Gas Stove Emissions Are a Public Health Concern: Exposure to Indoor Nitrogen Dioxide Increases Risk of Illness in Children, Older Adults, and People with Underlying Health Conditions

Policy Date: November 8, 2022
Policy Number: 20225

Abstract

"Natural" gas stoves generate a number of harmful air pollutants, with nitrogen dioxide (NO_2) most consistently identified in the scientific literature. Multiple high-quality scientific studies have shown that NO_2 concentrations are higher in homes that use gas stoves and that cooking with gas stoves without ventilation can result in home NO_2 concentrations that are above the ambient air quality standards of the Environmental Protection Agency (EPA). The EPA has determined that NO_2 is "causal" of more severe respiratory symptoms in people with asthma and that long-term exposure to NO_2 is "likely causal" of respiratory illnesses such as asthma. Furthermore, epidemiological studies have shown that gas stoves are associated with an increased risk of asthma in children as well as more severe asthma symptoms. Despite this evidence, few safeguards are in place to protect the health of the public from gas stove emissions, particularly in overburdened and underserved communities. While comprehensive federal law regulates outdoor air quality in the United States, there are no federal indoor air quality guidelines, and few state or local policies address indoor air pollution. Those living in smaller, older, less ventilated homes are at higher risk of the effects of indoor air pollutants from a variety of sources, introducing a disproportionate risk of illness among lower-income populations and people of color. Along with other healthy home improvements, health experts should advocate for an equitable, multipronged approach to combat indoor air pollution from gas stoves, including policy change, program development, education about emission mitigation, and investment.

Relationship to Existing APHA Policy Statements

The following existing APHA policy statements support this proposed policy statement by addressing issues and topics related to air pollution, respiratory disease, gas, energy policy, climate change, and health equity.

- APHA Policy Statement 201711: Public Health Opportunities to Address the Health Effects of Air Pollution
- APHA Policy Statement 20183: The Public Health Impacts of Energy Policy in the United States

- APHA Policy Statement 20197: Addressing Environmental Justice to Achieve Health Equity
- APHA Policy Statement 20157: Public Health Opportunities to Address the Health Effects of Climate Change
- APHA Policy Statement 20125: The Environmental and Occupational Health Impacts of High-Volume Hydraulic Fracturing of Unconventional Gas Reserves
- APHA Policy Statement 20046: Affirming the Necessity of a Secure, Sustainable and Health Protective Energy Policy

This proposed policy statement is also consistent with several archived policy statements: 200017 (Confirming Need for Protective National Health Based Air Quality Standards), 200012 (Reducing the Rising Rates of Asthma), and 8912 (Public Health Control of Hazardous Air Pollutants).

In addition, APHA is a signatory on the U.S. Call to Action on Climate, Health, and Equity: A Policy Action Agenda (2019), which calls for a "transition away from wood burning, oil, and natural gas use for home heating and cooking."

Problem Statement

Gas stoves (gas cooktop and oven combinations, interchangeably called gas ranges) are common household appliances across the United States. However, burning gas (i.e., combustion) creates harmful nitrogen dioxide (NO_2), particulate matter ($PM_{2.5}$), carbon monoxide (CO), formaldehyde (CH_2O), and methane (CH_4) pollution and has been increasingly linked to poor health outcomes at lower concentrations over the past 10 years.[1] The Environmental Protection Agency (EPA),[2] Health Canada,[3] and the World Health Organization (WHO)[4] have all revised their assessments of NO_2's health impacts in the last decade. Despite these revised health assessments, routine exposure from gas stoves remains an underrecognized health threat to residents.[5]

The most consistent evidence of gas stove pollution in the literature regards NO_2 emissions because electric stoves do not emit NO_2, which is an established marker for gas combustion.[6] Indoor NO_2 emissions from gas stoves can exceed indoor/outdoor concentration guidelines set by WHO and outdoor standards set by the EPA.[7] According to EPA estimates, households where gas stoves are used for cooking have between 50% and 400% higher levels of NO_2 than those with electric stoves.[8] Higher concentrations of NO_2 from gas stoves are associated with longer cooking times,[9,10] pilot lights,[9,11,12] and lack of ventilation.[9,13,14] A Lawrence Berkeley National Laboratory modeling study of homes in southern California estimated that during the winter, when ventilation in homes is lowest, 51% to 64% of homes using gas cooking stoves regularly experience indoor NO_2 levels that

exceed health-based outdoor air standards.[15] A study of in-home cooking practices in nine homes produced findings consistent with these modeling results, with four of the nine homes exceeding the National Ambient Air Quality Standards (NAAQS) for NO_2 when cooking without ventilation.[13]

Gas stoves are an important source of personal NO_2 exposure. People in the United States spend about 65% of their time in their place of residence and about 90% of their time indoors.[16] In a study of 18 cities and 15 countries, including Boston in the United States, NO_2 concentrations were measured in indoor and outdoor environments and compared with personal exposures. Personal exposures to NO_2 were more strongly correlated with indoor NO_2 concentrations than with outdoor concentrations. The most influential activity affecting personal exposure was using a gas stove in the home, with a 67% increase in mean personal NO_2 exposure.[17] In another study in which pediatric asthma patients were equipped with home-based NO_2 sensors, researchers found that patients in homes with gas stoves had a higher frequency of acute NO_2 exposures than patients in homes without gas stoves and that these acute exposures were positively correlated with hospital admissions.[18]

