or greater than 85 percent in the 1.0-3.0 µm range when tested in accordance with AHRI Standard 680.
[105] 24 Ca. Code Regs. Pt 6, § 150.0(m)(12)(A), (B)(i); 120.1(b)(1)(A),(B).The requirement applies to (1) mechanical space conditioning systems that supply air to occupiable space through ductwork exceeding 10 feet, (2) mechanical supply-only ventilation systems that provide outside air to occupiable space; and (3) the supply side of mechanical balanced ventilation systems, including heat recovery ventilation systems, and energy recovery ventilation systems that provide outside air.
[106] 24 Ca. Code Regs. Pt 6, §§ 150.0(m)(12)(B)(ii), 150.0(m)(12)(D), 120.1(b)(1)(B).
[107] 24 Ca. Code Regs. Pt 6, §§ 150.0(m)(12)(C), 120.1(b)(1)(B).
[108] Cal. Energy Comm., 2019 Standards Initial Statement of Reasons at 6 (1/18/18), available at: https://ww2.energy.ca.gov/title24/2019standards/rulemaking/documents/; Cal. Energy Comm., Staff Analysis of Air Filter Pressure Drop and Air Filter Sizing (4/23/18), available at: https://ww2.energy.ca.gov/title24/2019standards/rulemaking/documents/2018-05-09_hearing/Documents_Relied_Upon.php.
[109] 24 Ca. Code Regs. Pt 6, § 150.0(o)1I.

location must have a label or sticker placed by the system installer – visible to those replacing the filter – that discloses the system's design airflow rate and the allowable pressure drop for the installed air filter at the design airflow rate. This sticker must be visible to those replacing filters. The filters must be accessible to facilitate replacement.[110]

The CEC also amended its appliance efficiency regulations in 2017 to require that air filters for use in forced-air heating or cooling equipment be labeled to disclose information about the air filter's efficiency and pressure drop performance ratings "permanently and legibly, on an accessible and conspicuous place."[111] As a stand-alone measure and as a complement to the new state building code standards, this labeling requirement is important in helping consumers purchase filters that do not exceed the maximum allowable pressure drop at the system's design airflow rate and that may provide the highest efficiency appropriate for their mechanical system.

One concern associated with higher filter efficiency that was addressed by the CEC is whether increased air flow resistance across the filter would require bigger systems that cost more and use more energy. The agency reviewed pressure drop performance data for currently available air filters and conducted its own additional filter testing and found no significant correlation between MERV rating and pressure drop for the tested models. CEC staff identified "a MERV rating of 13 as being effective at filtering out PM2.5 while also being available in a one inch form factor with a negligible effect on pressure drop compared to an average filter with the currently required MERV rating of six."[112]

CEC staff also found that "filters with the same pressure effects as a one-inch MERV 6 filter and higher MERV ratings are broadly available at a two-inch filter depth, increasing the breadth and depth of selections available to consumers."[113] The CEC Staff Analysis found that air filter pressure drop can be reduced by increasing the amount of air filter media surface area available to the system's airflow, which can be accomplished by adjusting the number of pleats inside the filter frame, the face area of the air filter and filter grille, and/or the depth of the filter and filter grille.[114]

Although the CEC was not required to undertake a cost-benefit analysis for the filtration measure, state law requires that building energy efficiency standards promulgated by CEC be cost-effective "when taken in their entirety."[115] In a report prepared in connection with the code revision process, a California investor-owned utilities group estimated the added cost of the filtration requirements in new homes to

[110] 24 Ca. Code Regs. Pt 6, §§ 150.0(m)(12)(E), 150.0(m)(12)(B)(iii, iv), 120.1(b)(1)(E), (B)(iii).
[111] 20 Ca. Code Regs. § 1607(12). Filters manufactured on or after April 1, 2019 must include filter efficiency for the three primary particle size ranges, airflow resistance, and MERV rating (or equivalent).
[112] Cal. Energy Comm., 2019 Standards Initial Statement of Reasons at 38 (1/18/2018), available at https://ww2.energy.ca.gov/title24/2019standards/rulemaking/documents/. A recent study of ventilation and filtration in 19 homes in Toronto noted that there is a "large variation in filter pressure drop for filters with the same MERV" and found that filter pressure drop "was not strongly correlated with filter nominal efficiency." Alavy, et al., Energy Use in Residential Buildings: Analyses of High-Efficiency Filters and HVAC Fans, Energy & Buildings v. 209 (2020) (finding also that "fan energy consequences of high-efficiency filters are negligible").
[113] Id.
[114] Cal. Energy Comm., Staff Analysis of Air Filter Pressure Drop at 4 (4/23/18), available at https://ww2.energy.ca.gov/title24/2019standards/rulemaking/documents/2018-05-09_hearing/Documents_Relied_Upon.php. *See also* Nat'l. Acad. of Sciences, Engineering, and Medicine – Health and Medicine Division, Health Risks of Indoor Exposure to Particulate Matter: Workshop Summary at 62 (2016), available at http://nationalacademies.org/hmd/Activities/PublicHealth/Health-Risks-Indoor-Exposure-ParticulateMatter/2016-FEB-10.aspx (summarizing comments of William Fisk).
[115] Ca. Public Resources Code § 25402(b)(3).

be $191 per single-family home and $78 per unit in high-rise, multifamily buildings. These costs reflect primarily the provision of a larger (two-inch) filter grille and filter. The single-family home estimate also includes a second return grille for certain one-story homes due to potential higher pressure drop, though the CEC found that MERV ratings were not a significant predictor of air filter pressure drop for MERC 13 filters.[116]

Green Building Codes: Going Beyond Minimum to Reduce Indoor Exposures

Green building – also known as "high performance" building – is characterized by the integrated consideration of a wide range of environmental and health features that go beyond minimum building codes. Green building policies are thus a potential vehicle for advancing best practices for improving indoor air quality.

As is the case with general building codes, green building policies frequently incorporate third-party standards. Most of the widely-adopted model green building standards for residential construction do not currently require high-efficiency filtration. Nevertheless, jurisdictions adopting green building policies can modify or augment third-party standards to ensure that they require higher-efficiency filtration.

This section begins by describing the third-party green building standards commonly referenced in state and local policies, followed by examples of state and local policies that incorporate green building *requirements* for new residential construction. Though not discussed here, the same considerations apply to policies that offer *incentives* such as expedited permitting, bonus density, reduced permitting fees, or tax credits.

Third-Party Green Building Standards. Though states, tribes, and local jurisdictions may develop their own green building standards, they are more likely to adopt policies that incorporate standards or rating systems developed by non-governmental organizations. These voluntary, third-party standards typically cover a wide array of issues, from energy and water conservation to siting and indoor environmental quality. Yet they vary in how they address those issues – both in the individual criteria they include and in whether those criteria are mandatory or optional items.

The following are examples of prominent standards referenced by government policies.[117]

- *International Green Construction Code (IgCC)/ASHRAE 189.1* – the 2018 version of the IgCC was published jointly by the ICC and ASHRAE as a model green building code for all building types except

[116] California Statewide Codes and Standards Enhancement (CASE) Program, Residential Indoor Air Quality – Final Report at 42-45, Tables 12, 13 (2017), https://efiling.energy.ca.gov/GetDocument.aspx?tn=222202&DocumentContentId=27372 .

[117] There are numerous other green building standards that are less frequently incorporated into policies but have notable filtration-related requirements for residential projects. *See, e.g.*, Southface Energy Institute, Earthcraft Homes (for climate conditions in the Southeast, requires MERV 13 filters on HVAC systems); Intl. WELL Building Inst., WELL Building Standard, https://www.wellcertified.com/about-iwbi/ (emphasizing "features that support and advance human health and wellness" and including requirements for PM filtration). In addition, the Build it Green system, designed for single-family and multifamily homes, is widely used in California. Build it Green, GreenPoint Rated, https://www.builditgreen.org/greenpoint-rated.

one and two family dwellings and townhouses, and is designed to be fully compatible with the ICC family of codes.[118]

- *Leadership in Energy and Environmental Design (LEED)* – a widely-used rating system of the U.S. Green Building Council, which certifies projects that meet one of several sets of LEED criteria, including two that address new home construction: LEED-Homes (residential buildings six stories or less) and LEED-Building Design (other building types).[119]
- *Enterprise Green Communities* – the only green building rating system designed specifically for affordable housing projects, developed and managed by Enterprise Community Partners.[120]

In addition to these standards, EPA has developed the Indoor airPLUS criteria, a voluntary labeling program that "builds on the foundation of EPA's ENERGY STAR requirements for new homes and provides additional construction specifications to provide comprehensive indoor air quality protections in new homes."[121] Indoor airPLUS is a stand-alone protocol, an optional add-on to EPA Energy Star Homes program, and now a requirement for meeting The Department of Energy's (DOE) Zero Net Energy Home Standard.[122]

The above standards all require whole-building mechanical ventilation systems and the siting of outdoor air intakes in compliance with ASHRAE 62.2. They vary with respect to provisions governing filtration efficiency. As described in the following chart, none of these standards *require* high-efficiency filtration (except in some cases, for homes built in PM nonattainment areas). Some offer optional credits for high-efficiency filters, though such provisions do not guarantee that a project will choose to include this feature. Thus, where states incorporate these or other third-party green building standards into their policies, an important consideration is whether to augment the standard with stronger filtration and other IAQ-related measures.

[118] ICC, et al., International Green Construction Code (2018), available at: https://www.iccsafe.org/products-and-services/i-codes/2018-i-codes/igcc/. The IgCC now incorporates the technical provisions of ASHRAE Standard 189.1 (Standard for the Design of High Performance, Green Buildings Except Low-Rise Residential Buildings).
[119] U.S. Green Building Council, LEED Rating System, https://www.usgbc.org/leed.
[120] Enterprise Community Partners, Green Communities, https://www.enterprisecommunity.org/solutions-and-innovation/green-communities.
[121] U.S. EPA, Basic Information about Indoor airPLUS, https://www.epa.gov/indoorairplus/basic-information-about-indoor-airplus.
[122] See U.S. DOE, Guidelines for Participating in the DOE Zero Energy Ready Home Program, https://www.energy.gov/eere/buildings/guidelines-participating-doe-zero-energy-ready-home-program.

Air Filtration Requirements in Selected Green Building Standards				
2018 Intl. Green Construction Code (IgCC) (incl. ASHRAE 189.1-2017)	**LEED for Building Design and Construction (v4)**	**LEED for Homes (v4)**	**Enterprise Green Communities (2020)**	**EPA Indoor airPLUS (V1. Rev. 04)**
Required: *MERV 8* rated PM filters or air cleaners provided upstream of all cooling coils or other devices with wetted surfaces through which air is supplied to an occupiable space. (§ 8.3.1.3(a))	**Required:** Minimum ventilation requirements of *ASHRAE Standard 62.1–2010* (§4-7).** (EQ Prereq: Min. IAQ Perf.)	**Required:** Air filters rated *MERV 8* or higher installed in all ducted, recirculating space conditioning systems. (EQ Prereq: Air Filtering)	**Required**: For each dwelling unit, whole-house mechanical ventilation system per *ASHRAE 62.2-2010*.* (§ 7.7)	**Required**: Mechanical whole-dwelling ventilation meeting all require-ments of *ASHRAE 62.2-2010** or later. (§ 4.5) Central forced-air HVAC systems have filter rated *MERV 8* or higher. (§ 4.7)
Required: In PM2.5 *non-attainment* areas, particle filters or air cleaners required for each ventilation system that provides outdoor air: *MERV 13* in PM2.5 areas; *MERV 8* in PM10 areas. (§ 8.3.1.3(a))	***"Enhanced IAQ Strategies" Credit (1 point)*:** Install air filters rated *MERV 13* or higher for each ventilation systems that supply outdoor air to occupied spaces.	**Required**: Air filters rated *MERV 6* or higher for mechanically supplied outdoor air for systems with 10 or more feet of ductwork. (EQ Prereq: Air Filtering)	***Recommended***: Install filters rated *MERV 13* or high for outdoor air ventilation equipment, esp. in PM non-attainment areas and/or within 500 feet of busy roads. (§ 7.7) (new in 2020)	***Recommended*:** Filters rated at *MERV 13* or higher for central forced-air HVAC systems and for air inlets. (§§ 4.7, 4.5)

***ASHRAE 62.2-2010** and later versions require minimum *MERV 6* filtration for mechanical systems that supply air to an occupiable space through ductwork exceeding 10 feet in length and through thermal conditioning components. (See §6.7)

****ASHRAE 62.1-2010** requires PM filters or air cleaners rated *MERV 6* or higher upstream of all cooling coils or other devices with wetted surfaces through which air is supplied to an occupiable space. Separate requirements for *PM non-attainment areas*: For PM2.5, *MERV 11* particle filters or air-cleaning devices to clean outdoor air prior to its introduction to occupied spaces; For PM10, *MERV 6* filters. (See §§ 5.8, 6.2.1.1-.2.)

[*Note:* These requirements have been revised in more recent versions of the standard. ASHRAE 62.1-2019 requires *MERV 8* filters for recirculating air and also for supply air in PM10 nonattainment areas.]

State Green Building Policies. At the state level, only California has adopted a mandatory green building code that applies to all residential construction. The **California** Green Building Standards Code (CALGreen) is not based on a third-party standard. It establishes both mandatory and optional measures, including a variety of IAQ items.[123] The MERV 13 filtration standard recently established in the state Energy Code exceeds the filtration requirements of the green building standards code.

In **Oregon***,* Executive Order 17-20 (Accelerating Efficiency in Oregon's Built Environment to Reduce Greenhouse Gas Emissions and Address Climate Change) directs the state building codes agency to "conduct code amendment of the state building code to require newly constructed residential building to achieve at least equivalent performance levels with the 2017 U.S. Department of Energy Zero Energy Ready Standard by October 1, 2023." Though the Oregon Executive Order is focused on energy, the referenced federal standard incorporates EPA's Indoor airPLUS criteria and thus provides a ready model for integrating IAQ goals as the state upgrades its building code.

Other states have adopted green building codes to serve as models for *voluntary* use in new residential construction. For example, **Rhode Island** has adopted Voluntary Stretch Codes to help projects maximize financial incentives offered by state. The codes are also an option for satisfying the state's green building requirement for public buildings, including public multi-family housing.[124] The code for larger residential buildings is based on the 2015 IgCC and includes a requirement for air-conditioning system filters to be rated at MERV 11 or higher. The code for one- and two-family homes and townhouses is based heavily on the Department of Energy's Zero-Energy Ready Homes standard (which incorporates EPA's Indoor airPLUS protocol), though alternate compliance paths are also acceptable.[125]

Local Green Building Policies. Many local jurisdictions have adopted green building codes.[126] While most are voluntary standards tied to financial and other incentives, some localities have adopted green building criteria that are mandatory for at least some types of residential construction.

For example, **Montgomery County,** the largest jurisdiction in Maryland, requires new multifamily residential or mixed-use residential buildings with at least 5,000 square feet to comply with the IgCC (2012) or LEED Silver criteria.[127] In 2007, **Boston**, Massachusetts amended its Municipal Zoning Code to require that all projects undergoing Large Project Review must be "LEED Certifiable under the most appropriate LEED building rating system."[128] In the **District of Columbia**, multifamily residential projects that are more than three stories and at least 10,000 square feet must comply with the District's Green Construction Code (GCC). The GCC consists of an amended version of the 2012 IgCC, but the code allows

[123] 24 Ca. Code Regs. Pt. 11.

[124] See R.I. Gen. Laws 37-24; R.I. Office of Energy Resources, Rhode Island Stretch Codes, http://www.energy.ri.gov/policies-programs/lead-by-example/rhode-island-stretch-codes.php.

[125] Both stretch codes are available at: R.I. Office of Energy Resources, Rhode Island Stretch Codes, http://www.energy.ri.gov/policies-programs/lead-by-example/rhode-island-stretch-codes.php.

[126] *See generally* U.S. Dept. of Energy, Going Beyond Code, https://www.energycodes.gov/sites/default/files/documents/GoingBeyondCode.pdf; Envtl. Law Inst., Municipal Green Building Policies: Strategies for Transforming Building Practices in the Private Sector (2008), https://www.eli.org/research-report/municipal-green-building-policies-strategies-transforming-building-practices-private.

[127] Code of Montgomery County Regs. §§ 08.00.03.01 et seq.; *see generally* Montgomery County Dept. of Permitting Svcs., County IgCC Program, https://www.montgomerycountymd.gov/DPS/Resources/Files/COMBUILD/ProgramDescription.pdf.

[128] Boston Municipal Zoning Code Art. 37.

several "alternative compliance paths" using other third-party standards.[129] Multifamily housing projects owned or financed (15 percent or more) by the District are subject to a separate law, the Green Building Act, which requires that buildings containing at least 10,000 square feet of residential occupancies be designed and constructed to meet or exceed the Enterprise Green Communities Criteria "or a substantially equivalent standard."[130]

Requirements for Publicly-Funded Residential Construction: Opportunities for Reducing Indoor Exposures in New Affordable Housing

This section focuses on policies that establish green and healthy building requirements for an important subset of residential buildings – affordable housing construction projects subsidized with government funding. States, tribes, and local governments administer a variety of programs to help finance the construction and rehabilitation of affordable housing. Increasingly, policymakers and agencies are establishing laws, regulations, program guidelines, and other policies requiring that such projects meet criteria that go beyond the jurisdiction's current minimum building code. These policies typically incorporate a third-party green building standard.

Establishing Green Building Requirements for State-Funded Projects Generally. Some state policies include a general requirement that all state-funded construction must comply with referenced green building criteria. **South Carolina**, for example, requires that state-funded new construction projects over 10,000 square feet must meet the LEED Silver standard or a two-globes rating under the Green Globes Rating System.[131] In lieu of referencing a third-party green building standard, jurisdictions can establish their own set of green building criteria for government-funded projects. In **Connecticut**, the Housing Finance Authority (CHFA) has developed design and construction standards that apply to multifamily housing developments seeking construction funding administered through the CHFA and the Connecticut Department of Housing. The guidelines require, among other things, that projects provide MERV 8 filters "located so that return and ventilation air pass through prior to conditioning" and "[s]ize the air handler to accommodate the reduced air pressure caused by the filter."[132]

Including Green Building Requirements in State-Administered Federal Funding Programs. There are a number of federal funding programs that support the development of affordable housing. One Department of Housing and Urban Development (HUD) program, the Low Income Housing Tax Credit (LIHTC) program, awards tax credits to developers of affordable rental housing. The LIHTC is administered by the states, which prepare annual Qualified Allocation Plans (QAPs) that set forth their priorities and selection criteria for awarding the credits. While federal regulations require that state

[129] 12-A D.C. Mun. Regs § 101.4.9.4. The 2012 version of the IgCC required MERV 11 (or higher) filters for air conditioning systems that serve occupied spaces and handle a component of outdoor air; this provision is not in the current (2018) version of the IgCC. Alternative compliance paths referenced in the D.C. code are ASHRAE 189.1, Enterprise Green Communities, LEED, the National Green Building Standard (ICC 700), and EPA's Energy Star Program (New Homes or Multifamily High Rise).
[130] D.C. Stat. § 6-1451.02.
[131] S.C. Stat. §§ 48-52-830, 48-52-810(10(a). Under the Green Building Initiative's Green Globes rating system for new construction, projects that include MERV 13 filtration gain 5 points, and projects without MERV 13 gain no points. Green Globes for New Construction Technical Reference Manual at 195, available at: https://www.thegbi.org/files/training_resources/Green_Globes_NC_Technical_Reference_Manual.pdf.
[132] Conn. Housing Finance Auth., 2020 Multifamily Design, Construction and Sustainability Standards at 54, https://www.chfa.org/assets/1/6/2020_Multifamily_Design,_Construction_and_Sustainability_Standards.pdf?8976.

QAPs mandate consideration of energy efficiency in selecting projects, the regulations do not address indoor air quality.[133]

Many states have prioritized green and healthy housing by incorporating third-party green building standards in their QAPs.[134] A number of state plans reference the Enterprise Green Communities standard (the only standard developed specifically for affordable housing projects), either alone or as one of several green building standards the developer can select for its project.[135] In some cases, the green building standards are included as one of many *optional* measures that can earn points on a LIHTC application. Some states, though, include green building standards as a *requirement* that funded projects must achieve.

For example, **Georgia**'s 2019 QAP requires applicants to obtain a sustainable building certification from one of four listed green building standards.[136] **Colorado**'s 2019 QAP requires projects to comply with the Enterprise Green Communities criteria or to be certified under the LEED or National Green Building standard.[137] **Pennsylvania**'s 2019-2020 QAP requires projects to meet the mandatory requirements of the Green Communities standard or be certified by another third-party standard listed in the plan.[138] And **Louisiana**'s draft 2019 QAP requires applicants for new construction projects to meet the criteria of either LEED-New Construction or Enterprise Green Communities.[139] States can also express program priorities by deducting points for features that are less desirable. For example, **Alabama**'s 2020 QAP deducts points for each "incompatible use" located within 0.3 mile of the proposed project, and the non-exhaustive list of incompatible uses includes: pig or chicken farms; processing plants; airports; and solid waste disposal facilities.[140]

Other HUD programs provide block grants to states or localities for community development activities that may include affordable housing – e.g., the Community Development Block Grant (CDGB) program, the HOME Investment Partnerships Program (HOME), the Neighborhood Stabilization Program (NSP), and the National Housing Trust Fund program. States have an opportunity to incorporate green and healthy building requirements into these programs as well – e.g., through program guidance and the multi-year Consolidated Plans that outline their housing priorities and govern the use of the block grant

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[133] *See* 25 C.F.R. 42(m)(C).

[134] Amer. Planning Assoc., Green Goes Mainstream in Low-Income Housing at 34 (2013) http://mrsc.org/getmedia/5C1945EA-F7D2-4AF1-9A97-3E221D65F0D7/Fuhry.aspx ("In 2012, 27 QAPs mentioned third party green building certifications, quadruple the number from five years ago.").

[135] *See* N.Y. State Energy Devt. Admin., Benefits of Affordable Residential Green Building Incentives at 19 (2018), https://www.nyserda.ny.gov/-/media/Files/Publications/building-stock-potential-studies/18-39-Benefits-Affordable-Residential-Green-Building-Incentives.pdf.

[136] State of Georgia, 2019 Qualified Allocation Plan at 26, https://www.dca.ga.gov/sites/default/files/2019_qualified_allocation_plan.pdf. The listed standards are: EarthCraft House; Enterprise Green Communities; LEED for Homes; and the National Green Building Standard.

[137] Colorado 2019 Qualified Allocation Plan at 50, https://www.novoco.com/sites/default/files/atoms/files/colorado_2019_final_qap_123118.pdf.

[138] Pennsylvania Qualified Allocation Plan 2019-2020 at 15-16, https://www.phfa.org/forms/multifamily_application_guidelines/guidelines/2019_and_2020/2020-mpg-03.pdf. The QAP also includes requirements for air conditioning.

[139] Louisiana Draft 2019 Qualified Action Plan at 24, https://www.lhc.la.gov/hubfs/Document%20Libraries/Housing%20Development/Funding%20Opportunities/QAP/2019%20DRAFT%20QAP%20-%20April%2017,%202019.pdf.

[140] Alabama 2020 Housing Credit Qualified Allocation Plan at A-8, A-9, http://www.ahfa.com/Content/Uploads/ahfa.com/files/MF%20Allocation/2020%20docs/AHFA%202020%20QAP.pdf.

funds.[141] States can also incorporate IAQ priorities in administering residential construction programs of other agencies, such as the Department of Agriculture.[142]

Incorporating Enhanced Filtration in Green Building Standards for Schools

A considerable number of states have adopted green building requirements specifically for schools. Most of these reference third-party green building standards, including a standard created exclusively for schools – the Collaborative for High Performance Schools (CHPS) criteria. The CHPS Core Criteria include a number of IAQ-related prerequisites, including a requirement that filters for new HVAC systems be rated MERV 11 or higher (except unit ventilators, for which filters can be rated MERV 7), and an optional enhancement of MERV 13 or higher. CHPS National Core Criteria v. 2.2 at page 44-45, https://chps.net/sites/default/files/CHPS_National_Core_Criteria_2016%20update.pdf.

For a listing of state policies that require school construction to comply with CHPS or other green building criteria, see Envtl. Law Inst., Healthy, High Performance School Facilities: Developments in State Policy (rev. 2017) at https://www.eli.org/buildings/healthy-high-performance-schools.

Discussion

States, tribes, and local governments can reduce indoor exposure to particulate matter in homes by including higher-efficiency filtration and related measures in their building codes. Some jurisdictions require legislation to adopt a new building code, while others can use rulemaking to update the codes.[143] When incorporating third-party model building codes and standards, policymakers can modify the models to incorporate stronger filtration. Indeed, prior to the International Residential Code's inclusion of mechanical whole-house ventilation, a number of states (e.g., Minnesota, Washington, Vermont) had adopted such a requirement into their own version of the code.

Mounting evidence of the harm caused by exposure to particulate matter and advances in filter technology make high-efficiency filtration an important consideration for new and revised building codes and green building policies. There are nonetheless some important practical issues to address in establishing stronger filtration requirements.

Statewide vs. Local Filtration Requirements. One consideration in establishing higher filter efficiency requirements is whether to do so throughout a state or only in areas most affected by high levels of outdoor PM. ASHRAE 62.1 (Sec. 4) takes the latter approach for *commercial* buildings, requiring that buildings located in PM2.5 nonattainment area must have particle filters or air-cleaning devices with a minimum MERV 11 rating prior to its introduction to occupied spaces. ASHRAE 62.1 (Sec. 4.2) also

[141] *See* HUD Exchange, Consolidated Plan, https://www.hudexchange.info/programs/consolidated-plan/.
[142] Department of Agriculture regulations, which establish design requirements for all agency-financed multifamily housing, require housing proposals to give "maximum consideration to energy conservation measures and practices." 40 C.F.R. 3560.60.
[143] *See generally,* ICC, Code Adoption Process by State: Revised June 2019, https://www.iccsafe.org/wp-content/uploads/Code-Adoption-Process-by-State-June-2019.pdf.

requires an investigation before completing the ventilation system to "identify local contaminants from surrounding facilities that will be of concern if allowed to enter the building."

California, a state with multiple areas in non-attainment for PM2.5, rejected this location-specific approach. In addition to posing enforcement challenges where non-attainment areas extend across more than one local jurisdiction, an approach based on NAAQS compliance would not necessarily protect residents from local pollution sources that are not captured by state NAAQS air monitoring. In its comments on the recent Energy Code revision, the California Air Resources Board pointed out that "even within attainment areas, homes and buildings may have PM levels that exceed California Ambient Air Quality Standards due to their proximity to local sources, such as busy roadways, rail yards ports, airports, and stationary sources."[144] Thus, CARB supported a MERV 13 requirement "in all ducted buildings statewide, rather than just in PM2.5 non-attainment areas, because that would provide equal protection to all areas and population groups of concern," including environmental justice communities that often experience higher exposures.[145]

A requirement tied to NAAQS attainment status might not protect people from high-PM episodes such as the increasingly severe wildfire smoke events in many states, discussed in Chapter Three. And, as noted in Chapter One, even PM2.5 levels below current federal standards may pose health risks.

Where a state does not adopt stronger filtration requirements for the state as a whole, local governments may be able to do so through their own building codes and other policies governing new home construction. Local jurisdictions can also consider policies to protect residents from exposure to specific local sources, such as high-volume roads. The next section in this chapter discusses policies that incorporate best practices for reducing exposure from vehicle emissions, a significant source of air pollution in neighborhoods throughout the county.

Implementation Considerations. Studies show that higher-efficiency filters can reduce indoor PM significantly. At the same time, even with design and construction requirements for high-efficiency filtration in place, filter effectiveness depends in part on how the system is used "in real-world situations."[146]

One practical consideration relating to filtration effectiveness is whether building owners and managers will replace filters according to the manufacturer's recommendations and with the appropriate efficiency rating. Proper filter replacement requires that occupants and managers understand the recommended practices. In this regard, California took an important step in including a building code requirement that filters be clearly labeled with the filter efficiency rating, to help ensure that consumers select appropriate replacement filters. Agencies can also develop consumer education materials that explain the importance of filtration and key maintenance and operation practices.

A related concern is the cost of replacement filters. High efficiency filters may last a few months or longer, depending on factors such as the type and size of the filter, the amount of time the system is

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[144] Cal. Air Resources Board, Air Resources Board Staff Comments on Proposed 2019 Residential Standards at 2 (6/26/17), available at: https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=17-BSTD-01.

[145] Id.

[146] *See generally* EPA Residential Air Cleaners Technical Summary, supra, at 16. *See also* D. Fugler, ROCIS Initiative, Protecting Homes from Outdoor Pollutants at 12-14 (2014), http://rocis.org/sites/default/files/user-files/ROCIS_HomesFINAL1120.pdf (noting that despite certain challenges and drawbacks, "the installation and usage of proper filters is almost always part of a good air quality solution").

running, and the pollutant load.[147] Though one- or two-inch MERV 13 filters can be purchased for under $20, regular filter replacement may nonetheless be a barrier for low-income households.[148]

Consumer awareness and cost are also factors affecting the amount of time people run their mechanical systems. When mechanical systems are not running, filters are not functioning as designed. California's Energy Code addresses the problem of occupants turning off mechanical ventilation systems by establishing labeling requirements for the system's On/Off switches to help homeowners understand "the importance of continuous operation of the ventilation system for maintaining indoor air quality."[149] Installing forced air systems that operate efficiently at low speeds may help address concerns about increased energy usage and cost from operating the system fan for filtration without heating or cooling.

Chapter Three discusses policies and programs to address cost barriers to maintaining and operating in-duct and portable air filters. That chapter also discusses property maintenance codes, which are a potential regulatory vehicle for ensuring that the ventilation and filtration standards in place for residential construction – including new rental properties – are implemented after the building is occupied.

Integrating Health into Green Building Requirements. Reducing greenhouse gas emissions from buildings is an important climate mitigation strategy, and jurisdictions will likely continue to establish green building standards as building code overlays or as separate requirements for government-funded construction. Although these policies tend to focus primarily on energy and other resource conservation strategies, they present an important opportunity to protect health at the same time.

Most state and local green building requirements for new residential construction currently do not mandate high-efficiency filtration. This may be partly due to fact that the third-party residential green building standards most commonly incorporated into state and local policies do not themselves currently include high-efficiency filtration as a required element. Until those standards are strengthened, policymakers can modify the standards or adopt their own green building criteria to ensure that green residential construction is equipped to provide high-efficiency filtration.

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[147] U.S. EPA, Guide to Air Cleaners in the Home, 2nd ed., at 7 (2018), https://www.epa.gov/sites/production/files/2018-07/documents/guide_to_air_cleaners_in_the_home_2nd_edition.pdf.

[148] A 2019 ELI online search for several filters tested by the California Energy Commission in connection with its 2019 Energy Code update found that the cost of a 1- or 2-inch MERV 13 filter ranged from $9-$19, while the cost of a 1-inch MERV 6 filter ranged from $4-$6. *See also* Cal. Statewide Codes and Standards Enhancement (CASE) Program, Residential Indoor Air Quality – Final Report at 45 (2017), https://efiling.energy.ca.gov/GetDocument.aspx?tn=222202&DocumentContentId=27372 (estimating the incremental cost of replacing MERV 13 filters vs. MERV 6 or 8, to be $18.25 per year); Lawrence Berkeley Nat'l. Lab, Air Cleaning, https://iaqscience.lbl.gov/air-summary (noting "The incremental costs of using higher efficiency filters, e.g., those with a MERV 11 rating, are modest — less than a U.S. dollar per person per month…and the predicted health benefits are substantial.").

[149] Cal. Energy Comm., 2019 Residential Compliance Manual for the 2019 Building Energy Efficiency Standards at 4-89 (2018), available at: https://ww2.energy.ca.gov/2018publications/CEC-400-2018-017/CEC-400-2018-017-CMF.pdf. *See also* Cal. Energy Comm., 2019 Title 24, Pt. 6, Building Energy Efficiency Standards Rulemaking - Final Statement of Reasons at 11 (10/2/18), available at https://ww2.energy.ca.gov/title24/2019standards/rulemaking/documents/.

Part II
Addressing Local PM Sources and New Residential Construction: High-Volume Roads

Emissions from cars and trucks are a complex mix of gases and particle compounds. These "traffic-related air pollutants" include PM2.5, PM10, and especially ultrafine particles. The particles in vehicle emissions include black carbon or soot (common in diesel truck emissions) and semi-volatile compounds such as polycyclic aromatic hydrocarbons. In addition to particulate matter, vehicle emissions contain carbon monoxide, nitrogen oxides, oxides of sulfur, and other volatile and semi-volatile organic compounds.[150] Thus, reducing exposure to traffic-related air pollutants may help reduce the risk of health impacts from a range of air pollutants.

Concentrations of traffic-related air pollutants are frequently elevated next to busy roads, and people who live or work near those roads are more highly exposed to particulate matter and other pollutants.[151] Traffic-related air pollution creates hotspots that are not necessarily reflected in the air quality monitoring carried out by government agencies.[152] Within cities, vehicle pollution "is a major source of local variability in air pollution levels, with the highest concentrations and risk of exposure occurring near roads."[153]

Reducing emissions from motor vehicles is a critical action for improving public health and mitigating climate change. Yet even with increased attention to reducing emissions from vehicles, pollution hotspots will continue to be an important public health challenge for some time. Indeed, California's air agency recently noted that "while vehicle emissions rates have declined because of increasingly stringent emissions standards for cars and trucks, recent studies continue to show high near-roadway concentrations and serious health impacts linked to traffic emissions."[154]

In addition, there are significant non-combustion sources of particulate matter from vehicles – e.g., re-suspended road dust, tire wear, and brake wear – that "will need to be considered more closely in future assessments of the impact of motor vehicles on human health."[155]

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[150] T. Boehmer, et al., "Residential Proximity to Major Highways – United States 2010," *Centers for Disease Control and Prevention Morbidity and Mortality Weekly Report Supplement*, vol. 62, no. 3 at 46 (2013), available at: https://www.cdc.gov/mmwr/pdf/other/su6203.pdf [hereinafter "Boehmer, Residential Proximity to Major Highways"]; Health Effects Institute, Traffic-Related Air Pollution: A Critical Review of the Literature on Emissions, Exposure, and Health Effects at 3-26 (2010), https://www.healtheffects.org/publication/traffic-related-air-pollution-critical-review-literature-emissions-exposure-and-health [hereinafter "HEI Traffic-Related Air Pollution Report"]; Community Assessment of Freeway Exposure and Health (CAFEH), Improving Health in Communities Near Highways: Design Solutions from a Charrette at 12, 52 (2011), available at: https://sites.tufts.edu/cafeh/files/2011/10/CAFEH-Report-Final-2-26-15-hi-res1.pdf.

[151] Though in-vehicle exposures are not discussed in this report, people who spend a considerable amount of time inside vehicles on busy roads (e.g., commercial drivers, commuters, school children) also face potentially high air pollution exposures.

[152] *See, e.g.*, HEI Traffic-Related Air Pollution Report, supra, at 3-10 (noting that concentrations of pollutants on roadways "are high compared with ambient concentrations measured at air-monitoring stations and are highly variable" and that short-term UFP measurements on freeways in California and Minnesota indicate levels that are an order of magnitude higher than results from fixed-site air-monitoring stations).

[153] Boehmer, Residential Proximity to Major Highways, supra, at 46.

[154] CARB 2017 Technical Advisory, supra, at 12.

[155] Id. at 5. *See also* HEI Traffic-Related Air Pollution Report, supra, at 2-40.

In the following sections, this chapter discusses:

- The health effects of near-road exposures and the extent of the problem;
- Best practices for addressing those exposures in new residential construction; and
- Examples of state and local policies incorporating those practices.

Chapter Three describes policies and programs that may help address the problem of *existing* homes located near high-volume roads.

While the focus here is on near-road exposures, the considerations discussed below might also apply to housing and other sensitive uses located near stationary pollution sources, such as ports, airports, distribution centers, and other industrial facilities.[156]

Near-Road Exposures: Nature and Extent of the Problem

Health Effects. Scientific evidence of the negative respiratory, cardiovascular, and other health effects from exposure to traffic-related pollutants is well established. According to a widely-cited 2010 review of the scientific evidence on primary traffic emissions by the Health Effects Institute (HEI), "the evidence is sufficient to support a causal relationship between exposure to traffic-related air pollution and exacerbation of asthma."[157] The HEI panel "also found suggestive evidence of a causal relationship with onset of childhood asthma, non-asthma respiratory symptoms, impaired lung function, total and cardiovascular mortality, and cardiovascular morbidity, although the data are not sufficient to fully support causality."[158]

Diesel particulate matter has long been recognized as a carcinogen by the state of California; it is estimated that "about 70% of known cancer risk related to air toxics" in California is attributable to diesel PM.[159] Others, including the World Health Organization's International Agency for Research on Cancer, have also identified diesel engine exhaust as carcinogenic.[160]

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[156] Numerous studies dating back decades have shown that communities of color and low-income communities are disproportionately located near and affected by pollution from hazardous waste sites, landfills, and other polluting facilities. *See, e.g.,* United Church of Christ, Toxic Wastes and Race in the United States (1987), http://d3n8a8pro7vhmx.cloudfront.net/unitedchurchofchrist/legacy_url/13567/toxwrace87.pdf?1418439935; U.S. EPA, Environmental Equity: Reducing Risk for All Communities (1992).

[157] HEI Traffic-Related Air Pollution Report, supra, at 3-26.

[158] Id. at xv. The results of another study focused on southern California, published in 2016, suggested that "a large burden of preventable CHD [coronary heart disease] mortality is attributable to NRAP [near-roadway air pollution] and is likely to increase even with decreasing exposure by 2035 due to vulnerability of an aging population." The study noted that the "results are likely to be relevant to other large North American cities with dispersed populations and high traffic volumes." R. Ghosh, et al., Near-Roadway Air Pollution and Coronary Heart Disease: Burden of Disease and Potential Impact of a Greenhouse Gas Reduction Strategy in Southern California, *Envtl. Health Persp.*, v. 124, no. 21 at 193 (2016), available at http://dx.doi.org/10.1289/ehp.1408865.

[159] Cal. Air Resources Board, Overview: Diesel Exhaust and Health, https://ww2.arb.ca.gov/resources/overview-diesel-exhaust-and-health. The state recently increased its estimates of cancer risks from exposure to toxic air contaminants, including those emitted by transportation-related sources. *See* CARB 2017 Technical Advisory, supra, at 14.

[160] *See* WHO, Intl. Agency for Research on Cancer, Diesel and Gasoline Engine Exhausts and Some Nitroarenes at 467 (2019), https://monographs.iarc.fr/wp-content/uploads/2018/06/mono105.pdf and Agents Classified by the IARC Monographs, v. 1-125, https://monographs.iarc.fr/wp-content/uploads/2018/06/mono105.pdf . *See also* Cal. Air Resources Board, Summary: Diesel Particulate Matter Health Impacts, https://ww2.arb.ca.gov/resources/summary-diesel-particulate-matter-health-impacts.

Extent of the Problem. Estimates of the number of people affected by near-road exposures vary, depending in part on the distance from the road, the type of road, and the type of buildings included in individual studies. Additionally, the potential exposure zone around roads can vary depending on meteorological and topographical conditions, among other factors.[161]

Researchers at the Centers for Disease Control analyzed data from multiple sources and found that "approximately 4% of the total U.S. population [over 11 million people] lives within 150 meters of a major highway, suggesting increased exposure to traffic-related air pollution and elevated risk for adverse health outcomes." The analysis considered this a "conservative" estimate, because only certain roads (interstates, freeways and expressways) were included; a "relatively small buffer distance" of 150 meters [roughly 500 feet] was used in order to capture people "at highest risk for exposure;" and the estimate did not account for cumulative exposure to traffic from multiple roads.[162] According to the U.S. EPA, "[m]ore than 45 million people in the U.S. live, work or go to school within 300 feet of roadways where high concentrations of air pollution from motor vehicle emissions have been observed."[163]

The percentage of the population exposed to traffic-related air pollution is generally expected to be higher in urban areas because of higher population density, more roads, and higher traffic volume.[164]

The 2010 HEI panel concluded that "[i]n light of the large number of people residing within 300 to 500 m of major roads...the sufficient and suggestive evidence for [the associated] health outcomes indicates that exposures to traffic-related pollution are likely to be of public health concern and deserve public attention."[165]

Disparate Impacts. Near-roadway exposures pose health risks in many communities across the country. However, studies have shown that low-income and minority populations may experience disproportionate exposure to pollution from vehicle emissions. The Health Effects Institute found that "there is sufficient evidence to suggest an inverse association between socioeconomic status and exposure to air pollution from traffic. More recent studies also point to the possibility of other demographic groups being more highly exposed, including nonwhites, ethnic minorities, and children…."[166]

The analysis of near-road exposure data by CDC researchers reached several conclusions about disparate impacts. The analysis found that "[s]ocial and demographic disparities exist with respect to

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[161] Boehmer, Residential Proximity to Major Highways, supra, at 46 (citations omitted). *See also* Community Assessment of Freeway Exposure and Health (CAFEH), Improving Health in Communities Near Highways: Design Solutions from a Charrette at 13-15 (2014), https://sites.tufts.edu/cafeh/files/2011/10/CAFEH-Report-Final-2-26-15-hi-res1.pdf.

[162] Boehmer, Residential Proximity to Major Highways, supra, at 47-48. A study published in 2013 found that in the U.S. there are "59.5 million people living within 500m of roads with greater than 25,000 AADT [annual average daily traffic], an area where residents are potentially exposed to elevated concentrations of many mobile source emissions." G. Rowangould, "A Census of the US Near-Roadway Population: Public Health and Environmental Justice Considerations," 25 Transportation Research Pt. D at 61 (2013), available at https://www.sciencedirect.com/science/article/pii/S1361920913001107?via%3Dihub.

[163] U.S. EPA, Recommendations for Constructing Roadside Vegetation Barriers to Improve Near-Road Air Quality Fact Sheet at 1 (2016), available at https://www.epa.gov/sites/production/files/2016-08/documents/recommendations_for_constructing_roadside_vegetation_barriers_to_improve_near-road_air_quality.pdf.

[164] Boehmer, Residential Proximity to Major Highways, supra, at 48. *See also* HEI Traffic-Related Air Pollution Report, supra, at 3-13 (reviewing a study of two large North American cities suggesting that between 30% and 40% of total urban population lies within" 300 to 500 m from highways and major roads).

[165] HEI Traffic-Related Air Pollution Report, supra, at xv.

[166] Id. at 3-35.

residential proximity to major highways," and that "[l]arger disparities were observed for indicators of minority status than for traditional indicators of socioeconomic status (i.e. poverty and educational attainment)."[167] According to the researchers, "The greatest disparities were observed for race/ethnicity, nativity, and language spoken at home; the populations with the highest estimated percentage living within 150 meters of a major highway included members of racial and ethnic minority communities, foreign-born persons, and persons who speak a language other than English at home…."[168] The analysis also noted that while "[d]isparities by educational attainment and poverty status were less pronounced," a more consistent pattern was observed for poverty status.[169] California-specific studies similarly have shown that poor and minority communities "are more likely to live near busy roadways, and therefore may be more at-risk for the health effects related to exposure to traffic emissions."[170]

Practices for Reducing Near-Road Exposures in New Homes

Setbacks/Buffers. An important strategy to consider in reducing near-road exposures is to avoid siting new homes and other sensitive uses near high-volume roads in the first place.

One issue to address in establishing a setback is the definition of a high-volume road. In its 2017 Technical Advisory on reducing near-road exposures, the California Air Resources Board used the definition of a high-volume roadway established in state law governing the siting of school facilities: those that "on an average day, have traffic in excess of 50,000 vehicles in a rural area and 100,000 vehicles in an urban area."[171] These measurements of traffic have been used by others to define high-volume roads, though CDC researchers note that "several studies have reported adverse health effects associated with residential proximity to roads with average daily traffic volume as low as 10,000 vehicles per day."[172]

The distance from which sensitive uses should be separated from high-volume roads has not been definitively established, partly because individual studies have analyzed data for different types of roads, populations, and other factors. Nevertheless, a number of recent reports by researchers and government agencies suggest that vehicle emissions are a concern within 500 to 1,000 feet (150 to 300 meters) of highways and high-volume roads, although people living at greater distances may be affected as well. A distance of 500 feet (approximately 150 meters) is equivalent to about two city blocks.

- According to the HEI review, "[b]ased on a synthesis of the best available evidence, the Panel identified an exposure zone within a range of up to *300 to 500 meters* from a highway or a major

[167] Boehmer, Residential Proximity to Major Highways, supra, at 46, 48-49 (citations omitted).
[168] Id. at 47 (citation omitted). According to the report, the evidence suggests a "multiplicative interaction" between the higher exposure of minority communities to traffic-related air pollution and the negative impacts from social and behavioral determinants of health such as stress and poor nutrition. Id. at 49.
[169] Id. at 47. For more information on disparate impacts of roadway pollution, see G. Rowangould, "A Census of the US Near-Roadway Population: Public Health and Environmental Justice Considerations," 25 Transportation Research Part D at 61 (2013), available at https://www.sciencedirect.com/science/article/pii/S1361920913001107?via%3Dihub; D. Brugge et al., "Developing Community-Level Policy and Practice to Reduce Traffic-Related Air Pollution Exposure," *Environmental Justice* Vol. 8, No. 3 (2015) at 96-97, available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4939908/.
[170] CARB 2017 Technical Advisory, supra, at 3.
[171] Id. at 2; Ca. Public Resources Code § 21151.8.
[172] Boehmer, Residential Proximity to Major Highways, supra, at 46 (citations omitted). *See generally*, Community Assessment of Freeway Exposure and Health (CAFEH), Improving Health in Communities Near Highways: Design Solutions from a Charrette at 49 (2014), https://sites.tufts.edu/cafeh/files/2011/10/CAFEH-Report-Final-2-26-15-hi-res1.pdf.

road as the area most highly affected by traffic emissions (the range reflects the variable influence of background pollution concentrations, meteorologic conditions, and season)."[173]

- The CDC analysis found that "[t]raffic emissions are highest at the point of release and typically diminish to near background levels within *150 to 300 meters* of the roadway…."[174]

- In its 2005 *Air Quality and Land Use Handbook*, the California Air Resources Board recommended a minimum setback distance of *500 feet* for sensitive uses.[175] In its 2017 Technical Advisory, however, the agency noted that more recent research findings "highlight the possibility that near-roadway pollution exposure had been previously underestimated and that people living as much as *1,000 feet* from freeways were being adversely impacted by poor air quality at night and in the early morning."[176] The agency concluded that "exposure reduction strategies may be needed to protect people that live and spend time in environments that are more than 500 feet from high volume roadways."[177]

*Building and Urban Design Practices for Reducing Near-Roadway Exposures***.** The CARB Technical Advisory identifies a number of evidence-based exposure-reduction strategies that could be employed for new building projects sited near high-volume roadways, as well as for existing buildings already located near those roads. The agency emphasizes the importance of considering site-specific factors, community well-being, equity concerns, and other variables and tradeoffs in determining the best approach for a particular project.[178]

Filtration of indoor air is a core strategy for mitigating near-road exposures to particulate matter. As discussed earlier, high-efficiency in-duct and portable filtration can be very effective at removing small particles from the air. Filtration is generally not as effective for the gaseous pollutants emitted from vehicles. CARB notes that "filtration technologies for gaseous pollutants can be useful in some circumstances but generally are not as effective as particle filters."[179] Thus, filtration can effectively reduce PM exposure, but may not address other vehicle pollutants to which residents may be exposed.

[173] HEI Traffic-Related Air Pollution Report, supra, at xv, 7-5.
[174] Boehmer, Residential Proximity to Major Highways, supra, at 46 (citations omitted).
[175] Cal. Air Resources Board, Air Quality and Land Use Handbook: A Community Health Perspective at 4 (2005), available at: https://ww3.arb.ca.gov/ch/handbook.pdf. This setback recommendation applies to separating sensitive uses from freeways, urban roads with 100,000 vehicles/day, or rural roads with 50,000 vehicles/day.
[176] CARB 2017 Technical Advisory, supra, at 12 (citations omitted).
[177] Id. at 14.
[178] Id. at 40.
[179] Id. at 36. *See generally* EPA Residential Air Cleaners Technical Summary, supra, at 32-33.

Strategies to Reduce Air Pollution Exposure in Buildings Near Roadways: *Excerpts*: California Air Resources Board 2017 Technical Advisory	
Strategy	**Exposure Reduction Benefit**
High-efficiency Filtration	"High efficiency filtration with mechanical ventilation or portable high efficiency air cleaners, can be highly effective for reducing indoor pollution concentrations."[180]
Solid barriers (e.g., sound walls) installed along highways	Helps "reduce near-road downwind concentrations by increasing vertical dispersion of pollutants emitted by vehicles."[181]
Vegetation	Has the "potential to alter pollutant transport and dispersion," though effectiveness depends on the specific location, type, and design of the vegetation and on local conditions (e.g., wind).[182]
Urban Streetscape Design	Better pollutant dispersion and air quality in "street corridors characterized by buildings with varying shapes and heights...and spaces that encourage air flow (e.g., parks)." In addition, wider sidewalks, bike paths, and transit lanes can both facilitate air flow and encourage alternative transportation.[183]

The Technical Advisory also notes several strategies that did not meet the agency's criteria for inclusion based on the scientific, peer-reviewed literature in 2016, but have nonetheless demonstrated some potential as exposure reduction measures. These strategies include: locating air intakes away from sources of pollution; installing green (vegetation) walls and roofs on buildings to help remove pollutants from the air; and increasing building height to increase vertical distance from a roadway.[184] Other studies and reports have recommended practices such as double glazing windows, placing windows and balconies away from the road, and sealing windows.[185]

[180] CARB 2017 Technical Advisory, supra, at 36.
[181] Id. at 30.
[182] Id. at 32-35. *See also* EPA, Recommendations for Constructing Roadside Vegetation Barriers to Improve Near-Road Air Quality (2016) (summarizing research on best practices for building roadside vegetative barriers to improve air quality), https://www.epa.gov/air-research/recommendations-constructing-roadside-vegetation-barriers-improve-near-road-air-quality; S. Paulsen, et al., Effectiveness of Sound Wall-Vegetation Combination Barriers as Near-Roadway Pollutant Mitigation Strategies at 140 (2017) (CARB-funded study finding that mitigation of PM is "more effective with a combination barrier of soundwall and vegetation than either one alone"), https://ww3.arb.ca.gov/research/single-project.php?row_id=65195.
[183] CARB 2017 Technical Advisory, supra, at 26. Other researchers have recommended avoiding or mitigating "urban canyons," where tall buildings are located on either side of a narrow road, thus impeding dispersal of air pollutants. *See, e.g.*, D. Brugge et al., Developing Community-Level Policy and Practice to Reduce Traffic-Related Air Pollution Exposure, *Environmental Justice,* vol. 8, no. 3 at 98 (2015); Stephanie Bell et al., Avoiding the TRAP: Traffic-Related Air Pollution in Toronto and Options for Reducing Exposure at 20 (2017), available at: https://www.toronto.ca/legdocs/mmis/2017/hl/bgrd/backgroundfile-108070.pdf.
[184] CARB 2017 Technical Advisory, supra, at 46, 51.
[185] *See, e.g.*, County of Los Angeles Dept. of Public Health, Public Health Recommendations to Minimize the Health Effects of Air Pollution Associated With Development Near Freeways and High-Volume Roads at 3-4 (March 2019), available at:

Policies for Reducing Near-Road Exposures in New Homes

This section highlights policies aimed at reducing indoor exposure to vehicle-related pollutants. Many of the examples provided here are from California, where the problem is perhaps most acute and has accordingly received much attention. Nonetheless, exposure to pollutants from high-volume roads is a problem in many parts of the country, particularly in urban areas.[186]

The policies described below are provided as potential models that other jurisdictions might consider in identifying strategies to protect impacted communities. The examples include both state and local policies, as local governments play a central role in ensuring that land use decisions protect sensitive populations from near-road exposures. The types of policy options available to local jurisdictions depend in part on the authorities and framework for local policymaking as established in state law.

This section discusses policies relating to new residential construction only, while Chapter Three discusses how policies such as housing maintenance codes can potentially address exposures in existing buildings. Chapter Three also provides examples of how government funding programs can help mitigate near-roadway exposures in existing homes by financing upgrades to existing mechanical systems or providing portable air cleaners with high-efficiency filters.

Building Codes. As discussed in the previous section, reducing infiltration, providing adequate ventilation and filtration, and locating air intakes away from polluting sources are building code elements that can help reduce exposure to outdoor PM. In the absence of a state building code incorporating these elements, local jurisdictions with potential for future residential and other development near major roads can strengthen their building codes to include high-efficiency filtration and other best practices for reducing exposure. These requirements could be established jurisdiction-wide or more narrowly – e.g., for specified types of buildings located within a stated distance of a major roadway.

The city of **Los Angeles** took this step in 2016, with the enactment of Municipal Ordinance No. 184245. The ordinance amended the city building code to require enhanced filtration (MERV 13) in mechanically-ventilated residential buildings located within 1,000 feet of a freeway.[187] (For more on the ordinance and other Los Angeles policies, see the Los Angeles profile at the end of this section.)

Public Health/Environmental Protection Policies. States have adopted a variety of environmental and public health laws designed to identify and mitigate the impacts of new development projects. Around 20 states have laws that require environmental impact review for a broad range of projects, similar to the National Environmental Policy Act (NEPA) at the federal level.[188]

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http://www.publichealth.lacounty.gov/place/docs/DPH%20Recommendations%20to%20Minimize%20Health%20Effects%20of%20Air%20Pollution%20Near%20Freeways_Final_March%202019.pdf.

[186] *See* HEI Traffic-Related Air Pollution Report, supra, at 3-10; Boehmer, Residential Proximity to Major Highways, supra, at 47-48; G. Rowangould, "A Census of the US Near-Roadway Population: Public Health and Environmental Justice Considerations," 25 Transportation Research Part D at 61 (2013), available at https://www.sciencedirect.com/science/article/pii/S1361920913001107?via%3Dihub.

[187] Los Angeles Mun. Ord. No. 184245, available at: https://planning.lacity.org/ordinances/docs/cugu/184245.pdf.

[188] *See generally*, U.S. Council on Envtl. Quality, States and Local Jurisdictions with NEPA-like Environmental Planning Requirements, https://ceq.doe.gov/laws-regulations/states.html.

These state "little NEPA" laws could potentially be used to ensure consideration and mitigation of the health impacts from siting residential projects near high-volume roadways.[189]

States may also have policies that apply to the siting of specific facilities – e.g., the siting of certain types of polluting facilities near sensitive uses, or the siting of sensitive uses near existing environmental hazards. As described at the end of this chapter, there are many state laws and regulations restricting the siting of schools near hazards such as roadways. State policies directly restricting the siting of *residential* developments are less common.

One local jurisdiction that has used its public health code to address the siting of new residential developments near roadways is **San Francisco**. In 2008, the city adopted Health Code Article 38, in order to "maintain and increase the stock of infill housing and other sensitive use development in the City while reducing the risk to human health from air pollutants…."[190] The law directs the city to create (and update) an Air Pollutant Exposure Zone map and requires residential and other sensitive use projects located in the Zone to provide filtration equivalent to MERV 13.[191] This requirement for high-efficiency filtration, which applies to new construction, major alterations, and permitted changes of use, was enacted several years before the state's new MERV 13 requirement was adopted.

Article 38 requires the Air Pollutant Exposure Zone map to include all locations within the city estimated to exceed a stated PM2.5 concentration or stated excess cancer risk from air pollutions, and to include all sites located within 500 feet of a freeway, even if not otherwise captured by the modeling estimates.[192]

In addition to requiring filtration equivalent to MERV 13, the law requires that air intakes for the HVAC system be located away from air pollution sources.[193] Covered projects must obtain the Health Department's approval of an Enhanced Ventilation Proposal meeting the law's requirements, and the city Department of Building Inspection may not issue a permit for the project's ventilation system unless it is in compliance with the approved proposal.[194]

Notably, the law also requires proper *maintenance* of the enhanced filtration systems, "following standard practices, and as specified by the manufacturer." Failure to do so is subject to "enforcement and possible penalties" under the nuisance or other provisions of the health code. Projects must also provide information about the proper use of the enhanced filtration system in accordance with rules developed under the law.[195]

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[189] *See, e.g.,* City of Los Angeles, Il Villaggio Toscano Project Final Environmental Impact Report at III-39—40 (ENV-2004-6000-EIR) (2013), https://planning.lacity.org/eir/VillaggioToscano/FEIR/index.html (discussing high-efficiency filtration and setbacks to mitigate near-road exposures for proposed residential construction project).

[190] San Francisco Health Code § 3803.

[191] Id. § 3807. Other sensitive uses include: state-licensed adult day care centers, child care centers and homes, community treatment centers; schools and educational occupancies; and certain health care facilities. Id. § 3904; San Francisco Ord. No. 224-14.

[192] San Francisco Health Code § 3806. Locations are subject to the law if the estimated cumulative PM2.5 concentration is greater than 10 $\mu g/m^3$, or if the estimated cumulative excess lifetime cancer risk from air pollutants is greater than 100 in a million. The law sets lower threshold levels for areas identified by the Health Department as "Health Vulnerable Locations" based on data such as respiratory and cardiovascular-related hospitalizations or non-accident mortality. Id. §§ 3804, 3806.

[193] Id. § 3809.

[194] Id. § 3807.

[195] Id. § 3810.

Land Use Regulation. State law establishes the framework within which local governments develop and implement land use policies governing new residential, commercial, and industrial development. While the specific regulatory tools vary from state to state, localities typically are delegated broad authority to control land use and to regulate development in furtherance of their general police powers for protecting public health and welfare. Though a detailed discussion of local land use authority is beyond the scope of this report, the following examples illustrate how some local jurisdictions have used land use policies to address public health concerns arising from the siting of residential buildings near high-volume roads.

The Comprehensive Plan. The Comprehensive Plan, also known as the Master Plan or General Plan, "creates the blueprint for the future development and preservation of a community….[and] guides not only the physical and economic development of the municipality, but also accommodates social, environmental and regional concerns."[196] Thus, plans typically address a wide range of issues in establishing the policies and principles that in turn guide the adoption of land use regulations and land use decisions. Following are examples of localities that have used their comprehensive plans to address the siting of sensitive uses near high-volume roads and other polluting sources.

In **Fulton County, Georgia,** the Comprehensive Plan recommends adoption of local zoning policies requiring that "new sensitive land uses … are sited beyond 500 feet from the center line of a freeway" or that they include "feasible measures such as separation/setbacks, landscaping, barriers, ventilation systems, air filters/cleaners, and/or other effective measures to minimize potential impacts from air pollution."[197]

In California, state law requires cities and counties to adopt comprehensive General Plans, to which their zoning ordinances must then conform. Plans must include seven mandatory elements set out by statute, but local jurisdictions are free to include additional elements or topics.[198] State legislation enacted in 2016 introduced a new requirement that cities and counties with "disadvantaged communities" incorporate environmental justice into their general plans, whether as a separate element or as goals, policies, and objectives integrated in the other elements.[199] The law explains that the environmental justice element (or related goals and policies) should identify policies that reduce pollution exposure, including through the improvement of air quality.[200]

[196] J. Nolon and P. Salkin, Land Use at 43 (West, 2006).

[197] Fulton County Dept. of Planning and Community Services, 2035 Fulton County Comprehensive Plan 2016-2035 at 96 (2016), available at: http://ww2.co.fulton.ga.us/fcpcsd-comprehensive-planning/2035-comp-plan.

[198] Ca. Govt. Code § 65300-03. The mandatory elements are: land use; circulation; housing; conservation; open space; noise; and safety. Id. § 65302(a)-(g).

[199] Ca. Senate Bill No. 1000; Ca. Gov. Code 65302(h) (defining "disadvantaged communities" as areas identified by California EPA pursuant to state law or a "low-income area that is disproportionately affected by environmental pollution and other hazards that can lead to negative health effects, exposure, or environmental degradation").

[200] Id. According to the state General Plan Guidelines, "Air quality considerations are also required for cities and counties who are required to include an environmental justice element in their general plans, and are optional elements in other areas…" Cal. Governor's Office of Planning and Research, General Plan Guidelines at 15 (2017), available at: http://opr.ca.gov/planning/general-plan/.

Following are two examples of California municipalities that have incorporated into their general plans policies aimed at mitigating near-roadway exposures.[201]

The city of **Hayward, California** has adopted a General Plan that addresses local pollution sources, such as major roads, as part of its Environmental Health goal. The Plan directs the city to: "avoid locating new sensitive uses such as schools, childcare centers, and senior housing, to the extent feasible, in proximity to sources of pollution….Where such uses are located in proximity to sources of air pollution…the City shall encourage building design, construction safeguards, and technological techniques to mitigate the negative impacts of hazardous materials and/or air pollution on indoor air quality." An accompanying graphic notes that "[f]reeways and major arterial streets are major sources of air pollution in Hayward."[202]

The Plan's Natural Resource goal includes similar policies: (1) "The City shall minimize exposure of sensitive receptors to toxic air contaminants (TAC), fine particulate matter (PM2.5), and odors to the extent possible, and consider distance, orientation, and wind direction when siting sensitive land uses in proximity to TAC- and PM2.5-emitting sources and odor sources in order to minimize health risk;" and (2) "The City shall require development projects to implement all applicable best management practices that will reduce exposure of new sensitive receptors (e.g., hospitals, schools, daycare facilities, elderly housing and convalescent facilities) to odors, toxic air contaminants …and fine particulate matter…." [203]

The city of **San Jose, California,** has adopted a General Plan that establishes the following policies as part of its Toxic Air Contaminants goal: (1) "Require new residential development projects and projects categorized as sensitive receptors to incorporate effective mitigation into project designs or be located an adequate distance from sources of toxic air contaminants (TACs) to avoid significant risks to health and safety;" (2) "Encourage the installation of appropriate air filtration at existing schools, residences, and other sensitive receptor uses adversely affected by pollution sources;" and (3) "Encourage the use of pollution absorbing trees and vegetation in buffer areas between substantial sources of TACs and sensitive land uses."[204]

Zoning and Related Regulations. Comprehensive Plans create the framework within which local governments adopt zoning ordinances, which in turn "contain standards that dictate what, where and how building occurs on the land."[205] Zoning ordinances determine the allowed and prohibited uses within each defined zone and may address density, setback requirements, design standards, and other features of development within a zone.[206] They may also establish conditional uses – uses that are allowed, but only when they meet specified conditions. Closely related to zoning ordinances are

[201] Other examples include the California cities of Murrietta, Chula Vista, National City, and Southgate, as well as Ventura County. Cal. Governor's Office of Planning and Research, General Plan Guidelines at 194 (2017), available at: http://opr.ca.gov/planning/general-plan/.

[202] City of Hayward, Hayward 2040 General Plan at 3-173 (2014), available at: https://www.hayward-ca.gov/your-government/documents/planning-documents/general-plan.

[203] Id. at 3-125.

[204] City of San Jose, Envision San Jose 2040 General Plan at 3-13--3-14 (rev. 2018), https://www.sanjoseca.gov/home/showdocument?id=22359. Other policies in the San Jose Plan relate to the siting of polluting sources near existing homes – e.g., requiring "completion of air quality modeling for sensitive land uses such as freeways," and reviewing projects generating "significant heavy duty truck traffic" to designate truck routes that minimize exposure of sensitive receptors to particulate matter and TACs.

[205] J. Nolon and P. Salkin, Land Use at 43 (West, 2006).

[206] *See* J. McElfish, Nature-Friendly Ordinances at 38 (Envtl. Law Inst., 2004).

subdivision regulations and land development ordinances that control the creation of building lots and that may include design criteria for reviewing proposed developments.[207]

Using these tools, local governments could consider re-zoning areas near major roadways and/or other polluting sources to exclude residential and other sensitive uses. Alternatively, they could establish set-back distances or other design/performance standards as special conditions of approval for certain new projects to reduce near-road exposures. Following are examples of two California cities that have established such requirements through their planning and zoning ordinances.

The City Council in **Oakland, California** has addressed near-road exposures in its Standard Conditions of Approval (SCA), which are designed to achieve consistency among projects that receive discretionary planning-related approvals. Prior to the state's adoption of a MERV 13 requirement, the city revised is SCA to include measures applicable to all new dwelling units, schools, daycare centers, parks, nursing homes, or medical facilities that are located within 1,000 feet of a freeway or road with at least 10,000 vehicles per day. Applicants for these projects must "incorporate appropriate measures into the project design in order to reduce the potential health risk due to exposure to toxic air contaminants" and submit those measures to the city for review and approval prior to the issuance of permits. Specifically, the applicant may either (1) hire a qualified consultant to prepare a Health Risk Assessment and include any identified measures to reduce the health risk to acceptable levels; or (2) incorporate the measures listed in the SCA. These measures include:

- Installing air filter devices rated MERV 13 or higher (MERV 16 for projects located in the West Oakland Specific Plan area) and providing building managers/operators an operation and maintenance plan that includes a maintenance and replacement schedule for the filter;
- Locating sensitive receptors as far from pollution sources as possible; and
- Planting trees or vegetation between sensitive receptors and pollution sources.

The Standard Conditions of Approval also require maintenance, repair, and/or replacement of the installed health risk reduction measures, including the HVAC system.[208]

The city of **Irvine, California** has adopted a special set of zoning ordinances that apply to the Irvine Business Complex (IBC) Residential and Mixed-Use Overlay District, which are "intended to provide for the orderly transition of certain portions of the IBC from exclusively industrial and/or office areas into pedestrian-oriented districts that accommodate a mixture of retail, office, and residential units."[209] Applicants for new residential developments in the IBC that are within 500 feet of Interstate 405 are required to install high-efficiency filters (minimum MERV 14) in residential ventilation systems.

The ordinance also addresses long-term maintenance and replacement of the filters in the individual units. The owner or property manager is required to maintain and replace MERV 14 filters in accordance with the manufacturer's recommendations, and the homeowner's association must incorporate requirements for long-term maintenance in the covenant conditions and restrictions and inform

[207] *See* J. Nolon and P. Salkin, Land Use at 107-108 (West, 2006).
[208] City of Oakland, Standard Conditions of Approval (Item 24, Exposure to Air Pollution (Toxic Air Contaminants)) at 12-13 (rev. 2018). The restrictions also apply to projects located near certain rail lines, distribution centers, rail/truck yards, ferry terminals, airports, stationary pollutant sources requiring an air permit, gas stations, and dry cleaners using PERC. The development standards were first adopted in 2008 (Ord. No. 12899); among other things, subsequent revisions increased the threshold distance from 500 feet to 1,000 feet and included proximity to roadways with lower traffic levels.
[209] City of Irvine Zoning Code § 5-8-1.

homeowners of their responsibility to maintain the MERV 14 filter. The ordinance also requires sales professionals, owners, property managers, and homeowner's associations to inform residents and potential residents of the increased risk of exposure to diesel particles when windows are open.[210]

Agency Guidance. Short of establishing requirements, localities can make formal recommendations to encourage consideration of near-road exposures when siting sensitive uses.

The 2005 California Air Resources Board recommendation for siting sensitive land uses such as homes, schools, daycare centers, playgrounds, and medical facilities stated: "Avoid siting new sensitive land uses within 500 feet of a freeway, urban roads with 100,000 vehicles/day, or rural roads with 50,000 vehicles/day."[211] CARB's 2017 Technical Advisory echoed this recommendation, but also found that strategies may be needed to protect people living at greater distances.[212]

A number of regional air districts in California have issued their own recommendations to guide local action. For example, the **Santa Barbara Air Pollution Control District** issued a 2017 guidance recommending that "residences, schools, day care centers, playgrounds, and medical facilities should not be sited within 500 feet of Highway 101" and outlining strategies for incorporating filtration and other measures into development projects.[213] In 2016, the **Bay Area Air Quality Management District** developed a guidebook for local jurisdictions in the Bay Area that discusses recommended best practices for reducing exposure to traffic-related air pollutants and other local air pollution sources for incorporation into "city or county General Plans, neighborhood or specific plans, land use development ordinances, or into single projects."[214] Guidance and recommendations for setbacks issued by the Los Angeles County Department of Public Health are described in the following profile.

[210] Id. § 5-8-4 (4e). Prospective tenants or residents also must be notified of the potential health risk from Interstate 405.
[211] Cal. Air Resources Board, Air Quality and Land Use Handbook: A Community Health Perspective at Table 1-1 (2005), https://ww3.arb.ca.gov/ch/handbook.pdf.
[212] CARB 2017 Technical Advisory, supra, at 10.
[213] Santa Barbara Air Pollution Control District, Development near Busy Roadways: Guidance for Santa Barbara County (2017), available at: https://www.ourair.org/wp-content/uploads/sbcapcd-near-roadway-June2017-final.pdf.
[214] Bay Area Air Quality Mgmt. District, Planning Healthy Places: A Guidebook for Addressing Local Sources of Air Pollutants in Community Planning at iii (2016), available at: http://www.baaqmd.gov/plans-and-climate/planning-healthy-places.

Developing Local Strategies for Reducing Near-Road Exposures: Strengthening Building, Health, and Land Use Policies in Los Angeles

Los Angeles is well known for its freeways that run through the city. As of April 2018, city officials estimated that around 500,000 people lived within 1,000 feet of a freeway, and found that "[o]nly a marginal number of recently constructed buildings have any design features or equipment to counter freeway pollution."[215] To address the problem, the City and County of Los Angeles have developed a variety of policies, guidance documents, and reports.

Building Code Changes – Air Filtration Requirements. In 2016, a few years before the state adopted its MERV13 filtration requirement for new construction, the city enacted an ordinance to "address cumulative health impacts resulting from incompatible land use patterns within the City of Los Angeles." The ordinance amended the city's building code to require that "mechanically ventilated buildings within 1,000 feet of a freeway provide regularly occupied areas of the building with air filtration media for outside and return air that provides a Minimum Efficiency Reporting Value (MERV) of 13. Filters shall be installed prior to occupancy, and recommendations for maintenance with filters of the same value shall be included in the operation and maintenance manual."[216] To aid in implementation and enforcement, the city building department has included a description of the requirement in the forms used by the agency when reviewing projects.[217]

Notably, the city's Housing and Community Investment Department (HCID) will be incorporating the filtration requirement into its routine housing code inspection program to help ensure that buildings are *maintaining* the required MERV 13 filtration. In July 2018, the HCID issued an Inter-Departmental Memorandum establishing that the agency's code enforcement unit would identify any multifamily rental properties subject to the new filtration requirements and that inspectors would verify compliance in those properties as part of the routine Systematic Code Enforcement Program inspections that occur every four years.[218]

Land Use Regulation – Policy, Guidance, and Zoning Changes. In 2015, the city published a health and wellness element in its General Plan, which included a policy statement to guide decisionmakers: "Reduce negative health impacts for people who live and work in close proximity to industrial uses and freeways through health promoting land uses and design solutions." The plan stated that new or rehabilitated buildings "in close proximity to industrial uses and freeways should incorporate mitigations that are known to protect health and wellbeing; such as air filtration systems,

[215] L.A. Dept. of City Planning, Freeway Adjacency/Air Quality at 3 (Apr. 2018), available at: http://planning.lacity.org/StaffRpt/InitialRpts/CF%2017-0309.PDF.
[216] L.A. Mun. Code §99.04.504; L.A. Mun. Ord. 184,245, https://planning.lacity.org/ordinances/docs/cugu/184245.pdf.
[217] L.A. Dept. of Building Safety, Green Building Code Plan Check Notes (2017) and Correction Sheet for Newly Constructed Residential Buildings (2017), https://www.ladbs.org/forms-publications/forms/green-building/green-building-for-2017-codes.
[218] L.A. HCID., Inter-Departmental Memorandum – Interior HVAC Filtration under CUGU (7/9/18), available at: http://clkrep.lacity.org/onlinedocs/2017/17-0309_rpt_PLAN_07-26-2018.pdf (App. A). *See also* L.A. HCID, Systematic Code Enforcement Program (SCEP) inspections, https://hcidla.lacity.org/Inspections-and-Fees.

landscaping and vegetation known to absorb pollutants, double-paned windows, and similar strategies."[219]

A 2016 city ordinance created a Supplemental Use District, the "Clean Up Green Up" District, to further reduce cumulative impacts from a range of polluting sources. Among other things, the ordinance establishes setbacks for certain industrial uses and requires new public buildings within 1,000 feet of a freeway to notify the public of potential health risks from ultrafine particles and other pollutants.[220]

In April 2018, the Department of City Planning (DCP) produced a report on freeway adjacency and air quality to provide "an overview of the air quality challenges facing Los Angeles…the various strategies that are currently being explored to reduce mobile emissions sources, and potential additional strategies to limit exposure to pollutant matter and noxious gases." In addition to reducing mobile emissions, the report identified three "effective strategies" to reduce exposures: (1) use of high-efficiency filters (including proper maintenance); (2) limitations on siting "sensitive uses" adjacent to freeways; and (3) building design/location and use of "landscaping screens."[221]

In September 2018, DCP updated Zoning Information Bulletin No. 2427, providing an Advisory Notice to certain discretionary project applications located within 1,000 feet of a freeway. Such applicants are directed to DCP's Urban Design Studio to review potential design features that may reduce air pollution exposure. These design features focus on: locating occupied open space areas (play areas, courtyards, patios, balconies, etc.) as far from the freeway sources as possible; prioritizing the location of non-habitable uses such as parking structures nearest the freeway; and screening the project site with substantial vegetation and/or a wall barrier.[222] Similar design features were also included as best practices in the Citywide Design Guidelines adopted by the Planning Commission in October 2019.[223]

Public Health – Guidance. In March 2019, the Los Angeles County Department of Public Health issued updated recommendations to minimize the health effects of near-road exposures. While acknowledging the benefits of infill development and the need for affordable housing, the guidance recommends that "due to the potential health risks, particularly for low income populations already experiencing significant health inequities, sensitive land uses [including housing and schools] should be located at least 500 feet from freeways." The guidance adds that "consideration should be given to extending this minimum buffer zone based on site-specific conditions, given the fact that unsafe traffic emissions may be present at greater distances." The guidance also includes "best practice mitigation measures" for the building (e.g., MERV 13 filter installation/replacement, outdoor air intake location; double-glazing windows), the site (sound walls, vegetation barriers), and transportation.[224]

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[219] L.A. Dept. of City Planning, Plan for a Healthy Los Angeles at 89 (2015), https://planning.lacity.org/odocument/7f065983-ff10-4e76-81e5-e166c9b78a9e/Plan_for_a_Healthy_Los_Angeles.pdf.

[220] The ordinance focused on three areas (Boyle Heights, Pacoima/Sun Valley, and Wilmington) "to reduce cumulative health impacts resulting from land uses including….concentrated industrial land use, on-road vehicle travel, and…transportation corridors, which are incompatible with…homes, schools and other sensitive uses." L.A. Mun. Ord. No. 184246, §§13.18(A),(F)(4).

[221] L.A. Dept. of City Planning, Freeway Adjacency/Air Quality at 4 (2018), available at: http://planning.lacity.org/StaffRpt/InitialRpts/CF%2017-0309.PDF.

[222] L.A. Dept. of City Planning, Zoning Information No. 2427: Freeway Adjacent Advisory Notice at 1-2 (Sept. 2018), available at: http://zimas.lacity.org/documents/zoneinfo/ZI2427.pdf; ELI Email communications with L.A. Dept. of City Planning (Dec. 2019).

[223] L.A. Planning Commission, Citywide Design Guidelines at 28 (2019), https://planning.lacity.org/odocument/f6608be7-d5fe-4187-bea6-20618eec5049/Citywide_Design_Guidelines.pdf.

[224] L.A. County Dept. of Public Health, Public Health Recommendations to Minimize the Health Effects of Air Pollution Associated with Development Near Freeways and High-Volume Roads at 1-4 (rev. Mar. 2019).

Discussion

Policymakers and government agencies can help prevent near-road exposures by establishing requirements for new residential development through their building codes, land use planning policies, or public health laws. Even as we work toward a future of dramatically reduced emissions from vehicles, exposure to these pollutants is a problem now and will be for some time. A 2019 analysis of data from Boston University's Database of Road Transportation Emissions found that in nearly all of the 100 U.S. metropolitan areas with the highest vehicle emissions, "total emissions have increased since 1990."[225] Studies estimate that tens of millions of people in communities around the country are living close enough to major roadways to be at risk of increased exposure to particulate matter and other vehicle-related air pollutants.

The most health-protective strategy to address near-road exposures is to locate homes, schools and other sensitive uses away from major roadways. While studies discuss various setback distances, existing policies and guidance recommend a minimum 500-foot setback for residential and other sensitive uses.

Establishing setbacks from roadways is complicated by other important public policy goals. Development of affordable housing is a critical need in most cities, and options for siting such projects may be limited. Smart growth, including infill development close to sustainable transit options, is also an important goal – not only for reducing vehicle emissions overall, but for addressing a wide range of other health and environmental impacts related to urban sprawl.

In its 2017 guidance on the subject of near-road exposures, the California Air Resources Board recognized the complexity of this issue, noting "it is important that planners and decisionmakers consider a variety of variables and tradeoffs when deciding which exposure reduction strategies make the most sense." [226] The agency emphasized the importance of weighing site-specific factors, community well-being, safety, and equity concerns, and other factors. In weighing these factors, it is especially important to engage a broad range of stakeholders, including the affected communities.

Establishing setbacks or buffers from heavily traveled roads will not be feasible or desirable in many cases. Where residential buildings are constructed or renovated within a specified distance of roadways, local policies can require high-efficiency filtration and other site-specific measures to reduce indoor exposures. Though they may not protect against all traffic-related pollutants, these strategies can significantly reduce exposure to PM. It is also important for policies to address building operations and maintenance, to help ensure that the design and construction strategies are effective in practice. Chapter Three takes up this issue, along with other considerations for reducing exposures in existing homes.

[225] N. Popovich and D. Lu, "The Most Detailed Map of Auto Emissions in America," *The New York Times* (Oct. 20, 2019), https://www.nytimes.com/interactive/2019/10/10/climate/driving-emissions-map.html.
[226] CARB 2017 Technical Advisory, supra, at 40.

State Policies Restricting the Siting of New Schools Near Roadways

A nationwide study estimated that 3.2 million students attend schools located within 100 meters of a major roadway, and another 3.2 million attend schools within 100-250 meters of a major roadway. Schools serving predominantly low-income students and those serving African-American students were more likely to be located near roads. S. Kingsley, et al., *Proximity of US Schools to Major Roadways: a Nationwide Assessment* (2014).

In 2008, Congress directed EPA to publish model school siting guidelines that take into account "the special vulnerabilities of children to hazardous substances or pollution exposures…." Pub. Law 110-140. EPA's 2011 *School Siting Guidelines* cover a range of environmental issues, including nearby highways, for consideration in local school siting. In 2015, EPA published *Best Practices for Reducing Near-Road Pollution Exposure at Schools,* addressing the siting of new schools near roads, as well as actions to reduce exposures at existing schools.

While there has been relatively little state policy activity around the siting of housing near environmental hazards, a 2006 survey of state policies found that more than half of all states had policies regulating the siting of schools in relation to environmental hazards. Some policies require investigation of potential sites for environmental hazards, while others discourage, restrict, or prohibit siting a school near specified environmental hazards. *See* Rhode Island Legal Services, Not in my Schoolyard: Avoiding Environmental Hazards at School through Improved School Site Selection Policies.

These state policies vary in the specific environmental hazards they mention. **California**'s education law addresses near-road exposures most directly by prohibiting school districts from approving the acquisition of a school site within "500 feet of the edge of the closest traffic lane of a freeway or other busy traffic corridor," *unless* the governing boards determines through analysis that the air quality at the site will not pose significant health risks to students. Ca. Educ. Code § 17213(c) (2019); *see also*, Ca. Pub. Resources Code § 21151.8(a)(3)(B)(iii).

West Virginia restricts siting schools near major roads, though it does not mention air pollution or require a specific setback distance: "For the safety of students, the school site shall be located away from hazards…such as…railroads, arterial highways, heavily traveled streets, traffic, and congestion." W. Va. Code of State Rules § 126-172-1 (202.06). Similarly, **New Mexico**'s education law requires prior written approval of the state Public Education Department before a local school board may construct any public school within 400 feet of any "main artery of travel." N.M. Stat. Ann. § 22-20-2.

A number of other state policies require consideration of "traffic" hazards or "air pollution" more generally, and might provide an opportunity to consider traffic-related air pollution. In **Kentucky**, e.g., prior to contracting for a school site, school districts must certify that there are no health or environmental hazards, including "airborne particulates." 702 Ky. Admin. Regs. 4:050.

For a review of state policies addressing environmental hazards in the siting of *child care facilities, s*ee Envtl. Law Inst., Addressing Environmental Site Hazards at Child Care Facilities: A Review of State Policy Strategies (2018), https://www.eli.org/research-report/addressing-environmental-site-hazards-child-care-facilities-review-state-policy-strategies.

Chapter Three

Reducing Exposure to Outdoor Particulate Matter in Existing Homes

Stronger policies governing new construction and rehabilitation are critical for developing healthier, more resilient housing. But newly constructed and renovated homes represent only a fraction of the U.S. housing stock. The median age of owner-occupied homes is 37 years, while the median age of rental units is slightly older, at 42 years.[227] Many existing homes in the United States were constructed without the features that can provide effective protection against outdoor particle pollution. Policies and programs are needed to help protect people where they are living now and in the decades to come.

There is not a one-size-fits-all approach to reducing indoor exposure to outdoor PM in existing homes. The choice of strategies is influenced by many variables, including the nature of the outdoor PM source, the location and features of the building itself, and whether occupants rent or own the home. Jurisdictions may be able to modify existing regulatory and financial assistance mechanisms to address the problem; in some cases, new laws or regulations may be needed.

State, tribal, and local policies and programs can be crafted to reduce indoor PM exposures broadly or targeted to a particular source of concern, such as roadway pollution, wood burning, or wildfires. Regardless of the scope of the initiative, a central consideration is ensuring that the benefits reach those who are most vulnerable to the health risks from PM exposure. This includes people who are at greater risk due to their age or medical status and who are not in a position to take recommended actions for reducing their exposure.

Part I of this chapter describes technical practices – such as upgrading filters and adding portable air cleaners – for reducing outdoor PM in existing homes. It also discusses filtration and other approaches to addressing extreme PM events; here the report focuses on wildfires, given the rising incidence of large wildfires that can increase air pollution and respiratory impacts over a large area.[228]

Part II discusses policies that offer a potential regulatory vehicle for reducing indoor exposures, notably housing and property maintenance codes.

Part III reviews selected financial assistance programs that could be used to provide material assistance to those who are most vulnerable to the effects of PM exposure, highlighting weatherization and other housing assistance programs, as well as programs targeting wildfire smoke exposure.

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[227] Harvard Univ. Joint Center for Housing Studies, America's Rental Housing: Expanding Options for Diverse and Growing Demand at 15 (2017), https://www.jchs.harvard.edu/sites/default/files/americas_rental_housing_2015_web.pdf.

[228] *See* N. Boegelsack, et al., A Critical Examination of the Relationship between Wildfires and Climate Change with Consideration of the Human Impact, Journal of Envtl. Protection (2018), https://file.scirp.org/pdf/JEP_2018050715591048.pdf; U.S. Global Change Research Program, Fourth National Climate Assessment: Volume II - Impacts, Risks and Adaptations in the United States (2018), https://nca2018.globalchange.gov/downloads/NCA4_2018_FullReport.pdf; J. Abatzoglou & A. Williams, Impact of Anthropogenic Climate Change on Wildfire across Western US Forests," *Proceedings of the Natl.l Acad. of Sciences* (2016), http://www.pnas.org/content/early/2016/10/05/1607171113.abstract?tab=dsb; W. Fisk and W. Chan, Health Benefits and Costs of Filtration Interventions that Reduce Indoor Exposure to PM2.5 During Wildfires, *Indoor Air,* vol. 27 at 191 (2017), available at: https://www.ncbi.nlm.nih.gov/pubmed/26843218\.

Part I
High-Efficiency Filtration and Other Measures for Reducing Exposures in Existing Homes

Many of the best practices for reducing indoor exposure to outdoor PM in new homes apply to existing buildings as well, however existing homes may pose greater challenges for implementing those strategies. For example, air sealing older homes that have leaky envelopes and no mechanical ventilation systems can help reduce significantly the inflow of outdoor air and outdoor particles, but may also raise the levels of particles that are generated indoors. Good filtration can help reduce infiltration of outdoor particles in existing homes, but some homes lack forced-air cooling or heating systems that can provide higher-efficiency in-duct filtration. For those home, portable air cleaners are a potential solution.

The following sections discuss:

- High-efficiency in-duct and portable air filters as a core strategy for reducing indoor PM exposures in existing homes. Some of the strategies described in Chapter Two for reducing near-road exposures in new buildings – e.g., installing barriers or relocating playgrounds and other open areas of a building – might also be feasible to implement for some existing buildings located near roads and industrial facilities.
- Recommendations for reducing exposure during high-pollution events, with a focus on wildfires. These measures emphasize filtration as well as other interventions and behavioral changes that can be employed during periods when PM levels are unusually high.

High-Efficiency Filtration in Existing Homes

In-duct Filtration. EPA recommends that consumers who are concerned about small particles use "furnace filters with at least a MERV 13 rating or as high a MERV rating as the system fan and filter track can accommodate."[229]

Many existing homes with forced heating or cooling systems use low-efficiency filters that are typically one-inch thick.[230] Before switching to a higher-efficiency filter, it is important to make sure that the mechanical system can handle the new filter – i.e., that added resistance of the filter will not impede airflow and affect the equipment.[231] As noted in Chapter Two (Sec. IB), recent research has determined that it is possible to have high-efficiency filtration without increasing airflow resistance significantly.

It is sometimes possible to use a higher-efficiency filter that is one-inch thick. Alternatively, filters that are thicker and more highly pleated can help lower airflow resistance. If the system has a filter box that can accommodate a pleated filter greater than one-inch thick, it may be possible simply to substitute a higher-efficiency filter without making changes in the air handling system.[232]

In some cases, the home's mechanical system will need to be retrofitted in order to accommodate a high-efficiency filter. Modifications may include increasing the size of the filter slot and changing the

[229] EPA Residential Air Cleaners Technical Summary, supra, at 9. *See also* EPA Wildfire Smoke Guide, supra, at 31.
[230] EPA Residential Air Cleaners Technical Summary, supra, at 20.
[231] Id. at 9, 38.
[232] Id. at 21; Lawrence Berkeley Nat'l. Lab., What Type of Furnace Filter Should I Use in My Home, https://iaqscience.lbl.gov/faq/what-type-furnace-filter-should-i-use-my-home.

sizing and configuration of return ducts. Other retrofit actions to enhance filtration include upgrading to more efficient motors and blowers and adding controls so that the system can operate continuously or intermittently.[233] These modifications require a trained professional, which brings added financial cost.

If system retrofit or replacement is not an option, it is often possible to switch to a MERV 8 or higher filter that has verified low-pressure performance and fits in the standard one-inch slot, and this can still provide substantial improvement over the low-efficiency filters commonly used in homes.[234]

Portable Air Cleaners. In situations where retrofits are not an option or there is no mechanical cooling/heating system, a portable air cleaner – also sometimes called an air purifier – can provide high-efficiency filtration. Research has shown that using the proper size and type of portable air cleaner can substantially reduce levels of particulate matter.[235]

Portable units, which are designed to filter the recirculating air in a single room or area of a home, reduce particulate matter generated from indoor sources and also from outdoor air after it has entered the home. Air cleaners that use HEPA filters are generally equivalent to MERV 16 filtration or greater and offer the highest available particle removal efficiency of fibrous media air filters for a wide range of particle sizes.[236]

Choosing an air cleaner that will function well in a particular home can be confusing. In 2018, EPA published a guide that provides tips for selecting and using an air cleaner. The guide emphasizes the importance of avoiding portable air cleaners (and furnace/HVAC filters) that intentionally produce ozone.[237] Indeed, because of the well-documented health effects, the state of California has taken regulatory action to limit the ozone emitted from indoor air cleaning devices available for sale in California.

[233] Reducing Outdoor Contaminants in Indoor Spaces (ROCIS), Air Handler Inquiry, http://rocis.org/air-handler-inquiry; D. Fugler, ROCIS, Protecting Homes from Outdoor Pollutants at 13 (2014), http://rocis.org/sites/default/files/user-files/ROCIS_HomesFINAL1120.pdf; Lawrence Berkeley Nat'l. Lab., What Type of Furnace Filter Should I Use in My Home, https://iaqscience.lbl.gov/faq/what-type-furnace-filter-should-i-use-my-home.

[234] EPA Residential Air Cleaners Technical Summary, supra, at 21-Fig. 4; Nat'l. Academies of Sciences, Engineering, and Medicine, Health Risks of Indoor Exposure to Particulate Matter: Workshop Summary at 71-72 (2016), available at http://nationalacademies.org/hmd/Activities/PublicHealth/Health-Risks-Indoor-Exposure-ParticulateMatter/2016-FEB-10.aspx (summarizing comments of William Fisk); Lawrence Berkeley Nat'l. Lab., What Type of Furnace Filter Should I Use in My Home, https://iaqscience.lbl.gov/faq/what-type-furnace-filter-should-i-use-my-home.

[235] B. Singer, et al., Reducing In-Home Exposure to Air Pollution (2016), https://ww3.arb.ca.gov/research/apr/past/11-311.pdf (testing portable air cleaners using HEPA filters in a home with exhaust-only ventilation); EPA Residential Air Cleaners Technical Summary, supra, at 7 ("Intervention studies...have consistently found statistically significant reductions in indoor exposures to indoor PM2.5, PM10, and/or particle number counts with the use of portable air cleaners").

[236] EPA Residential Air Cleaners Technical Summary, supra, at 20.

[237] U.S. EPA, Guide to Air Cleaners in the Home, 2d ed. at 5 (2018), https://www.epa.gov/sites/production/files/2018-07/documents/guide_to_air_cleaners_in_the_home_2nd_edition.pdf. The guide also provides consumers information on evaluating the clean air delivery rate (CADR) and noise levels of an air cleaner.

Limiting Ozone Emissions from Air Cleaning Devices:
California's Testing, Certification, and Labeling Program

According to the California Air Resources Board, "It is well-documented that ozone can cause respiratory tract irritation and inflammation, serious breathing difficulty including asthma, permanent lung damage, and cardiovascular effects." Ozone generators – portable or in-duct air cleaners that intentionally create ozone – can produce high levels of ozone.

In 2008, California became the only state to limit ozone emissions from indoor air cleaning devices. Pursuant to a 2006 state law, CARB adopted a regulation that sets an ozone emission concentration standard for air cleaners and requires all air cleaning devices sold in the state to be tested, certified, and labeled as meeting the standard. The regulation applies to "any indoor air cleaning device for use or intended for use in occupied spaces," but exempts specified industrial devices and certain in-duct systems. 17 Ca. Code Regs. §§ 94800–94810.

In December 2019, CARB approved amendments to the regulations that establish, among other things, emissions and certification requirements for electronic *in-duct* air cleaning devices as well.

CARB maintains a Consumer's Air Cleaner Portal web page, which includes a link to a list of CARB-certified indoor air cleaning devices, along with other general information on air cleaners.

Sources: https://ww2.arb.ca.gov/our-work/programs/air-cleaners-ozone-products/air-cleaner-information-consumers; https://ww2.arb.ca.gov/our-work/programs/air-cleaners-ozone-products/air-cleaner-regulation-ab-2276.

Filtration and other Practices for Reducing Indoor Exposures during Wildfire Smoke Events

The smoke from wood burning is a mixture of gases and particles. In addition to particulate matter, wildfire smoke contains carbon dioxide, carbon monoxide, hydrocarbons and other organic chemicals, nitrogen oxides, and trace minerals. Particulate matter (mainly PM2.5) is considered the principal health threat from exposure to wildfire smoke.[238]

Studies indicate that the health effects of wildfire smoke exposure are similar to those of urban particle pollution generally.[239] However, the intensity of the exposure is often much greater. For example, the California Rim Fire of 2013 produced PM2.5 levels 35 times the EPA 24-hour standard.[240] Wildfire smoke episodes can last for weeks or even months.[241] To cite just one example, the Seeley Lake area of Montana experienced PM levels in the unhealthy to hazardous range for 43 days during summer

[238] EPA Wildfire Smoke Guide, supra, at 1, 12.
[239] Id. The Guide notes, "Although the body of literature specifically examining the health effects attributed to wildfire smoke exposure has grown, the initial understanding of potential health effects was derived from studies focusing on components of ambient air pollution, primarily in urban settings, that are also found in wildfire smoke (e.g., fine particulate matter and carbon monoxide)." Id. at 4.
[240] K. Navarro, Air-Quality Impacts and Intake Fraction of $PM_{2.5}$ During the 2013 Rim Megafire, *Environ Sci. Technol*. 1:50(21), at 11967 (2016), available at: https://www.ncbi.nlm.nih.gov/pubmed/27652495.
[241] EPA Wildfire Smoke Guide, supra, at 18.

2017.[242] The duration of wildfire smoke episodes is one reason that they may "also cause mental health concerns and psychological stress."[243]

Extent of the Problem. In recent decades, the incidence of large wildfires in the United States has risen dramatically, along with average annual acreage burned.[244] In 2015, wildfires burned over 10 million acres, the most on record; 2017 was a close second, and 2018 was sixth largest in total acres burned.[245] This trend is expected to continue as a result of conditions associated with climate change.[246]

Wildfires have had the greatest impact on the western U.S., and some western states and tribes now have fire seasons that last most of the year.[247] Wildfires in the West are larger and burn more acreage, though more wildfires occur in the East (including the central states).[248] In 2017, the top five states in total number of wildfires were Texas, California, North Carolina, Georgia, and Florida.[249]

The health risks from wildfire smoke exposure are not limited to people living in communities where the fire is raging. Smoke from wildfires can increase air pollution over hundreds or even thousands of square miles.[250] In California, smoke from the devastating 2018 Camp Fire spread over hundreds of miles to the Bay Area and Sacramento, where it produced "a yellowish haze that…blocked out the blue sky."[251] In August 2018, wildfire smoke from the western U.S. reached Baltimore, creating a "code orange" alert for sensitive groups.[252] And in Minnesota, an air quality alert was issued in July 2019 for the entire northern third of the state as wildfires in Canada produced thick smoke and "some of the highest measured AQI values since monitoring began in the 1990s."[253]

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[242] *See* Montana House Joint Res. 42 (2019), https://leg.mt.gov/bills/2019/HouJoint/HJ0042_1.pdf.
[243] EPA Wildfire Smoke Guide, supra, at 4.
[244] *See* U.S. EPA, Climate Change Indicators: Wildfires (2016), https://www.epa.gov/climate-indicators/climate-change-indicators-wildfires.
[245] U.S. Congr. Research Service, Wildfire Statistics, (rev. Oct. 2019), https://fas.org/sgp/crs/misc/IF10244.pdf.
[246] *See* NASA, Six Trends to Know about Fire Season in the West (2018), https://climate.nasa.gov/blog/2830/six-trends-to-know-about-fire-season-in-the-western-us/; U.S. Global Change Research Program, Fourth National Climate Assessment: Volume II Impacts, Risks and Adaptations in the United States at 514, 516 (2018), https://nca2018.globalchange.gov/downloads/NCA4_2018_FullReport.pdf.
[247] *See, e.g.,* State of California, Wildfires and Climate Change: California's Energy Future at 1 (2018), https://www.gov.ca.gov/wp-content/uploads/2019/04/Wildfires-and-Climate-Change-California%E2%80%99s-Energy-Future.pdf ("The state's fire season is now almost year round" and around 25 percent of the state population, or 11 million people, live in high-risk areas); U.S. Forest Service, The Rising Cost of Wildfire Operations: Effects on the Forest Service's Non-Fire Work at 2 (2015), http://www.fs.fed.us/sites/default/files/2015-Rising-Cost-Wildfire-Operations.pdf.
[248] U.S. Congr. Research. Service, Wildfire Statistics, (rev. 10/19), https://fas.org/sgp/crs/misc/IF10244.pdf. The top five states in number of acres burned in 2017 were Montana, Nevada, California, Texas, and Oregon.
[249] Natl. Interagency Fire Center, National Report of Wildland Fires and Acres Burned by State (2018), https://www.predictiveservices.nifc.gov/intelligence/2018_statssumm/fires_acres18.pdf.
[250] W. Fisk and W. Chan, Health Benefits and Costs of Filtration Interventions that Reduce Indoor Exposure to PM2.5 During Wildfires, 27 *Indoor Air* at 191 (2017), available at: https://www.ncbi.nlm.nih.gov/pubmed/26843218; *see also* A. Larsen, Impacts of Fire Smoke Plumes on Regional Air Quality 2006–2013 (2018), https://www.nature.com/articles/s41370-017-0013-x.
[251] S. Werthan, "The Scary Reach of the Camp Fire's Flames," *Slate* (Nov. 12, 2018), https://slate.com/technology/2018/11/wildfire-smoke-camp-fire-health-impacts-respirator-mask.html.
[252] *See* S. Dance, Maryland Weather: Wildfire Smoke from Western U.S. Affecting Air Quality in Baltimore as Heat Index Nears 100, *Baltimore Sun* (8/16/18), https://www.baltimoresun.com/weather/bs-md-heat-humidity-20180816-story.html.
[253] Minn. Pollution Control Agency, Air Mail Newsletter: Record-breaking Wildfire Smoke Returns to Minnesota (Aug. 2019), https://content.govdelivery.com/accounts/MNPCA/bulletins/257004b?mnpca_17=#link_5. The monitors at the Red Lake and Leech Lake Tribal Nations saw hourly values over 250 on the AQI scale, the highest hourly values ever measured in Minnesota.

Recommendations for Reducing Exposure. Following are key recommendations from EPA's recently revised *Wildfire Smoke: A Guide for Public Health Officials*, [referred to here as the "*Wildfire Smoke Guide*"] which provides public health officials detailed information on evidence-based actions that can reduce indoor exposure during a wildfire smoke event.[254]

- **Stay indoors**, with doors and windows closed, with the caveat that doing so in a home without air conditioning increases the risk of heat stress.
- **Reduce indoor sources of air pollution,** such as smoking cigarettes, using gas or wood-burning stoves and furnaces, spraying aerosol products, frying and broiling meat, burning candles and incense, and vacuuming, which can all increase indoor particle levels.
- **Use air conditioners in recirculate mode, with filters –** set window units or central air conditioning systems to "recirculate" rather than "outdoor air" and run the system continuously with the highest efficiency filter the system can handle.
- **Turn off or adjust mechanical ventilation systems –** mechanical supply and exhaust ventilation systems that bring in outdoor air can be turned off or adjusted.
- **Use portable air cleaners** that do not generate ozone**,** operating them continuously in locations within the home where people spend the most time.
- **Create a "clean room" at home** using the above practices, preferably in an interior room with few windows and doors, such as a bedroom.
- **Use cleaner air shelters** (for people displaced days or weeks) **or cleaner air spaces** (for people who need relief for part of the day) that provide air conditioning and effective particle filtration.
- **Use respiratory protection** in the form of masks with high filtration efficiency (such as disposable N95 or P100 respirators), which may provide some protection for adults if they are used correctly.

Some of these best practices may apply to other types of severe air-pollution episodes, such as surface temperature inversions that can trap pollutants near the ground and result in high outdoor particle counts. Temperature inversions are more common in winter and at night, though certain meteorological and geographic conditions can prolong inversions and stagnant air for several days.[255]

Some of the practices (e.g., filtration, adjusting outdoor air supply, reducing other indoor sources) may also be relevant for homes located near sources of ongoing PM emissions, such as high-volume roads, which may experience higher PM levels during certain times of the day. In its 2017 Technical Advisory on near-road exposures, the California Air Resources Board noted that pollution concentrations near high-volume roadways may be higher "during the night and the very early morning (i.e., 1-2 hours before sunrise), largely as a result of diurnal meteorological patterns."[256]

[254] For a fuller discussion of these recommended practices, see EPA Wildfire Smoke Guide, supra, at 18-31.
[255] *See* Utah Dept. of Health, Air Pollution and Public Health in Utah, http://health.utah.gov/enviroepi/healthyhomes/epht/AirPollution_PublicHealth.pdf (noting that strong inversions are especially problematic if there is significant residential wood burning).
[256] CARB 2017 Technical Advisory, supra, at 19.

Reducing Near-Road Exposures in Existing Homes in Boston, Massachusetts

Chapter Two of the report discussed state policies for reducing indoor PM exposure in *new* residential development located near high-volume roads. State and local polices are also important for reducing exposures for the many people already live in close proximity to such roads, a result of highways placed in existing communities or residential projects sited near existing highways.

Since 2008, the Community Assessment of Freeway Exposure and Health (CAFEH) project, led originally by Tufts University and now by the University of Connecticut, has conducted a series of community-based participatory research projects in partnership with local communities in the Boston area. CAFEH has studied and addressed pollution from highways. The project has focused especially on Boston's Chinatown neighborhood and on the nearby city of Somerville, two communities located in close proximity to multiple highways.

Building on its early work identifying both the scope of the problem and research-based solutions, the CAFEH project has conducted multiple community charrettes since 2014 that explored a variety of measures to mitigate near-road exposures in these communities, ranging from sound barriers to enhanced ventilation and filtration.

Current projects are investigating which types of air handling systems and filtration are most protective against infiltration of outdoor pollutants, whether freestanding air filters offer benefits to near highway residents, and the feasibility and acceptability of noise barriers along highways. Related activities include educating communities about traffic pollution impacts and influencing the design of new/retrofitted housing and school buildings near highways.

Sources: CAFEH*, Improving Health in Communities Near Highways: Design Solutions from a Charrette* (2011), https://sites.tufts.edu/cafeh/files/2011/10/CAFEH-Report-Final-2-26-15-hi-res1.pdf; CAFEH, https://sites.tufts.edu/cafeh/about/the-cafeh-research/near-highway-pollution-from-research-to-action/; https://sites.tufts.edu/cafeh/

Discussion

There are a number of practical challenges to consider when developing policies and programs to implement best practices for reducing PM exposure in existing homes.

Lack of Air Conditioning. Homes that lack air conditioning not only pose health risks from heat stress, but can also hinder people from reducing their exposure to wildfire smoke and other PM sources.

EPA's *Wildfire Smoke Guide* notes: "An important caveat about advising people to stay inside and close windows and doors of homes without air conditioning is the increased risk of heat stress."[257] Air-conditioning equipment itself may provide some filtration, and when set to recirculation mode can help keep the house cool while windows are closed. The guide recommends that people without air conditioning visit buildings with air conditioning and appropriate filtration in order to cool off.[258]

[257] EPA Wildfire Smoke Guide, supra, at 18.
[258] Id.

However, people who lack air conditioning for financial reasons may also lack resources to find alternate housing or to travel to shelters during high pollution events.

While around 90 percent of households in the U.S. were estimated to have air conditioning in 2017, there are some parts of the U.S. where this percentage is much lower. [259] For instance, in the Seattle-Tacoma-Bellevue metropolitan area, which has been impacted by wildfire smoke in recent years, fewer than half of all households were estimated to have air conditioning; in Colorado, around two-thirds of all households were estimated to have air conditioning.[260] Nationwide surveys of household air conditioning *use* in 2015 showed differences by income group: around 82.7 percent of households with income under $40,000 were estimated to use air conditioning, compared to 91.5 percent of households with an income above $100,000.[261] It was also estimated that a higher rate of owner-occupied households use air conditioning (90 percent) than do rental households (under 83 percent).[262]

Costs of purchasing and running equipment. The cost of purchasing a portable air cleaner or air conditioning unit is generally reasonable, but still may be prohibitive for lower-income households. Smaller portable air cleaner models cost $50 - $200, while larger and more-efficient models may cost over $300.[263] As noted in Chapter Two (Section IE) above, concerns about increased energy use and higher utility bills, as well as the cost of replacing filters, may affect whether people will operate and maintain the equipment as recommended for effective filtration. Air conditioners and air filters (portable and in-duct) are only effective if the systems are running.

Some organizations and local governments have provided information on a lower-cost, do-it-yourself approach to providing filtration by attaching a high-efficiency filter to a box fan. [264] EPA has noted that there is "some limited evidence to support the filtration efficiency of these DIY devices" but that there are concerns that the box fan's motor may overheat when operated with a filter attached. Because of the safety concerns, EPA does not currently endorse the use of this approach and advises those who use the devices to exercise caution and not to operate them unattended or when sleeping.[265]

Noise. Noise is an important consideration for the design and installation of new mechanical systems. For existing homes, the noise level of mechanical systems as well as portable air cleaners can be a deterrent to using the units. The high airflow rate needed to achieve maximum filtration efficiency can be noisy in some portable units, and this may prompt people to turn the units off or to run the units at a lower airflow rate than needed to effectively address high PM levels.[266]

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[259] U.S. Census Bureau, American Housing Survey (2017), available at https://www.census.gov/programs-surveys/ahs/data/interactive/ahstablecreator.html?s_areas=00000&s_year=2017&s_tablename=TABLE1&s_bygroup1=1&s_bygroup2=1&s_filtergroup1=1&s_filtergroup2=1.

[260] Id.

[261] U.S. Energy Info. Admin., Residential Energy Consumption Survey – 2015 RECS Survey Data, https://www.eia.gov/consumption/residential/data/2015/index.php#ac.

[262] Id.

[263] Cal. Air Resources Board, Air Cleaning Devices for the Home: Frequently Asked Questions, at 5 (rev. July 2014), https://ww3.arb.ca.gov/research/indoor/acdsumm.pdf. EPA notes that models that cost less than $200 "often do not clean the air as well and may not be helpful for wildfire smoke." U.S. EPA, Wildfire Smoke Factsheet: Indoor Air Filtration, https://www3.epa.gov/airnow/smoke_fires/indoor-air-filtration-factsheet-508.pdf. Depending on the home and the pollutant levels, a home might need more than one unit.

[264] Puget Sound Clean Air Agency, DIY Air Filter, https://www.pscleanair.org/525/DIY-Air-Filter.

[265] EPA Wildfire Smoke Guide, supra, at 24.

[266] EPA Residential Air Cleaners Technical Summary, supra, at 8.

Lack of Awareness of When and How to Take Action. Extreme smoke episodes notwithstanding, building residents and managers may not always realize when outdoor PM levels warrant taking actions such as reducing the entry of outdoor air or using portable air cleaners.

The Clean Air Act requires every state to establish a network of permanent air monitoring stations for criteria pollutants, including PM2.5 and PM10, and EPA runs the AirNow website (airnow.gov) to communicate this monitoring information via the familiar color-coded air quality levels.[267] The number of PM2.5 air monitors that must be deployed in metropolitan areas depends on the population of the city: more than one million (2-3 PM2.5 monitors), 500,000 to one million people (1-2 monitors), or 50,000-500,000 (0-1 monitor).[268] Thus, each monitor covers a large area and will not necessarily reflect local conditions. In 2010, EPA established a requirement that states with a population over one million deploy one "microscale monitoring station" near roads to measure NO2, along with a PM2.5 monitor; cities with more than 2.5 million people must deploy two such monitoring stations.[269] During wildfire smoke episodes, this stationary network of air monitors may be supplemented by portable monitors provided by the U.S. Forest Service and by state, tribal, and local agencies.[270]

Part II
Strengthening Policies for Reducing Exposures in Existing Homes

Building codes that establish ventilation and filtration standards for new construction and renovation also commonly include a requirement for mechanical systems to be maintained to operate according to the original design conditions. Under the International Residential Code, building owners are responsible for maintaining existing and new mechanical systems, as well as other required devices, in proper operating condition and in accordance with the original design and the code under which they were installed. The model code further authorizes the state or local building official to require that mechanical systems be re-inspected.[271] In addition to such general maintenance requirements, state or local policies that require high-efficiency filtration in new construction can expressly require that filters be properly maintained and replaced.

Although building code standards in effect at the time a building is constructed or renovated govern the future operation of the building, those standards can be supplemented by other laws and regulations. This section discusses housing codes and other policies that address health and safety in existing homes. While these laws and regulations may apply to owner-occupied homes in some cases, they are most importantly a policy tool for establishing minimum standards for rental housing, which made up

[267] *See* U.S. EPA, Air Quality Monitoring, https://www3.epa.gov/airquality/montring.html.
[268] 40 C.F.R. 58, app. D, Table D-5. The higher number of monitors in the range is required if pollution is above a stated level.
[269] 75 Fed. Reg. 6474-01; U.S. EPA, Quality Assurance Handbook for Air Pollution Measurement Systems Volume II at 3-4 (2017), https://www3.epa.gov/ttnamti1/files/ambient/pm25/qa/Final%20Handbook%20Document%201_17.pdf. The new rules also set a new one-hour standard for NO_2 to address near-road exposures. EPA monitoring regulations define "microscale" as covering "area dimensions ranging from several meters up to about 100 meters." 40 C.F.R. 58 app. D, 1.2.
[270] EPA Wildfire Smoke Guide, supra, at 33 (noting, "Agencies submit continuous PM data to AirNow from over 1,200 PM2.5 monitors and 500 PM10 monitors, plus temporary monitors, on an hourly basis.").
[271] ICC, International Residential Code § M1202.3.

approximately 36 percent of all occupied housing units in the U.S. in 2018.[272] The average income in rental households across was around half that of owner-occupied households in 2017.[273]

In general, current policies governing rental housing do not directly address particle pollution. States, tribes, and local governments could consider how to apply their existing policies to reduce indoor PM exposures or, alternatively, how to strengthen the policies to protect tenants, especially vulnerable individuals at highest risk from local PM sources or high-pollution episodes.

Housing Codes: Strengthening Minimum Property Maintenance Standards

Housing codes (also referred to as property maintenance or sanitary codes) are the primary regulatory vehicle for establishing minimum health and safety standards that must be maintained in housing. In many cases, housing codes are also means of enforcing standards established in the building codes in effect at the time the housing was permitted. Chicago's housing code states plainly this relationship between the housing and building codes: "Every existing building shall comply with the code requirements in force and applicable to such building, at the time of its construction or alteration, and shall also comply with such provisions of this chapter which are specifically made applicable to all existing buildings."[274]

Many, but not all, local jurisdictions in the U.S. are currently covered by a state or local housing code. Housing codes are most often adopted at the local level, but more than a dozen states have adopted a statewide minimum housing code.[275] These state codes may give localities the authority to promulgate their own codes, provided the local requirements are at least as stringent.

While some housing codes set standards for all housing, they are more commonly a policy for regulating rental properties. The codes apply not only to private housing, but also to public and federally-subsidized residential properties, which are subject to additional federal requirements.[276] Local officials usually have authority for enforcing the codes by conducting inspections, issuing citations, and pursuing administrative, civil and criminal enforcement actions in the event of noncompliance with housing codes.

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[272] U.S. Census Bureau, American Community Survey: Occupancy Characteristics (Table ID: S2501) (2018), https://data.census.gov/cedsci/table?q=S2501&table=S2501&tid=ACSST1Y2018.S2501&lastDisplayedRow=27.

[273] U.S. Census Bureau, American Housing Survey (2017), https://www.census.gov/programs-surveys/ahs/data/interactive/ahstablecreator.html?s_areas=00000&s_year=2017&s_tablename=TABLE9&s_bygroup1=2&s_bygroup2=1&s_filtergroup1=1&s_filtergroup2=1 (data showing $36,100 average income versus $70,000).

[274] Mun. Code of Chicago § 13-196-010.

[275] *See* Code Md. Regs. § 05.02.03.03; 19 N.Y. Admin. Regs. § 1226.1; R.I. Regs. t. 10, rule 6; Ca. H&S Code §§ 17910–17998.3; Ct. Stat. §§ 47a-50--67; 31 De. Code t. 31, §§ 4101 et seq.; 105 Code Ma. Regs. §§ 410.001– .990; Mi. Code §§ 125.401–.543; N.H. Stat. §§ 48–a:1–:15; N.J. Admin. Code §§ 5:28-1.1–.13; Tn. Code §§ 68-111-101—108; Vt. Admin. Code §§ 12–5–25:1.0–11. Some of these codes are limited in their applicability or implementation.

[276] Federal requirements for federally-subsidized and public housing, not discussed here, do not expressly establish indoor cooling requirements, but do include certain general standards and requirements that could potentially be applied to address indoor exposure to outdoor PM. *See, e.g.,* 24 C.F.R. Pt. 982.401(h) (requiring units participating in HUD's Housing Choice Voucher program to be "free from dangerous levels of air pollution"); 24 C.F.R. 5.703(f) (requiring public housing units to be free of health and safety hazards, including "air quality").

Some states and localities have adopted a housing code based on the ICC's model International Property Maintenance Code (IPMC), while others have developed their own codes.[277] Although housing codes address a variety of indoor environmental quality conditions, they typically do *not* include requirements for air filtration or air conditioning, or otherwise directly address indoor exposure to particulate matter generated outdoors. [Note that housing codes do address certain *indoor* PM sources – such as cooking, smoking and the use of unvented heaters – those policies will be discussed in future ELI reports.]

Following are provisions of the IPMC that are most relevant to addressing these exposures, as well as examples of state-specific (or local) housing codes provisions that go beyond the IPMC.[278] The city of Tukwila, Washington is noteworthy for amending the IPMC to incorporate elements of a model healthy housing code, and those provisions are described in more detail.

General Standard of Habitability. The IPMC (Section 301.2) prohibits a person from occupying premises as an owner-occupant or allowing another person to occupy premises that are "not in a sanitary and safe condition and that do not comply with the requirements" of the code. In an extreme situation, such as a wildfire smoke episode, this and similar state and local habitability provisions could potentially be used to require action by the property owner to reduce exposure.

Weathertightness. A common element of housing codes is the requirement that the premises be maintained in weathertight condition. While applied most commonly to address incursion of water or dampness, such provisions could potentially be applied to prevent and remedy excessive infiltration of outdoor air. The IPMC requires: "Every window, skylight, door and frame…shall be kept in sound condition, good repair and weathertight."[279] Individual state housing codes include variations on this theme. The **Massachusetts** housing code is somewhat more explicit in addressing infiltration of air; according to the code, structural elements must be watertight and weathertight, and elements are deemed weathertight only if "all cracks and spaces…are caulked or filled in as to prevent infiltration of exterior air or moisture."[280] Although reducing infiltration can limit entry of outdoor pollutants, it is also important to ensure adequate ventilation to prevent the concentration of indoor pollutants.

Air Conditioning Requirements/Thermal Standards. The IPMC does not require air conditioning. The only provisions relating to thermal comfort (Section 602, Heating Facilities) require maintaining a minimum temperature (68° F) to protect against cold.

State and local housing codes generally do not require air conditioning or establish thermal standard. One exception is the city of **Dallas**. The Dallas Municipal Code, which establishes minimum standards for all residential and non-residential structures, requires owners of rental housing units to "provide, and maintain, in operating condition, refrigerated air equipment capable of maintaining a room temperature of at least 15 degrees cooler than the outside temperature, but in no event higher than 85 [degrees] F in

[277] ICC, International Property Maintenance Code (2018), https://codes.iccsafe.org/content/IPMC2018. The IPMC is updated every three years. This summary describes provisions in the most recent (2018) version. Though most states have adopted older versions of the code, those versions do not differ significantly in terms of the provisions discussed here.
[278] Note that this report has not conducted an exhaustive review of *local* housing codes, and there may be local jurisdictions with code provisions stronger than the IPMC that are not discussed here.
[279] ICC, International Property Maintenance Code § 304.13.
[280] 105 Code Ma. Regs. §§ 410.500; 410.501.

each habitable room….” The Dallas code also requires that the owner maintain all fixed air conditioning systems and portable air conditioning units in operating condition. [281]

It is more common for local codes to establish requirements that apply *if* the rental housing owner does provide air conditioning equipment. The **District of Columbia** housing code includes fairly detailed provisions along these lines, including: “The owner of a rental habitation, who provides air conditioning as a service either through individual air conditioning units or a central air conditioning system, shall maintain such unit or system in safe and good working condition so that it provides an inside temperature at least fifteen degrees Fahrenheit (15° F) less than the outside temperature.”[282]

General Requirements for Maintaining Equipment. In addition to maintenance of air conditioning specifically, a common provision of state and local housing code is the general requirement that owners maintain mechanical equipment. Such requirements could be used to address ventilation/filtration systems. The IPMC (Section 603.1) requires that: “Mechanical equipment, appliances, fireplaces, solid fuel-burning appliances, cooking appliances and water heating appliances shall be properly installed and maintained in a safe working condition, and shall be capable of performing the intended function.”

Some housing codes include a provision concerning the operation of ventilation systems. For example, the **California** State Housing Law, which sets minimum standards for residential buildings for all jurisdictions in the state, establishes that the “lack of, or improper operation of required ventilating equipment” constitutes a substandard building condition.[283] The housing code for **Oakland**, California states: “Where mechanical ventilation is provided in lieu of the natural ventilation required by…this Code, such mechanical ventilating system shall be maintained in operation during the occupancy of any building or portion thereof.”[284]

[281] Dallas Mun. Code §§ 27-11(e), 27-11(o).
[282] D.C. Mun. Code § 14-510. The owner must have the system inspected by a licensed professional, file a report on the inspection with the D.C. government, and certify that any defects have been corrected.
[283] Ca. Health & Safety Code § 17920.3.
[284] Oakland Mun. Code § 15.08.260. *See also* De. Code § 4115; Cincinnati (OH) Code of Ordinances §§ 1117-41.1.

Integrating Health into Housing Codes: Tukwila, Washington and the National Healthy Housing Standard

The city of Tukwila has adopted the 2015 International Property Maintenance Code (IPMC) with city-specific amendments.[285] Many of these amendments are drawn from a model healthy housing standard developed in 2014 by the National Center for Healthy Housing and the American Public Health Association. The National Healthy Housing Standard "provides health-based provisions to fill gaps where no property maintenance policy exists and also a complement to the [IPMC] and other policies already in use by local and state governments and federal agencies for the upkeep of existing homes."[286] Thus, the Tukwila property maintenance code represents a significant departure from most housing codes. Following are notable provisions of the code relevant to reducing indoor exposure to outdoor particulate matter, along with relevant provisions of the National Healthy Housing Standard.

General Standard of Habitability. Tukwila augmented the IPMC requirement for maintaining safe and sanitary conditions by incorporating "health" as an element: "The owner shall ensure that the dwelling is maintained in a safe and healthy condition. The owner shall investigate occupant reports of unsafe or unhealthy conditions, respond in writing and make needed repairs in a timely manner."[287]

Ventilation and Filtration Requirements. The Tukwila code requires compliance with ASHRAE ventilation standards: "Every dwelling shall have a ventilation system compliant with ASHRAE Standard 62.2…or 62.1…as applicable to the dwelling." The code adds a requirement for MERV 8 filtration in forced air systems: "Any dwelling with a forced-air system "shall have a clean air filter installed in accordance with manufacturer specifications at each change in tenancy….This filter shall have a [MERV 8 rating]…unless the system is not equipped to use a MERV-8 filter."[288]

This provision is notable not only because existing codes generally do not include filtration requirements, but also because the MERV 8 requirement is more stringent than the current version of ASHRAE 62.2 (MERV 6 requirement), as well as the International Residential Code (no filtration requirement). The Tukwila code also requires that the filter be replaced at least annually, though city officials interpret this as requiring the tenant to replace the filter annually.[289]

The National Healthy Housing Standard includes a "Stretch Provision" regarding filter replacement: "Air filters are to be replaced at least every three months. The Standard also includes model language regarding operation and maintenance of mechanical equipment that is stronger than the comparable IPMC provision: "Facilities for heating, cooling, ventilation and humidity control shall be…*operated when necessary for the health and comfort of the occupant*s and in accordance with the design capacity of the installed equipment." [290]

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[285] City of Tukwila, Wa. Mun. Code § 8.28.020.
[286] *See* Nat'l. Center for Healthy Housing and Amer. Public Health Assoc., National Healthy Housing Standard at 4 (2014), http://www.nchh.org/Policy/NationalHealthyHousingStandard.aspx.
[287] Tukwila, Wa. Mun. Code § 8.28.020 (301.4).
[288] Id. at § 8.28.020 (403.6, 602.6). *See also* National Healthy Housing Standard § 5.3.1.
[289] Tukwila, Wa. Mun. Code § 8.28.020 (602.6). ELI communications with City of Tukwila Code Enforcement Office (Dec. 2019).
[290] National Healthy Housing Standard §§ 5.2.4, 5.1 (italics added).

Landlord-Tenant Laws

Nearly all states have enacted laws governing certain aspects of the landlord-tenant relationship. These laws set forth the rights and responsibilities of landlords and tenants and, in contrast to housing codes, are enforced privately by the parties.

Landlord-tenant laws cover an array of issues – from security deposits and prohibited lease terms to legal remedies in the event of noncompliance with the law. They do not typically establish specific requirements for ventilation, filtration, air conditioning, and other measures relating to reducing indoor PM exposure. Rather, they often include general requirements for maintaining the premises in a habitable condition and may also require compliance with any applicable state and local housing codes.

Following is a brief summary of common provisions in landlord-tenant laws that may provide a general basis for tenants to pursue remedies in the event of significant indoor exposure to outdoor PM levels. Since many state laws closely follow a model law, the Uniform Residential Landlord and Tenant Act (URLTA), the relevant provisions of the URLTA are noted.[291] The 1972 model law was revised in 2015 and adopted as the Revised Uniform Residential Landlord and Tenant Act (RURLTA), though state adoptions are based largely on the earlier version.[292]

General Habitability. Because some jurisdictions do not have housing codes, the URLTA includes minimum standards of habitability, requiring landlords not only to comply with applicable building and housing codes, but also to "make all repairs and do whatever is necessary to put and keep the premises in a fit and habitable condition…."[293] Some state landlord-tenant laws include additional detail and references to health in describing the general habitability and good repair requirements. For example, **Colorado** landlord-tenant law states that a landlord commits a breach of the implied warranty of habitability if the premises are "uninhabitable" as described in the law or otherwise unfit for human habitation, and is in "a condition that materially interferes with the tenant's life, health, or safety."[294] **Maryland**'s landlord-tenant law "provides a remedy and imposes an obligation upon landlords to repair and eliminate conditions and defects which constitute….a serious and substantial threat to the life, health or safety of occupants…"[295]

Requirements for Maintaining Equipment. The URLTA requires landlords to maintain "in good and safe working order and condition" all heating, ventilating, air-conditioning, and other facilities and appliances supplied or required to be supplied. The RURLTA requires "adequate ventilation and heating facilities that conform to law and are maintained in good working order." [296]

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[291] Uniform Law Comm., Uniform Residential Landlord and Tenant Act (URLTA) (1972).
[292] Uniform Law Comm., Revised Uniform Residential Landlord and Tenant Act (RURLTA) (2015), https://www.uniformlaws.org/committees/community-home/librarydocuments?communitykey=e9cd20a1-b939-4265-9f1e-3a47a538d495&tab=librarydocuments. The revised model act is notable for stronger IAQ provisions, however the provisions most relevant to outdoor PM are not significantly changed.
[293] URLTA § 2.104(a)(2). Under the RURLTA, landlords have a non-waivable duty to ensure that the premises "have reasonable measures in place…to prevent exposure to unsafe levels of radon, lead paint, asbestos, toxic mold, and other hazardous substances…." RURLTA § 302(a).
[294] Co. Stat. § 38-12-503 (2019 Co. Legis. Sev. Chj. 229, HB19-1170).
[295] Md. Real Prop. § 8-211(e).
[296] URLTA § 2.104(a)(4); RURLTA § 302(a)(5).

Weathertightness. The RURLTA added a requirement for "effective waterproofing and weather protection of the roof and exterior walls, including windows and doors."[297] Some state laws include weathertightness as part of the landlord's duty to provide a habitable dwelling. In **Colorado**, for example, a dwelling is deemed uninhabitable if it substantially lacks "[w]aterproofing and weather protection of roof and exterior walls maintained in good working order, including unbroken windows and doors."[298] In **Nevada**, a dwelling unit is not habitable if it "substantially lacks…[e]ffective waterproofing and weather protection of the roof and exterior walls, including windows and doors."[299]

Other Laws Addressing Indoor Environmental Conditions in Existing Homes

There are other types of laws and regulations that establish requirements relating to indoor air quality in existing housing. As suggested below, though, state and local policies in these areas tend to address *indoor* PM sources rather than PM generated outdoors.

- *Regulation of Products*. As described in Chapter Two (Section IB), **California** has adopted a regulation requiring the labels of air filters for forced-air heating or cooling equipment to include filter efficiency; airflow resistance; and MERV rating (or equivalent), "permanently and legibly, on an accessible and conspicuous place."[300] As noted earlier in this chapter, California also sets ozone emission standards and labeling requirements for air cleaning devices.[301] Another area of federal and state product regulation – emissions from new wood-burning equipment, such as wood stoves and fireplaces – is important for reducing both indoor and outdoor PM levels.[302]

- *Regulation of Individual Behavior.* A number of states have laws addressing individual actions that affect exposure to indoor sources of PM – e.g., laws prohibiting smoking in multifamily buildings or prohibiting the use of unvented space heaters. Many states and localities also have policies in place restricting the use of wood-burning devices indoors during certain seasons or periods when outdoor air quality is poor.

- *Regulation of Nuisances*. Public health laws often establish nuisance authority that can be used by state or local health officials to require remediation of housing conditions that pose a threat to health and safety. In general, these laws offer the state or local government recourse as a last resort, rather than as a mechanism for addressing more routine housing violations. Though not common, some jurisdictions establish specific housing conditions as nuisances. For example, **Utah** has enacted a law that makes drifting tobacco smoke in residential buildings a nuisance and sets forth the limited circumstances in which tenants may take legal action when they are harmed by

[297] RURLTA § 302(2).
[298] Co. Rev. Stat. § 38-12-505.
[299] Nv. Rev. Stat. § 118A.290. *See also* Or. Rev. Stat. § 90.320; Ca. Civ. Code § 1941.1.
[300] 20 Ca. Code Regs. § 1607(12).
[301] 17 Ca. Code Regs. §§ 94800–94810.
[302] In 2015, EPA promulgated a rule strengthening its emissions standards for new woodstoves and establishing the first emissions standards for other new wood-burning devices, including wood heaters and indoor wood-fired forced air furnaces. *See* 40 C.F.R. Pt. 60. For information about deadlines for compliance with the new standards, see U.S EPA, Compliance Requirements for Residential Wood Heaters, https://www.epa.gov/residential-wood-heaters/compliance-requirements-residential-wood-heaters.

drifting smoke.[303] **San Francisco**'s public health code defines a nuisance to include, "Any visible or otherwise demonstrable mold or mildew in the interiors of any buildings or facilities."[304]

Discussion

State and local housing codes and landlord-tenant laws are potential policy vehicles for helping to ensure that rental housing adequately protects residents from outdoor air pollution. These laws and regulations typically require compliance with the ventilation and filtration standards in building codes at the time the property was permitted, which will be increasingly important as jurisdictions begin to strengthen those codes. They also establish independent requirements for maintenance and operation.

Key challenges for addressing PM exposure in rental housing are the need for stronger property maintenance standards and the difficulty in ensuring effective implementation and enforcement of existing or new standards.

*Strengthening Housing Standards***.** There currently are no federal or state policies setting mandatory indoor air quality standards for particulate matter.[305] One challenge in establishing a mandatory standard for homes is the contribution from sources such as smoking, wood-burning, cooking, and using consumer products and equipment (e.g., candles, air fresheners, and printers).

Many state and local housing codes do include general provisions governing habitability and ventilation that could potentially be relied on to address a serious problem with infiltration of outdoor particulate matter. For the most part, however, such provisions do not require best practices for ventilation and filtration and are too vague to provide a basis for clear and consistent enforcement.

Policymakers could consider revising their laws and regulations to include health in the definition of habitability and to address two key items needed to protect residents from outdoor PM exposure – air conditioning and air filtration. Including these provisions in the housing code (or state landlord-tenant law) would enable government enforcement in situations involving serious health risks and could also facilitate private remedies for tenants.

Air Conditioning. States, tribes, and local governments can help ensure access to air conditioning for vulnerable populations by including in housing codes a maximum temperature standard or a requirement for cooling equipment that is capable of maintaining indoor temperature below a stated maximum. Air conditioning is important both for facilitating control of outdoor PM exposure and for reducing the risk of heat stress. At the same time, the increased use of air conditioning can result in negative public health impacts from pollutant emissions and energy use associated with the equipment.[306] Along with increasing access to affordable air conditioning units and to cooling shelters, policymakers can take steps to mitigate the environmental consequences of using air conditioners (and make them more affordable) by strengthening product energy-efficiency standards and phasing out the

[303] Utah Code § 78B-6-1101.
[304] San Francisco Health Code Art. 11, § 581.
[305] Agencies and organizations may have guidance documents with recommended parameters for PM and other indoor pollutants. *See, e.g.*, WHO, WHO Guidelines for Indoor Air Quality: Selected Pollutants at 4 (2010), http://www.euro.who.int/__data/assets/pdf_file/0009/128169/e94535.pdf (stating that the WHO 2005 air quality guidelines for PM are also applicable to indoor spaces).
[306] *See* D. Abel, et al., Air-Quality-Related Health Impacts from Climate Change and from Adaptation of Cooling Demand for Buildings in the Eastern United States: An Interdisciplinary Modeling Study, *PLoS Med* 15(7): e1002599 (2018), https://doi.org/10.1371/journal.pmed.1002599.

use of hydrofluorocarbons as refrigerants. Policymakers can also take steps to mitigate the heat island effect generally, through building design (e.g., cool roofs) and urban planning (e.g., shade and tree canopies).[307]

Filtration. To ensure that tenants are protected from outdoor particle pollution, owners could be required to provide the highest-efficiency filtration that the building's current mechanical system allows, and to replace filters according to the manufacturer's recommendations or at specified intervals. As discussed earlier, filters can last a few months or longer, and the cost differential for higher-efficiency filters is not substantial in many cases.

Where there is no high-efficiency in-duct filtration in the home, policymakers could consider a requirement for the provision of *portable* air cleaners to address significant local sources of pollution or episodes such as wildfires. During high-PM episodes, for example, an air cleaner unit could be placed in the unit and then removed following the emergency. The state of **Colorado** amended its landlord-tenant law in 2019 to incorporate this type of requirement to address a different indoor air quality problem – mold and dampness. The law now specifies that in cases where the premises has a mold or dampness problem that may materially affect the tenant's health or safety, the warranty is breached if the landlord fails to take certain steps specified in the law; these steps include installing "a high-efficiency particulate air filtration device to reduce tenants' exposure to mold….[and] maintain[ing] the containment until remedial actions are taken…."[308]

Applying Existing Laws and Regulations to Address PM Exposure. Most state and local housing codes and landlord-tenant laws include general standards or requirements that leave room for interpretation. Applying general provisions to address indoor exposure to high levels of outdoor-generated particle pollution could advance the broad purpose of most housing codes – to ensure that housing is maintained free of unsafe and harmful conditions. For example, a general requirement to *maintain* mechanical equipment, common in many housing codes, could be interpreted as requiring the maintenance/replacement of air filters consistent with applicable building code standards and according to the manufacturer's recommendations, as well as the maintenance of air conditioning that is supplied by the owner. Similarly, a requirement regarding the proper *operation* of mechanical equipment could be interpreted to require proper maintenance of air filters as well as operation of the system to provide adequate outdoor air or to limit outdoor air entry during high-pollution episodes such as wildfires.

Ensuring Effective Code Enforcement. Tenants in most states have some legal recourse in the event a property owner does not correct violations of state or local minimum habitability standards. Nevertheless, tenants face significant obstacles to using the law to remedy unhealthy conditions. Most tenants lack legal representation or information about their rights under the law and their lease. A shortage of alternative housing options creates an additional barrier for many tenants.

State and local governments can assist tenants in enforcing housing standards by developing written educational materials, strengthening procedural provisions in landlord-tenant laws, establishing

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[307] *See generally* B. Storrow, E&E News, States Target Potent Greenhouse Gases in Absence of Federal Action (4/5/19), https://www.scientificamerican.com/article/states-target-potent-greenhouse-gases-in-absence-of-federal-action/; Appliance Standards Awareness Project, https://appliance-standards.org/states; American Council for an Energy Efficient Economy, State and Local Policy Database (Urban Heat Island Mitigation), https://database.aceee.org/city/mitigation-urban-heat-islands; U.S. EPA, Heat Island Community Actions Database, https://www.epa.gov/heat-islands/heat-island-community-actions-database.
[308] Co. Stat. § 38-12-503, 2019 Colo. Legis. Serv. Ch. 229 (H.B. 19-1170).

specialized housing courts, and providing tenants legal representation. In the **District of Columbia**, tenants can bring a case against landlords for violating the housing code on an expedited basis; a court-created form to initiate the case provides a checklist of potential housing violations, including inadequate ventilation and inadequate air conditioning.[309] **Newark**, New Jersey adopted an ordinance establishing the Office of Tenant Legal Services and a pilot program to provide access to free legal representation for Newark's low-income tenants who are facing eviction.[310] In **Boston**, the city worked with Greater Boston Legal Services to create a new online tool to make it easier for tenants to respond on their own to an eviction case.[311]

Even with stronger tenant enforcement, municipal code enforcement programs are vital for implementing minimum health and safety requirements for existing housing. Following are considerations for addressing indoor PM exposure in the code enforcement process.

Modifying housing inspection checklists to include all relevant ventilation, filtration, and air conditioning requirements. This can be especially important where building codes require new housing to have mechanical systems that use higher-efficiency filters.

As noted in Chapter Two (Section IIC), **San Francisco's** health code provides that the MERV 13 filtration required for certain residential construction must be "properly maintained, subject to the Health Code's enforcement and penalty provisions."[312] The city of **Los Angeles'** Housing and Community Investment Department (HCID) has taken the notable step of incorporating filtration into its routine housing code inspection program to help ensure that new multifamily rental properties subject to the building code requirement for MERV 13 filtration continue to maintain that filtration. According to an HCID memorandum issued in 2018, agency inspectors would verify compliance as part of the routine Systematic Code Enforcement Program inspections that occur every four years.[313]

Prioritizing housing code inspections in areas where outdoor PM level are high. While most inspections are conducted in response to complaints, some jurisdictions conduct routine inspections. Scheduled inspections could be set up, e.g., for rental properties located very close to major roads or multiple stationary sources of air pollution. Additionally, housing code inspections could be undertaken in anticipation of or at the onset of wildfires or other high-pollution events in the area, to ensure that air conditioning systems are functioning properly and that required filters are in place. Such inspections could include, at a minimum, apply to filtration equipment that is centrally located and accessible to inspectors.

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[309] *See* District of Columbia Courts, Housing Conditions Calendar, https://www.dccourts.gov/services/civil-matters/housing-conditions-calendar; Superior Court of the District of Columbia, Civil Actions Branch, Verified Complaint to Enforce Housing Regulations, https://www.dccourts.gov/sites/default/files/HCC_HousingCodeComplaint.pdf.

[310] Newark Ord. 18-0673 (12/19/18). *See also* San Francisco No Eviction Without Representation Act of 2018, http://sfelections.sfgov.org/sites/default/files/Documents/candidates/Legal_Text_No_Eviction_Without_Representation.pdf (successful ballot initiative establishing right to legal representation for eligible tenants facing eviction); New York City Admin. Code, T. 26, Ch. 13: Provision of Legal Services in Eviction Proceedings (Local Law 136 of 2017) (directing the city to establish a program to make legal services available to tenants facing eviction proceedings).

[311] *See* Greater Boston Legal Svcs., Massachusetts Defense for Eviction (MADE): Self-Guided Eviction Help, https://www.gbls.org/MADE.

[312] San Francisco Health Code § 3810.

[313] L.A. HCID, Inter-Departmental Memo. – Interior HVAC Filtration under CUGU (App. A) (7/9/18), available at: http://clkrep.lacity.org/onlinedocs/2017/17-0309_rpt_PLAN_07-26-2018.pdf.

Prioritizing inspections in the homes of medically vulnerable individuals, where housing conditions may be impacting health. Code enforcement officials could explore opportunities for coordinating their work with sister health agencies or health care facilities, in order to reach vulnerable households. **Rhode Island** and **Boston** are examples of jurisdictions whose health departments have created programs for referring asthma patients to the appropriate housing agencies to address asthma triggers and other substandard conditions in the home.[314] Many hospitals and other health care facilities around the country participate in innovative programs known as Medical-Legal Partnerships, which address housing and other issues that may be affecting a patient's health – e.g., by referring patients to the local code enforcement agency.[315]

Housing code enforcement faces a number of constraints, including limited resources for conducting inspections and for ensuring the effectiveness of corrective actions taken by property owners. To help ensure compliance, code inspection efforts could be paired with a program of technical assistance to tenants and property owners – e.g., to provide guidance on recognizing when outdoor PM levels require action and on best practices for operating ventilation systems and providing filtration during those periods.[316]

Another critical challenge is ensuring that strengthened housing standards and code enforcement efforts do not lead to the displacement of tenants. While it is beyond the scope of this report to discuss housing policy strategies for preserving the supply of affordable housing, the final section of the report discusses some possible sources of direct financial and material support for improving housing conditions for vulnerable households.

[314] Boston Public Health Comm., Breathe Easy at Home, https://www.boston.gov/departments/public-health-commission/breathe-easy-home; R.I. Dept. of Health, Breathe Easy at Home Project, http://health.ri.gov/projects/breatheeasyathome/.

[315] Natl. Center for Medical Legal Partnerships, Partnerships, http://medical-legalpartnership.org/partnerships/.

[316] Building codes can assist this effort by requiring labeling of systems. As noted in Chapter Two, the California Energy Code now requires ventilation systems to be labeled with the following statement: *This switch controls the indoor air quality ventilation for the home. Leave it on unless the outdoor air quality is very poor.* 24 Ca. Code Regs. Pt 6, § 150.0(o)1I.

PM Exposure in Schools:
Prioritizing State Funding for Air Filtration in Existing Schools in California

Many existing schools lack HVAC systems capable of high efficiency filtration. State school modernization and improvement funding can play an important role in providing high-efficiency filtration in schools subject to high levels of outdoor PM. Two recent laws in California target funding to schools for enhanced filtration.

In 2018, California amended the state education law (AB 2453) to affirm that state school modernization funds may be used "to limit pupil exposure to harmful air pollutants by updating air filtration systems" and to encourage school districts to add air filtration systems to applications for modernization apportionments "when air pollution occasionally or regularly exceed levels known to be harmful to public health." The legislation also provided that schools in communities heavily impacted by pollution are eligible for certain state grants to implement air quality mitigation efforts, pending appropriations. Schools located in communities with "high cumulative exposure burdens for toxic air contaminants and criteria air pollutants" are eligible for grants that can be used to implement air quality mitigation efforts, *including air filter upgrades or installations* and planting of vegetation buffers. See Ca. Educ. Code 17074.25(c).

The grants referenced in AB 24553 were authorized under a 2017 law (AB 617) that required the Air Resources Board to: prepare a "statewide strategy to reduce emissions of toxic air contaminants and criteria air pollutants in communities affected by a high cumulative exposure burden;" select "locations around the state for preparation of community emissions reduction programs;" and provide grants for technical assistance to support program implementation. *See* Ca. Health and Safety Code 44391.2-.3.

Plans developed for two of the communities selected for participation – West Oakland and Muscoy/San Bernardino – include school air filtration as a priority strategy for reducing exposure to outdoor air pollution. The Bay Area Air Quality Management District recently approved a pilot project to install filtration systems at schools located within West Oakland and other communities impacted by pollution and is planning to develop a funding program by 2021 to expand on the pilot to assist in the installation of filtration systems in schools, retirement homes, and community centers.

Sources: Cal. Air Resources Board, Community Air Grants, https://ww2.arb.ca.gov/our-work/programs/community-air-protection-program/community-air-grants.

San Bernardino/Muscoy Community Emissions Reduction Plan (Draft, version 7.25.19), https://www.aqmd.gov/docs/default-source/ab-617-ab-134/steering-committees/san-bernardino/cerp/chapter-5g-draft-schools-july-2019.pdf?sfvrsn=8.

BAAQMD and West Oakland Envtl. Indicators Project, Owning our Air: The West Oakland Community Action Plan at 6-6 (2019), available at: http://www.baaqmd.gov/ab617woak.

Part III
Providing Funding for Reducing Exposures in Existing Homes

Funding is an important consideration in developing policies to reduce indoor PM exposures in the existing housing stock. For many tenants and homeowners who are most vulnerable to the health risks, financial assistance may be needed in order to take action to reduce exposure and remain in their homes.

A variety of public policy tools exist for improving conditions in affordable housing. This section discusses opportunities for providing direct financial or in-kind assistance to individuals through programs focused on:

- Energy retrofits (e.g., weatherization) and housing repairs; and
- Interventions to reduce exposures associated with wildfire smoke episodes.

Funding for Energy Retrofits and Housing Repairs

There are a multitude of state, tribal, and local housing improvement programs that could potentially be brought to bear in helping lower-income households reduce their exposure to outdoor air pollution. These include programs that support energy-efficiency retrofits of existing homes, a core strategy for mitigating climate change and reducing utility costs for lower-income households. Energy efficiency and health are compatible goals for retrofit projects, particularly when indoor air quality measures are expressly integrated into the program framework.

This report cannot describe fully the range of existing programs that fund home energy retrofits or repairs. This section focuses first on the largest single source of funding for improving the energy efficiency of low-income households, the federal Weatherization Assistance Program (WAP), which has also helped spur efforts to integrate energy efficiency and health goals in recent years.[317] A wide variety of other programs are available to help homeowners overcome financial barriers to implementing energy upgrades in existing homes.[318] Some of the strategies discussed below for integrating health into WAP projects may be relevant to those programs as well.

Following discussion of the Weatherization Assistance Program are brief descriptions of other types of housing-related funding programs that could potentially help reduce exposures in lower-income households.

The Weatherization Assistance Program. The federal Weatherization Assistance Program, run by the U.S. Department of Energy, provides grants to "increase the energy efficiency of dwellings owned or occupied by low-income persons…reduce their total residential expenditures, and improve their health and safety, especially low-income persons who are particularly vulnerable such as the elderly, the handicapped, and children."[319] The program funds weatherization services in around 35,000 homes each

[317] *See* Nat'l. Assoc. for State Community Services Programs, Weatherization Plus Health, https://nascsp.org/wap/waptac/wap-resources/weatherization-plus-health/about-weatherization-plus-health/.
[318] A 2010 report noted that there were "over 600 government and utility energy audit, rebate, loan, and grant programs" at the state and local levels. *See* Natl. Safe and Healthy Housing Coalition, Integrating Energy Efficiency and Healthy Housing at 1 (rev. 2010), http://www.nchh.org/Portals/0/Contents/Coalition_briefing_paper_energy.pdf.
[319] 42 U.S.C. § 6861.

year – a total of over seven million homes since the program was first established by Congress in 1976.[320] Appropriated funds are provided to states, the District of Columbia, U.S. territories, and some tribal governments ("grantees"), which then contract with local governments, community action agencies, and non-profit organizations to implement weatherization projects.

The Weatherization Assistance Program takes a "whole house" approach to energy efficiency that addresses the building envelope, heating and cooling systems, and certain appliances. A health and safety component was formally incorporated by federal regulation in 1993. Since then, DOE has issued a series of guidance documents, known as Weatherization Program Notices (WPNs), to clarify federal requirements and recommendations in the area of health and safety. *WPN 17-7: Weatherization Health and Safety Guidance* includes a "Table of Issues" addressing several issues that are relevant to indoor and outdoor sources of particulate matter.[321] For each issue, the Guidance indicates whether actions to address the hazard are required, allowed, or, in a few cases, categorically prohibited.

Two health-related weatherization items are especially significant for reducing indoor exposure to outdoor-generated PM:

- Ventilation. WAP projects must provide ventilation that complies with ASHRAE 62.2-2016 (with certain exceptions in Climate Zone 1) and follow-up testing to verify performance. Clients must be provided information about system operation and maintenance, along with a "disclaimer that ASHRAE 62.2 does not account for high polluting sources or guarantee indoor air quality."[322]

- Air-conditioning. Primary air conditioning system replacement, repair, or installation is allowed only in homes where current occupants meet the grantee's definition of "at-risk" and climate conditions warrant. The grantee's health and safety plan must include protocols for air conditioning system installation and repair, including "what justifications are required, and a definition of "at-risk" occupants which justifies installation of cooling systems."[323]

WAP grantees have some flexibility to develop their programs in ways that will maximize indoor air quality and health benefits while meeting program guidelines. An important policy tool for doing so is the Health and Safety Plan (H&S Plan), which grantees must submit as part of their application. The H&S Plan reflects both the amount of program funding the state or other jurisdictions intends to allocate to health and safety expenditures in the upcoming year and the specific types of measures that will be

[320] U.S. Dept. of Energy (DOE), The Weatherization Assistance Program, https://www.energy.gov/eere/wipo/weatherization-assistance-program.
[321] U.S. DOE, Weatherization Program Notice 17-7: Weatherization Health and Safety Guidance [hereinafter WPN 17-7] – Table of Issues (2017), available at: https://www.energy.gov/eere/wipo/downloads/wpn-17-7-weatherization-health-and-safety-guidance. Indoor sources addressed in the WAP guidance but not within the scope of this report include inspection and proper installation of solid fuel-fired appliances; replacement of unvented gas- or liquid-fueled space heater as the primary heat source; proper venting of combustion appliances; and informing clients of the importance of using exhaust ventilation when cooking. *See also* WPN 17 – Attachment A, available at: https://www.energy.gov/eere/wipo/downloads/wpn-17-7-weatherization-health-and-safety-guidance.
[322] WPN 17-7 Table of Issues and WPN 17-7 Attachment A, available at: https://www.energy.gov/eere/wipo/downloads/wpn-17-7-weatherization-health-and-safety-guidance. Grantees may voluntarily elect to adopt the most recent version of ASHRAE 62.2 as soon as they are prepared to implement the standard.
[323] Id.

implemented. Following are some of the ways that state weatherization H&S Plans and related policies can facilitate enhanced consideration of PM exposure and other indoor air quality issues.

Prioritizing Health and Safety in Eligibility Determinations. Grantees make decisions in their WAP policies, procedures, and plans about how eligible homes will be prioritized, given funding and other administrative limitations. Federal policy requires programs to give priority to elderly and disabled persons, families with children, and households with high energy use and/or a high energy burden.[324] **Massachusetts**' 2019 WAP plan authorizes sub-grantees to set aside up to 25 percent of their annual for "hardship" households projects that fall outside the regular priority groups; these are defined to include homes with "a condition that endangers the health and safety of the eligible low income household."[325]

Facilitating Air Conditioning as an Eligible Health and Safety Measure. States indicate in their H&S Plans whether they allow measures that are not required (but also not prohibited) under federal regulations. States can allow air conditioning and can define at-risk populations to include those most vulnerable not only to heat, but to exposure from high outdoor PM concentrations.

Enhancing Ventilation and Filtration in WAP Projects. WAP guidance requires installation of ventilation that meets the ASHRAE 62.2 standard, though state program requirements may exceed this standard to address local conditions and priorities.[326] The **New Jersey** 2019 H&S Plan notes that ASHRAE 62.2 addresses "normal household conditions and does not account for high polluting sources" and provides that "additional ventilation may be necessary and is allowed to address higher concentrations of humidity or pollutants."[327] ASHRAE 62.2 requires MERV 6 filtration in ducted mechanical systems; grantees could include in their H&S Plan a requirement or option for providing higher-efficiency filtration – e.g., in homes that are located near major roadways or other local sources of air pollution.

Maximizing and Leveraging Funds for Health and Safety Measures. Federal law establishes a maximum WAP expenditure of $6,500 per unit, adjusted for inflation.[328] In **Vermont,** state law establishes a higher average per unit expenditure of $8,500, adjusted for inflation, and further requires the state program to allow "flexibility to accommodate special circumstances in which greater energy savings can be realized or health and safety problems may be alleviated."[329]

In addition to overall spending limits, grantees must establish spending caps for health and safety (as a percentage of overall expenditures) in their H&S Plans.[330] Because federal policies and guidance do not mandate the cap, there can be significant variation across states and other grantees. WAP guidance

[324] 10 C.F.R. 440.16.
[325] Mass. Office of Housing and Economic Development, U.S. DOE, Weatherization Assistance Program (WAP) State Plan/Master File Worksheet at 10 (2019), https://www.mass.gov/files/documents/2019/04/18/FY2019WAPMaster.pdf.
[326] DOE's guidance for service providers states: "The DOE identified version of ASHRAE 62.2 is a minimum ventilation standard, so Grantees may have incorporated additional guidelines based on local conditions." U.S. DOE, WAP Health and Safety Frequently Asked Questions (rev. 9/17), https://www.energy.gov/sites/prod/files/2017/09/f36/wpn-17-7FAQs_9.24.17.pdf.
[327] New Jersey H&S Plan 2019 at 13, 23, https://www.state.nj.us/dca/divisions/dhcr/offices/docs/wap/2019_DOE_State_Draft_Plan.pdf.
[328] 42 U.S.C. § 6865. For 2019, the average expenditure limit was $7,541. U.S. DOE, WPN 19-1, Program Year 2019 Weatherization Grant Guidance at 7 (Dec. 18, 2018), https://www.energy.gov/sites/prod/files/2018/12/f58/WPN-19-1.pdf.
[329] 33 Vt. Stat. §2502.
[330] 10 C.F.R. 440.16.

notes that "15 percent is not a limit on H&S expenditures but exceeding this amount will require ample justification" and a second level of review.[331] Nevertheless, some states do allocate higher amounts. For example, **Iowa** has allocated 25 percent of WAP funds to Health and Safety in recent years; in its 2016 H&S Plan, the state indicated that actual Health and Safety expenditures were higher, and that amounts "over the 25% allowable costs [are] covered with other, non-DOE funds."[332]

Some states have created significant new initiatives to integrate weatherization and health. In 2015, the state of **Washington** set aside funding to expand the health focus of its weatherization program. Legislation amended the state's home weatherization law to authorize WAP grantees to use program awards and matching funds to make "healthy housing improvements," and the state reserved $4.1 million for a new Weatherization Plus Health pilot initiative.[333] A 2018 report discussed in detail the results of the pilot, including some of the challenges in establishing a fully integrated service model within the existing WAP structure. The report found that there is a significant need for healthy homes measures and offered a range of recommendations, including integrating Weatherization Plus Health services "into existing services rather than [offering them] as a stand-alone program."[334] In 2018, the state began to expand its Weatherization Plus Health work to the full weatherization network around the state, seeking "to integrate Weatherization Plus Health as a regular service" by 2021.[335]

Vermont has also taken notable programmatic steps to integrate weatherization and health. In 2014, the state weatherization program began using a centralized referral process to facilitate the coordination of energy, health, and housing services. Weatherization providers in the state use a Vermont-specific version of "One Touch" – an electronic tool developed by Tohn Environmental Strategies that helps connect weatherization clients to health and housing home visiting and repair programs."[336] The tool automatically prompts electronic referrals to a wide variety of public agencies and non-governmental organizations throughout Vermont, including the Asthma Program at the Vermont Department of Health.[337]

Other Housing Funding Programs. The following are examples of housing improvement programs that could potentially be adapted to assist vulnerable households in addressing indoor PM exposures.

Healthy Homes/Asthma Programs. Many public health agencies and non-governmental organizations throughout the U.S. implement programs to address indoor environmental problems in homes, with a special focus on helping people who have asthma. The programs may include in-home

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[331] U.S. DOE, Weatherization Grantee Health and Safety Plan Optional Template, available at https://www.energy.gov/eere/wipo/downloads/wpn-17-7-weatherization-health-and-safety-guidance. According to WPN 17-7, "As a general rule, budgets that exceed 15% of Program Operations will require justification."

[332] Iowa H&S Plan 2016 at 1, https://humanrights.iowa.gov/sites/default/files/media/5_Wx_H%26S_Plan_0.pdf.

[333] Rev. Code Wa. §§ 70.164.010, 040; Wa. Dep't of Commerce, Weatherization Plus Health, http://www.commerce.wa.gov/growing-the-economy/energy/weatherization-and-energy-efficiency/matchmaker/weatherization-plus-health-wxh/. An additional $4.2 million was set aside for projects to reduce asthma risks and save energy and for "basic measures to improve home health."

[334] Wash. State Univ., Washington State Weatherization Plus Health Pilot: Implementation and Lessons Learned at 8, (2018), http://www.commerce.wa.gov/wp-content/uploads/2018/08/WxHSummaryReport1.pdf.

[335] Wa. Dep't of Commerce, Weatherization Plus Health at , http://www.commerce.wa.gov/growing-the-economy/energy/weatherization-and-energy-efficiency/matchmaker/weatherization-plus-health-wxh/.

[336] One Touch, Vermont, https://onetouchhousing.com/locations/vermont/.

[337] Vt. Dept. for Children and Families, Vermont's Weatherization Program Awarded HUD Secretary's Healthy Homes Award, https://dcf.vermont.gov/news/7-25-17.

assessments, education about behavior change, and modifications to the home. In some cases, these modifications may include installing or fixing air conditioners or air filters.[338]

In recent years, there have been notable efforts to identify sustainable funding sources for implementing healthy homes interventions.[339] One area of activity has been the development of innovative health care financing strategies to pay for preventive services not traditionally covered by medical insurance.

The Medicaid program, a federal-state partnership that provides health insurance for low-income and disabled individuals, offers states some flexibility in structuring their programs to cover preventive services that could potentially include home supplies (such as HEPA filters, air cleaners, and air conditioners) and other evidence-based asthma management interventions.[340] A number of states have pursued Medicaid policy changes toward this end. According to a 2014 survey by the National Center for Healthy Housing, thirteen states reported an existing Medicaid policy in place to cover home-based asthma services; of these, five paid for low-cost supplies and two covered structural remediation.[341]

Using Medicaid and other healthcare financing mechanisms for home repairs and remediation to reduce asthma triggers may not be a viable strategy in all jurisdictions. States and localities have also obtained support for their healthy homes intervention programs from sources such as tobacco settlements, excise fees and taxes, and federal categorical and block grants.[342]

Housing Repair/Improvement Grant Programs. States, tribes, and local governments administer a variety of home repair and renovation programs that could potentially be a source of funding to low-income homeowners to pay for air conditioning or to retrofit ventilation systems to provide enhanced filtration.

These programs receive support from a variety of federal programs, including HUD's Community Development Block Grant (CDBG) program, which funds housing and economic development activities serving low- and moderate-income communities.[343] HUD awards CDBG funds to states, tribes, and entitlement communities (localities), which in turn distribute the funds to projects in accordance with

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[338] HUD, Guide to Sustaining Effective Asthma Home Intervention Programs (2018), https://www.hud.gov/sites/dfiles/HH/documents/HUD%20Asthma%20Guide%20Document_Final_7_18.pdf.

[339] *See generally* Natl. Center for Healthy Homes, More Financing Mechanisms for Healthy Homes Services (2019), https://nchh.org/resource-library/report_strategies-toward-sustainability_more-financing-mechanisms-for-hh-services.pdf; Green & Healthy Homes Initiative, Sustainable Funding and Business Case for GHHI Home Interventions for Asthma Patients (2015), https://www.greenandhealthyhomes.org/wp-content/uploads/Sustainable-Funding-and-Business-Case-for-GHHI-Home-Interventions-for-Asthma-Patients_0.pdf.

[340] *See generally* Green & Healthy Homes Initiative, Sustainable Funding and Business Case for GHHI Home Interventions for Asthma Patients (2015), https://www.greenandhealthyhomes.org/wp-content/uploads/Sustainable-Funding-and-Business-Case-for-GHHI-Home-Interventions-for-Asthma-Patients_0.pdf; Natl. Center for Healthy Homes, Medicaid 101, https://nchh.org/tools-and-data/financing-and-funding/healthcare-financing/medicaid-101/.

[341] Natl. Center for Healthy Homes, Healthcare Financing of Healthy Homes at 12, https://nchh.org/resource-library/Reimbursement%20Landscape_MAIN%20REPORT_FINAL%20(18%20November%202014).pdf.

[342] Natl. Center for Healthy Homes, More Financing Mechanisms for Healthy Homes Services (2019), https://nchh.org/resource-library/report_strategies-toward-sustainability_more-financing-mechanisms-for-hh-services.pdf; Natl. Center for Healthy Homes, Healthcare Financing of Healthy Homes https://nchh.org/tools-and-data/financing-and-funding/healthcare-financing/.

[343] 42 U.S.C. §§ 5301 et seq.; 24 C.F.R. Pt. 570. Federal agencies also administer a variety of loan programs for homeowners. *See, e.g.*, HUD, 203(k) Rehabilitation Mortgage Insurance, https://www.hud.gov/program_offices/housing/sfh/203k; USDA, Single Family Housing Repair Loans and Grants (Section 504 program), https://www.rd.usda.gov/programs-services/single-family-housing-repair-loans-grants.

federal regulations.[344] Priorities for distributing funds are incorporated into CDBG planning documents, which must be developed with citizen participation.[345]

The improvement of owner-occupied housing is one of the most common areas of CDBG activity. Grantees can provide "grants, loans, loan guarantees, interest subsidies, or other forms of assistance to homeowners for the purpose of repairs, rehabilitation, or reconstruction."[346] Grantees have "flexibility under the CDBG Program to design repair and rehabilitation programs that meet the needs of their residents," and thus can set up a program with CDBG funding to support emergency repairs, weatherization, and other activities that might include improvements to ventilation, filtration, and air conditioning in low-income households.[347] Grantees can also provide similar assistance for the rehabilitation of rental housing.[348]

Some states have established their own financial assistance programs for residential rehabilitation or repair. One example is **Minnesota**'s Rehabilitation Loan Program, carried out by Minnesota Housing. Loans up to $27,000 are available to low-income homeowners to improve the safety, livability, or energy efficiency of their homes. Loans are forgiven if the owner does not sell, transfer, or move out of the property during the loan term.[349] The agency's Rental Rehabilitation Deferred Loan program makes available loans for health and safety improvements to owners of affordable multifamily rental housing outside the metropolitan areas. Loans are typically issued as interest-free, deferred loans with a 20-year term, and 10 percent of the loan amount may be forgiven provided the owner maintains rent and income restrictions for the property.[350]

According to the Housing Trust Fund Project, nearly all states (and hundreds of local jurisdictions) operate housing trust funds, which "receive ongoing dedicated sources of public funding to support the preservation and production of affordable housing."[351] Within this broad purpose, state laws, regulations, and/or guidance determine eligible projects and priorities for funding. While these programs often emphasize new construction, they may also include rehabilitation and repair. The Housing Trust Fund Project provides a list of states with housing trust funds and the agencies that operate those programs.[352]

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[344] 42 US.C. § 5303.

[345] Documents that must be submitted to HUD include an Annual Action Plan and a three- to five-year Consolidated Plan. 24 C.F.R. 570.302, 24 C.F.R. Pt. 91. Consolidated Plans also cover other federal formula grant programs that might be relevant to home repair and rehabilitation, such as the HOME Investment Partnerships Program. 42 U.S.C. § 92.205.

[346] HUD, Basically CDBG at 4-2 (2012), https://files.hudexchange.info/resources/documents/Basically-CDBG-Chapter-4-Housing.pdf.

[347] Id. at 4-1.

[348] Id. at 4-5.

[349] Minn. Housing Finance Agency, Rehabilitation Loan/Emergency and Accessibility Loan Program, http://www.mnhousing.gov/sites/Satellite?c=Page&cid=1358904992980&d=Touch&pagename=External%2FPage%2FEXTStandardLayout.

[350] Loans may not be used for improvements that are not permanent fixtures to the property, with the exception of appliances. Minn. Housing Finance Agency, Rental Rehabilitation Deferred Loan Pilot Program Interim Guide, available at: http://www.mnhousing.gov/sites/Satellite?c=Page&cid=1358905404900&d=Touch&pagename=External%2FPage%2FEXTStandardLayout. Minnesota Statutes § 462A.05 provides general authority for the program.

[351] Housing Trust Fund Project, What are Housing Trust Funds, https://housingtrustfundproject.org/our-project/about/.

[352] Housing Trust Fund Project, State Housing Trust Funds 2019, https://housingtrustfundproject.org/wp-content/uploads/2019/01/State-htfund-admin-and-date-2019.pdf.

Energy Assistance Programs. Energy assistance programs are one mechanism for providing air conditioning to lower-income households. The largest source of such funds is the federal Low-Income Home Energy Assistance Program (LIHEAP).[353] All 50 states, the District of Columbia, several U.S. territories, and over 150 tribes and tribal organizations receive LIHEAP block grants from the U.S. Department of Health and Human Services each year.[354] Grantees in turn distribute the funds to eligible households.

LIHEAP block grant funds may be used for space-heating or space-cooling, as well as weatherization.[355] In fiscal year 2014, approximately 49 percent of all LIHEAP funds went to pay for heating assistance, while only seven percent were used for cooling aid and nine percent for weatherization.[356] Nonetheless, LIHEAP funds can be used both to subsidize utility costs for running air conditioners and to purchase or repair an air conditioning unit, and many states operate cooling programs with their LIHEAP funds.[357] The LIHEAP Plan (submitted with a grantee's annual funding application) includes a description of how states will provide cooling assistance, including how the program will prioritize vulnerable households.[358]

As states, territories, and tribes plan for future LIHEAP grants, they might consider expanding the portion of their grants dedicated to cooling assistance for vulnerable individuals, including those exposed to high outdoor PM levels from wildfires, major roadways, or other local air pollution sources. In light of rising average temperatures and more intense heat waves, increased overall funding for energy assistance programs may be needed to respond to the greater need for cooling.

States can also consider establishing or expanding laws that prohibit utilities from disconnecting a customer's service (e.g., due to nonpayment) during extreme weather. A number of states already have laws that prohibit shut-off in periods of high heat, as well as severe cold.[359]

[353] 42 U.S.C. §§ 8621-8630.
[354] U.S. Dept. of Health & Human Svcs., LIHEAP Fact Sheet (2018), https://www.acf.hhs.gov/ocs/resource/liheap-fact-sheet-0.
[355] Id.
[356] *See* Congr. Research Service, LIHEAP: Program and Funding (Summary) (rev. 2018), https://crsreports.congress.gov/product/pdf/RL/RL31865. Of the remaining funds, in addition to administrative costs and carryover funds, 21% went to "crisis assistance."
[357] *See* U.S. Dept. of Health & Human Svcs., State and Territory Cooling Programs, https://liheapch.acf.hhs.gov/tables/cooling.htm. *See also,* U.S. DHHS, State Low-Income Energy Assistance Snapshots, https://liheapch.acf.hhs.gov/snapshots.htm.
[358] *See* U.S. Dept. of Health & Human Svcs., State Fiscal 2019 LIHEAP Plans, https://liheapch.acf.hhs.gov/stateplans.htm. Some states prioritize households with older adults, young children, disabled individuals, or those with medical conditions.
[359] *See* U.S. Dept. of Health and Human Services, Utility Disconnection Policies, https://liheapch.acf.hhs.gov/Disconnect/disconnect.htm.

Innovative Funding for Improving Air Filtration in California: Using SEPs and Other Environmental Enforcement Settlement Funds

A Supplemental Environmental Project (SEP) is an environmentally-beneficial project that the defendant voluntarily agrees to undertake as part of the settlement of an environmental enforcement case. SEPs must generally reduce the impact of the violation on public health or the environment, and they cannot be projects the violator is already required to do. The U.S. EPA and many states have guidance on SEPs, and some states maintain lists of projects that could potentially be funded through a SEP.[360]

In Southern California, the **South Coast Air Quality Management District** (South Coast AQMD) has developed a project to install air filtration systems in schools, with support from SEP and other case settlement funds.[361] To become eligible for funding from state enforcement settlements, South Coast AQMD submitted a proposed project to the state Air Resources Board. Once approved, the project was available to the Attorney General and other state agencies to include in appropriate cases. By late 2019, the agency had provided filtration in 90 schools and two community centers in environmental justice communities exposed to multiple air pollution sources, including major roads and commercial facilities.

One notable case was a 2018 settlement with Southern California Gas concerning the Aliso Canyon gas leak, which included a $45 million SEP fund, of which $7 million was set aside by South Coast AQMD to install air filters in public schools in Los Angeles.[362] South Coast AQMD has also received SEP funding for air filter projects from enforcement cases brought by the agency itself. The settlement in a 2018 air pollution case against Brenntag Pacific, a cleaning-product maker/distributor, included a $250,000 SEP to install air filtration systems in an elementary school, high school, and community daycare facility.[363]

CARB recently approved a second South Coast AQMD SEP project proposal to install and maintain high-performance air filtration systems in *homes* located in communities heavily impacted by air pollution. South Coast AQMD will be administering its first residential air filtration SEP pending Board approval in spring 2020 for a pilot project to install air filtration systems in a small group of homes in a disadvantaged community in San Bernardino near the railyards.

The city of **San Francisco** has also used settlement funds to pay for mitigation projects in affected communities. In 2011, the city appropriated $1 million in settlement funds from a case it brought against the Potrero Power Plant, to be used for "neighborhood improvement and mitigation in the neighborhoods most impacted" by the plant. Around $150,000 of this amount was allocated for a project installing and evaluating measures – e.g., furnace filtration retrofits, building envelope air sealing, and portable air cleaners – to reduce near-road exposures in homes.[364]

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[360] EPA, Supplemental Environmental Projects, https://www.epa.gov/enforcement/supplemental-environmental-projects-seps.
[361] Information about South Coast AQMD SEPs is based partly on communications between ELI and the agency in late 2019.
[362] *See* Cal. Office of the Attorney General, Supplemental Environmental Projects (SEPs), https://oag.ca.gov/system/files/attachments/press-docs/supplemental-environmental.pdf and Notice of Lodging of Proposed Consent Decree, https://oag.ca.gov/system/files/attachments/press-docs/notice-lodging-and-proposed-cd-full.pdf.
[363] *See* SCAQMD, Meeting Agenda (2/2/18), http://www.aqmd.gov/docs/default-source/Agendas/Governing-Board/2018/brdpkg-2018-feb2.pdf.
[364] *See* San Francisco Dept. of Public Health, April 2014 Mirant Settlement Progress Report: Potrero Hill Community Health, https://www.sfdph.org/dph/files/reports/MirantReport-041114.pdf and Measurement Study to Evaluate Controls for Reducing

Funding to Reduce Wildfire Smoke Exposures

Although states, tribes, and local governments do not regulate indoor wildfire smoke exposure directly, agencies have increased their public health activities in this area in response to the growing frequency and intensity of wildfire events. Existing public health programs addressing wildfire smoke focus heavily on providing air quality monitoring data and communicating best practices for reducing exposure. Education and outreach programs are critical to giving people clear information on steps they should take during wildfire smoke episodes, and EPA's *Wildfire Smoke Guide* has been an important tool for facilitating consistent public health messaging and increasing public awareness.

Yet for some residents, information alone will not be enough to reduce risk. People who are most vulnerable to the health effects of smoke – especially those with lower incomes – may require *material* assistance in order to carry out a core recommendation communicated by EPA and public health officials: stay indoors in a location with effective filtration of outdoor air. State and local policies and programs can be developed in advance of wildfire smoke episodes to improve the resilience of residential buildings. Programs can also be developed to assist homeless individuals in finding adequate shelter from wildfire smoke events.

Legislation introduced in the U.S. Senate in June 2019 recognizes the need for such interventions. Senate Bill 1813 would authorize grants, equipment, supplies, and personnel to states, tribes, and local governments for wildfire smoke mitigation assistance, including provision of respirators, mechanical air filters, portable air filters, and upgrading HVAC systems in public buildings. The legislation would also require HUD to establish a program to "increase the smoke resiliency of dwellings owned or occupied by vulnerable persons" including activities such as "weatherization measures to mitigate air infiltration, installing air filtration systems, and providing assistance for related energy costs from the operation of those systems."[365]

States have begun to consider and enact policies that acknowledge broadly the increasing health threat posed by wildfire smoke episodes and the need to take action to assist vulnerable residents. In January 2019, **Oregon**'s Governor issued Executive Order 19-01, creating the Governor's Council on Wildfire Response and stating, "We know from the last several wildfire seasons that systems must be in place to protect our citizens from the smoke caused by wildfires" and that residents "most vulnerable to dangerous air quality must be quickly identified and appropriate resources must be used to protect them."[366] In September 2019, **California** enacted legislation directing the Sacramento Metropolitan Air Quality Management District to prepare a wildfire smoke air pollution emergency plan that includes, among other things, specific strategies to address vulnerable populations, and protocols for monitoring air quality at schools.[367]

In-Home Pollutant Exposures at Homes Near High Trafficked Roadways, https://sfgov.org/asthma/sites/default/files/SFDPH_IndoorAir7%20interactive.pdf.

[365] U.S. SB 1813 (Smoke-Ready Communities Act of 2019).

[366] Oregon Exec. Order 19-01, Establishing the Governor's Council on Wildfire Response (1/30/19), available at: https://www.oregon.gov/gov/admin/Pages/executive-orders.aspx.

[367] Ca. AB 661, https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200AB661. The original version of the bill required all air districts to prepare such a plan; the bill was amended to limit the requirement to a pilot program for the Sacramento district. Cal. Senate Committee on Environmental Quality, Bill Analysis (6/19/19), available at: https://leginfo.legislature.ca.gov/faces/billAnalysisClient.xhtml?bill_id=201920200AB661.

One type of direct assistance provided by many jurisdictions affected by wildfire smoke is the distribution of respiratory protection equipment in the form of N-95 masks, which can be helpful for some people if fitted and worn properly. The masks are relatively inexpensive, and a number of agencies have provided them – along with instructions – to community members during wildfire events.[368] However, they are not made for children, and adults with preexisting respiratory or other health problems may be unable to wear respirators because the masks may make it harder to breathe. EPA's *Wildfire Smoke Guide* notes that, while respirators "are widely available and offer some protection for adults if selected and used properly…the public should be advised to take more effective measures first to limit their exposures."[369]

Following are examples of state programs that provide direct material assistance to vulnerable populations to help them stay indoors with adequate filtration – programs for establishing cleaner air shelters and for providing equipment needed for people to create clean air spaces at home. At the end of the section is a description of Missoula, Montana's comprehensive strategy to reduce wildfire smoke exposure, which includes retrofitting schools and other public buildings to enhance filtration and providing air filtration equipment to needy residents.

Establishing Cleaner Air Shelters. As wildfires become larger and more destructive, tribes and local governments are increasingly called on to provide shelter at publicly-accessible buildings and to ensure that their availability is publicized widely through community organizations and programs, social media, and other outreach channels.

Though similar to providing cooling centers during heat waves, cleaner air shelters must also ensure adequate protection against outdoor PM. EPA's *Wildfire Smoke Guide* provides detailed guidance on setting up shelters and recommends that public health officials identify and evaluate public spaces for this purpose well in advance of fire season. Policymakers and agency officials are beginning to address one of the main problems in providing these shelters: many libraries, schools, and other public buildings lack mechanical systems capable of providing high-efficiency filtration.

- A **California** law enacted in October 2019 established the Wildfire Smoke Clean Air Centers for Vulnerable Populations Incentive Pilot Program to "provide funding through a grant program to retrofit ventilation systems to create a network of clean air centers in order to mitigate the adverse public health impacts due to wildfires and other smoke events." The program, administered by the California Air Resources Board, will create a network of clean air centers at schools, community centers, libraries, and other public buildings, in order to reduce exposure to wildfires and other smoke events. The law is notable for prioritizing applications for projects located in areas with documented high cumulative smoke exposure burdens and for requiring program guidelines and eligibility criteria to consider locating facilities near vulnerable populations, including communities with diverse racial and ethnic populations and low-income communities.[370]

[368] *See, e.g.*, C. Morgan, "Sacramento to Give Residents Masks Due to Poor Air Quality," *Sacramento Bee* (11/11/18), https://www.sacbee.com/latest-news/article221513700.html; Hoopa Valley Tribe, N95 Masks Available to the Public Distribution at K'ima:w Medical Center in Hoopa (Aug. 2015) http://www.riodelltimes.com/PressRelease/8.27.15FilterMasksAvailableToThePublicInHoopa.pdf.

[369] EPA Wildfire Smoke Guide, supra, at 26-27.

[370] Ca. AB 836. The original bill limited the pilot program to the San Francisco Bay Area but was subsequently amended to include a statewide program.

- In **Seattle**, where many homes lack cooling or air filtration, the city carried out a pilot project in 2019 to upgrade air filtration and enhance air sealing in five public facilities that have central cooling. The city plans to use the pilot to help determine improvements needed in older buildings, including community centers that rely on natural ventilation.[371]

- In the **San Francisco Bay Area**, the Bay Area Air Quality Management District (BAAQMD) has developed a Wildfire Air Quality Response Program that emphasizes cleaner air facilities as "the safest and most cost-effective option." Under this program, the BAAQMD plans to distribute grant funding to establish additional facilities across the Bay Area, and the agency is also working with the American Red Cross to develop strategies for prioritizing better air filtration at existing sheltering facilities and evacuation centers during emergencies. In addition, the BAAQMD has collaborated with the California Air Pollution Control Officers Association and local public health officers to provide community and school-based wildfire safety and health information, and the agency has recently amended rules that will increase the Air District's authority to take action during wildfire events.[372]

Providing Air Filtration and Air Conditioning. Beyond the financial and logistical challenges of establishing and maintaining cleaner air shelters, there may be practical challenges for residents in using the shelters. For example, some people may have physical or logistical difficulties traveling to the shelters. Others may not be able to stay in shelters for long periods of time, given work and other obligations. As noted earlier, EPA recommends establishing a "clean room" in the home by setting up a properly sized room air cleaner and running an air conditioner or central air conditioning system.

EPA's *Wildfire Smoke Guide* recommends that public health officials "consider approaches to supplying portable air cleaners" and notes that it is best to buy an air cleaner "before a smoke emergency occurs, particularly in homes with occupants in at risk groups." [373] State and local governments can help implement these recommendations by developing public policies and programs to assist vulnerable residents in obtaining equipment needed to set up clean air spaces in their homes *before* a wildfire smoke event. Portable air cleaners and air conditioners can potentially benefit vulnerable residents not only during wildfire events, but also during other episodes of poor outdoor and/or indoor air quality and in times of extreme heat.

In 2019, Montana considered, but did not enact, legislation focused on ensuring adequate filtration for reducing wildfire smoke in homes and other buildings. The bill called on the state to gather information about wildfire smoke filtration for residential and commercial buildings in the state, identify the air

[371] City of Seattle, Office of the Mayor, City of Seattle Upgrades Community Centers, Seattle Center Buildings with HVA and Air Filtration Systems (June 2019), https://durkan.seattle.gov/2019/06/to-protect-vulnerable-communities-in-preparation-for-wildfire-smoke-in-the-puget-sound-region-city-of-seattle-upgrades-community-centers-seattle-center-buildings-with-hvac-and-air-filtration-systems/.

[372] Bay Area Air Quality Mgmt. District, Wildfire Air Quality Response Program and Public Messaging (presentation) (9/4/19) http://www.baaqmd.gov/~/media/files/board-of-directors/2019/bod_presentation_090419-pdf.pdf?la=en. As noted, earlier, BAAQMD enacted a rule to authorize wood-burning bans during wildfire events. BAAQMD Regulation 6, Rule 3, available at: http://www.baaqmd.gov/rules-and-compliance/rules/reg-6-rule-3-woodburning-devices?rule_version=Under%20Development.

[373] EPA Wildfire Smoke Guide, supra, at 49, 22.

filtration status of publicly-owned buildings in smoke impacted areas, and develop legislation to update or revise related state laws, as appropriate.[374]

The **Hoopa Valley Tribe** and the **Yurok Tribe** are examples of jurisdictions that have carried out programs to distribute air filters to residents severely impacted by wildfire smoke events. The Hoopa Valley Tribe worked closely with medical centers to distribute portable air filters to susceptive individuals.[375] One source of funding for this effort was the federal Community Development Block Grant for Disaster Recovery (CDBG–DR) program, administered by the state of California.[376] The tribe designated a portion of the funding for providing health monitoring equipment and portable HEPA air cleaners to those with increased risk of health complications from smoke inhalation health and also used some of the funds to upgrade filtration systems in public buildings undergoing renovation.[377] The Yurok Tribe also used HUD CDBG-DR grant funding through the state of California to purchase two industrial portable HEPA filters for community shelters and 75 HEPA filters for eligible households.[378]

Non-governmental organizations have also developed programs to distribute portable air filters using public and private funding. For example, the Fire Department in Santa Fe, New Mexico provided funding to a non-profit organization, the Forest Stewards Guild, for the purchase of several air filters to prevent negative health impacts from smoke during prescribed fires. In addition to lending out the HEPA filters (typically to older adults) during prescribed burns, the program has also provided the filters to other communities in New Mexico for use in shelters and homes during wildfires. The Forest Stewards Guild is also working with Fire Adapted Communities of New Mexico and New Mexico State University, which have purchased additional portable air filters to lend to sensitive individuals in rural areas of northern New Mexico during smoke events.[379]

Another non-profit organization, Climate Smart Missoula, has partnered with the local health department in Missoula, Montana to implement one of the nation's leading programs for reducing wildfire smoke exposure.

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[374] A vote on the measure failed 50-49. Montana HJ 42 (2019), http://laws.leg.mt.gov/legprd/LAW0203W$BSRV.ActionQuery?P_SESS=20191&P_BLTP_BILL_TYP_CD=HJ&P_BILL_NO=42&P_BILL_DFT_NO=&P_CHPT_NO=&Z_ACTION=Find&P_ENTY_ID_SEQ2=&P_SBJT_SBJ_CD=&P_ENTY_ID_SEQ=.

[375] *See* Hoopa Valley Tribal Council, Hoopa Public Health Threat: 2015 Public Service Announcement (8/20/15) (on file with ELI); A. Hostler, "Hoopa Tribe Gets $4.1 Million for a Healthy Facelift," *Two Rivers Tribune* (9/16/11), http://www.tworiverstribune.com/2011/09/hoopa-tribe-gets-4-1-million-for-a-healthy-facelift/; J. Mott, et al., Wildland Forest Fire Smoke: Health Effects and Intervention Evaluation, Hoopa, California, 1999, *West. J. Med.* 176(3), 157–162 (2002), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1071703/.

[376] State of California, Action Plan for Disaster Recovery (2008 Wildfires), http://www.hcd.ca.gov/community-development/disaster-recovery-programs/cdbg-dr/docs/2008_DRI_Action_Plan.pdf. Congress has on multiple occasions enacted appropriations acts that provide CDBG-DR funding following declared disasters. The CDBG program regulations apply to the use of CDBG-DR funds, however appropriations acts may establish additional requirements and/or grant HUD authority to issue waivers from CDBG requirement. *See* HUD, CDBG-DR Laws, Regulations, and Federal Register Notices, https://www.hudexchange.info/programs/cdbg-dr/cdbg-dr-laws-regulations-and-federal-register-notices/.

[377] *See* A. Hostler, "Hoopa Tribe Gets $4.1 Million for a Healthy Facelift," *Two Rivers Tribune* (9/16/11), http://www.tworiverstribune.com/2011/09/hoopa-tribe-gets-4-1-million-for-a-healthy-facelift/.

[378] Cal. Dept. of Housing and Community Devt., Disaster Recovery Initiative Grant Performance Report, July 2011- September 2011 at 40, 42, http://www.hcd.ca.gov/community-development/disaster-recovery-programs/cdbg-dr/docs/3.DRI_08_July_2011_thru_September_2011_Performance_Report.pdf.

[379] ELI communications with Forest Stewards Guild (May 2019); Forest Stewards Guild, HEPA Air Filter Check-Out Contract, https://static1.squarespace.com/static/57b62cb1ebbd1a48387a40ef/t/5ad7c67070a6ad81ab1f7259/1524090483239/HEPA_Check_Out_Form.pdf; Fire Adapted New Mexico, Smoke. https://facnm.org/smoke.

Reducing Indoor Exposure to Wildfire Smoke in Missoula, Montana: Marshalling Resources to Help Vulnerable and Underserved Residents

Missoula is a city of around 75,000 people, located in western Montana. In the wake of record wildfire events in 2017, when indoor PM measurements in some public buildings showed pollutant levels comparable to those outdoors, the Missoula City-County Health Department (Missoula Public Health) redoubled its efforts to reduce the public health impacts of wildfire smoke. What is noteworthy about the approach taken by Missoula Public Health is its comprehensive scope and express focus on providing resources to help vulnerable and underserved populations, including those who are in financial need and those who are homeless.

Missoula Public Health changed its wildfire smoke strategy from "stay inside" to "stay inside with filtered air" and added the strategy of creating clean air spaces indoors through direct interventions and through policy and institutional controls. The program defines a smoke-ready community as one where public buildings have filtration for wildfire smoke, residents understand the health risks of wildfire smoke and have access to tools to protect themselves, and resources are on hand to help vulnerable and underserved residents.[380]

In conjunction with a strong communications effort that incorporates websites, press releases, and a regular local newspaper column, the program has provided high-efficiency filtration in homes, schools, and other locations serving vulnerable residents. In addition to building retrofits, the program aims to supply "appropriately sized, portable air cleaners with true…[HEPA] filtration in buildings without HVAC systems."[381] While Missoula Public Health provides portable air cleaners through a loan program, Climate Smart Missoula (CSM) lends and gives away units from its cache of air cleaners.

Schools have been a major emphasis of the Missoula program, which began loaning portable air cleaners to public schools in 2017 and has provided more than 70 air cleaners thus far. A 2018 report by CSM estimated a cost of $107,100 to provide portable HEPA air cleaners (not including filter replacement) to the 357 classrooms that still lacked any means to filter smoke and did not have plans for updating their HVAC systems. The report found that nearly 85 percent of schools in Missoula have filtration at MERV 8 or lower, and thus lack adequate methods for ensuring clean air during a Wildfire Smoke episode.[382]

The information in the report has provided additional impetus for achieving higher efficiency filtration in schools, including new schools. Missoula passed a school building bond that has supported a large number of school construction projects, and these projects must obtain plan review through Missoula Public Health. Through the joint efforts of the health department and Missoula County Public Schools, all

[380] S. Coefield, Missoula City-County Health Dept., Mitigation Measures in Missoula County (May 2019 webinar presentation), https://www.healtheffects.org/sites/default/files/Coefield-wildfires-HEI-2019.pdf.
[381] Id.
[382] Climate Smart Missoula, Clean Air Needs Assessment: Addressing wildfire smoke in public schools within Missoula County, https://www.missoulaclimate.org/uploads/4/3/2/6/43267085/cleanairneedsassessment_report_fall2018.pdf.

school construction and retrofit projects have included MERV 13 filtration.[383] In addition, the state has issued a proposed rule to require that existing public schools perform regular HVAC inspections and use higher-efficiency filtration.[384]

Missoula's air filter efforts extend beyond schools. The agencies distributed almost 100 portable units to daycares and preschools serving over 500 children in 2018.385 The program has also partnered with Missoula Aging Services, Meals on Wheels, and a local clinic to place filters in the homes of medically-needy residents.386 And Missoula's new library, set to open in 2020, will have MERV 13 filtration installed during wildfire season.

In 2017, CSM worked with the University of Montana on an assessment of indoor air quality during the summer wildfire season, which underscored the necessity of intentionally cleaning indoor air during a smoke event.387 Building on this initial assessment, Missoula Public Health, EPA, and the University on Montana launched a more rigorous study examining indoor air quality in public spaces with different types and levels of air filtration.[388]

Missoula Public Health and CSM have sought and obtained funding for their air filtration work from a wide variety of sources, including medical facilities, foundations, corporations, individual donations, manufacturer discounts, and the state's Public Health Emergency Preparedness Fund. The success of Missoula's initiative also reflects the strong support of partners within and outside government – including elected officials and agency managers – who share a sense of urgency about creating cleaner air spaces for vulnerable populations.[389]

Discussion

Financial assistance is a key consideration in developing policies and programs to reduce indoor PM exposure for vulnerable individuals. In light of the wide array of public health challenges that compete for limited funding, it is important to ensure that affected communities are included in the process of identifying funding priorities and developing programs to reduce exposure. It is also important for material assistance programs to educate recipients about how to use equipment effectively to reduce outdoor PM exposure (e.g., filter maintenance, adjusting air conditioners and ventilation systems during pollution events) and about opportunities for reducing other sources of PM in the home (e.g., using adequate kitchen exhaust and avoiding wood burning).

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[383] ELI communications with Missoula Public Health (Nov. 2019).
[384] S. Coefield, Missoula City-County Health Dept., Mitigation Measures in Missoula County (May 2019 webinar presentation), https://www.healtheffects.org/sites/default/files/Coefield-wildfires-HEI-2019.pdf; Mt. Dept. of Public Health & Human Svcs., Notice of Public Hearing in the Matter of the Adoption of New Rules I through IV, https://dphhs.mt.gov/Portals/85/publichealth/documents/SchoolHealth/School%20Rules/37-873pro-arm.pdf?ver=2019-06-26-144704-910.
[385] S. Luth, et al., Sustainable Missoula: Protecting our Children's Indoor Air in a Hotter, Smokier Climate, Missoula Current (10/5/18), https://www.missoulacurrent.com/opinion/2018/10/missoula-wildfire-smoke-2/.
[386] Climate Smart Missoula, HEPA Air Filtration, https://www.missoulaclimate.org/hepa-air-filtration.html.
[387] Climate Smart Missoula, Studying Indoor Air Quality, https://www.missoulaclimate.org/studying-indoor-air-quality.html.
[388] The study involves placing PurpleAir sensors inside and outside 18 buildings around Missoula, as well as using a portable air sensor that is being driven around the areas to track how pollution varies based on the topography. ELI communications with Missoula Public Health (Nov. 2019).
[389] Climate Smart Missoula, Clean Air for Schools and Daycares, https://www.missoulaclimate.org/clean-air-for-schools--daycares.html.

Leveraging Existing Programs. A review of existing financial assistance programs is a starting point for identifying potential resources. Weatherization and other energy-efficiency retrofit programs that already address infiltration and ventilation may be options for incorporating high-efficiency in-duct filtration in existing homes. Existing housing repair/rehabilitation and healthy homes programs might also be able to provide in-duct filtration, portable air cleaners, or air conditioning units in some cases. Energy assistance programs are a potential source of funding in most states to help purchase air conditioning units and to subsidize the utility costs of using cooling equipment. Healthy homes programs have begun to tap into health insurance and other innovative sources of funding for interventions in the homes of patients with asthma and other chronic diseases.

Jurisdictions that administer these and similar programs can consider adjusting program guidelines and priorities to assist households most at risk from indoor PM exposure. Coordination among agencies and with outside organizations might help maximize available resources and facilitate appropriate referrals to programs that can provide necessary repairs or upgrades in the home.

Where current funding programs cannot be adapted, jurisdictions might consider establishing a pilot program to address the most significant indoor PM exposures – e.g., by purchasing a cache of portable air filters to give or lend to homes in advance of wildfire smoke episodes, or by retrofitting mechanical systems to accommodate higher-efficiency filters in homes near major roadways. States, tribes, and local governments have developed a variety of such programs both within the scope of existing regulatory authorities and as new legislative measures.

Identifying Vulnerable Individuals. Limited resources can be focused on supporting individuals at greatest risk of health problems from PM exposure. This includes medically vulnerable individuals, such as older adults and people with acute or chronic respiratory and cardiovascular disease. It may also include communities of color and lower-income communities that are situated in close proximity to multiple local sources, including major roads and industrial facilities. Because children are also at increased risk, program assistance can be provided to home-based child care serving lower-income families.

Identifying individuals that are most vulnerable to outdoor pollution may thus be an important first step in developing a financial assistance program. Local agencies can work with medical facilities that seek help for patients whose home environment may be contributing to their health problems. This type of collaboration has been used, for example, in distributing air cleaners during wildfire smoke events.

Additionally, agencies can expand their community-level air quality monitoring to determine where air pollution is creating the greatest health risks. For example, in the **San Francisco Bay Area**, the Bay Area Air Quality Management District has implemented a Community Air Risk Evaluation (CARE) program since 2004 to "identify areas with high concentrations of air pollution and populations most vulnerable to air pollution's health impacts."[390] As part of this program, the BAAQMD has updated its methodology for identifying areas where the health impacts of air pollution are high, in order to prioritize and focus outreach, education, and other "activities that mitigate air pollution exposures from local emissions sources…such as grant and incentive funding, enforcement efforts, local and regional planning efforts,

[390] BAAQMD, Community Air Risk Evaluation Program, http://www.baaqmd.gov/community-health/community-health-protection-program/community-air-risk-evaluation-care-program

and the adoption of new and amended regulations."[391] The CARE program helped spur the passage of Assembly Bill 617 in 2017, which has provided impetus for additional local air monitoring. Among other things, the law directs the California Air Resources Board to determine, in consultation with community groups and other stakeholders, the need for additional community air monitoring and to select "the highest priority locations around the state to deploy community air monitoring systems, which shall be communities with high exposure burdens for toxic air contaminants and criteria air pollutants."[392]

The emergence of low-cost, reliable PM sensors has greatly expanded the opportunities for conducting community-level monitoring to refine air quality modeling and to identify and address local pollution sources.[393] Indeed, over a relatively short period of time there has been a dramatic surge in local ambient air quality monitoring initiatives by governments, researchers, community groups, and individuals.[394] In California alone, as of January 2019, "more than 2500 non-regulatory air quality sensors have been purchased and deployed across California by community groups, government agencies, private citizens, and others.[395] As the technology advances and these devices become more ubiquitous indoors – in the form of apps for smart phones or stand-alone and wearable devices – they will create new opportunities and challenges for agencies in developing policies and programs to assist community residents in reducing their risk from indoor exposure to particle pollution.

[391] Bay Area Air Quality Mgmt. District, Identifying Areas with Cumulative Impacts from Air Pollution in the San Francisco Bay Area at 4 (2014), available at: http://www.baaqmd.gov/community-health/community-health-protection-program/community-air-risk-evaluation-care-program/documents.

[392] Ca. AB 617, amending Ca. Health & Safety Code § 42705.5.

[393] *See generally,* U.S. EPA, Evaluation of Emerging Air Pollution Sensor Performance, https://www.epa.gov/air-sensor-toolbox/evaluation-emerging-air-pollution-sensor-performance; Lawrence Berkeley Natl. Lab., Air Quality Sensors, https://indoor.lbl.gov/air-quality-sensors.

[394] *See, e.g.*, Lane Regional Air Protection Agency (Lane County, Oregon), Air Quality Sensors, https://www.lrapa.org/307/Air-Quality-Sensors; Puget Sound Clean Air Agency, Air Monitoring Report (2018), https://www.pscleanair.org/385/Duwamish-Valley.

[395] Cal. Air Resources Board, Annual Report on the California Air Resources Board's Fine Particulate Matter Monitoring Program at 4 (2019), https://ww2.arb.ca.gov/sites/default/files/2019-02/pm25-monitoring-2019.pdf.

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