In 2020, about a third of Americans cooked primarily with gas.[19] The prevalence of gas stoves varied across incomes nationally; the prevalence was highest among the highest-earning households and lowest among households earning less than $20,000.[19] There is also variability by region. Gas stove prevalence rates are higher in California, the Northeast, and the Midwest than in the South.[19] While lower-income households are less likely to use gas stoves on a national scale, a study conducted in Baltimore revealed a gas stove prevalence rate of 83% in homes occupied by low-income populations.[20]

NO_2 exposure from gas stove emissions and health risks to children: The EPA has long recognized that NO_2 is associated with respiratory illnesses such as asthma, but in 2016 the agency changed the classification of short-term NO_2 exposure from “likely causal” to “causal” of asthma attacks and long-term NO_2 exposure to “likely causal” of the development of asthma.[2] A 2013 meta-analysis conducted by Lin et al. showed that children residing in homes with gas stoves have a 42% higher risk of current asthma and a 24% higher lifetime risk of asthma than children living in homes with electric stoves.[21] This is a comparable risk to a child living with a smoker in the home.[22] In the meta-analysis, 11 studies were included in the assessment of gas stoves and risk of current asthma, three of which were from North America. The results varied only minimally between regions, suggesting that the findings are externally valid for North America.[21]

The association between gas stoves and increased asthma incidence in children is consistent with NO_2's physiological effects. Biologically, children are more susceptible to air pollution because of developing lungs and immune systems, higher breathing rates, and propensity to breathe through their mouths.[23] Exposure to NO_2 in children is negatively correlated with healthy lung function.[23] Cooking with gas has also been shown to reduce lung function up to 3.4% in children.[24] Controlled human exposure studies in healthy adults (not available for children) show development of an allergic phenotype and increased airway responsiveness at high levels of NO_2 (1,000 parts per billion [ppb]), both of which are associated with the development of asthma.[2]

Indoor NO_2 at concentrations well below EPA outdoor health standards are associated with an increased risk of asthma symptoms in asthmatic children. A prospective study of young children (2–6 years of age) with an asthma diagnosis reported a dose-dependent increase in asthma symptoms among children in Baltimore. A 20-ppb increase in NO_2 levels was associated with statistically significant increases in asthma symptoms after adjustment for confounders (including age, sex, race, caregiver educational level, season of sampling, $PM_{2.5}$ exposure, and secondhand smoke exposure). Additional analyses were done to ensure that the effects of indoor NO_2 were independent of ambient NO_2 levels.[20] A prospective study of more than 1,000 asthmatic children (5–10 years of age) conducted in Massachusetts and Connecticut also revealed a dose-response relationship above a 6-ppb threshold; every 5-ppb increase in NO_2 levels was associated with a dose-dependent increase in the risk of asthma severity. Models were adjusted for age, sex, atopy, season of monitoring, race/ethnicity, mother's education, smoking in the home, and sensitization and exposure to indoor allergens.[12] Similarly, the 2013 Lin et al. meta-analysis showed that higher levels of indoor NO_2 (20 ppb) were associated with a 15% increased risk of wheezing in children (the meta-analysis results were adjusted for confounding factors, including smoking in the family).[21]

While no studies have yet explored the impact of the removal of gas stoves on asthma severity or asthma incidence, reductions in NO_2 in ambient air in Los Angeles were assessed in a multilevel longitudinal cohort drawn from the Southern California Children's Health Study. More than 4,000 children with no history of asthma were included in the study. The authors reported that with an annual median NO_2 reduction of 4.3 ppb, the incidence rate declined by 0.83 cases per 100 person-years.[25] In addition, a randomized study showed that when gas stoves were replaced with electric stoves, median NO_2 levels were 51% lower, falling from a median concentration of 19.7 ppb in homes with a gas stove to 9.7 ppb in homes that received an electric stove.[11] Further research is currently being conducted to build evidence

for the health co-benefits of gas stove removal in affordable housing units. The community group WE ACT for Environmental Justice is leading a pilot study, Out of Gas, In with Justice, that is replacing gas stoves with induction stoves and measuring health benefits in 20 affordable housing homes in New York.[26] Also, the California Energy Commission is funding a $4 million randomized control trial to investigate the impact of gas stove interventions on children with asthma.[27]

NO_2 exposure from gas stove emissions and health risks to older adults: Negative health effects from gas stoves among healthy adults have been inconsistently reported. This conforms with studies of the effects of air pollution; children are more biologically sensitive to air pollution than healthy adults. There are currently no studies of the health effects of cooking with gas stoves among older adults (typically considered those 65 years or older). However, older adults are more sensitive than younger adults to NO_2. Increased age is associated with a greater risk of weakened immune function, impaired healing, decrements in pulmonary and cardiovascular function, and a higher prevalence of chronic disease. The EPA found that older adults had more NO_2-related asthma hospital admissions and emergency department visits and concluded that "older adults are at increased risk for NO_2-related health effects."[2] Short-term NO_2 exposure, as well as long-term exposure to low levels of NO_2, is correlated with higher overall mortality rates among older adults.[2,28]

NO_2 exposure from gas stove emissions and environmental justice concerns: Low-income communities and communities of color are at much greater risk of harm from indoor pollution caused by gas stoves. A recent study conducted by the National Center for Healthy Housing (NCHH) and Enterprise Community Partners revealed that 90% of rental homes did not have adequate ventilation to remove gas stove emissions and recommended removing gas stoves.[14] Another study showed that gas stove pollution was highest in multi-unit buildings.[10] Because of the long history of housing discrimination, communities of color are disproportionately renters living in smaller spaces. Renters often have little or no control over the fuel type or quality of their appliances and frequently lack the financial means or property owner permission to choose an electric stove and ensure high-quality ventilation. This combination of circumstances means that low-income renters are often using older stoves that are not adequately ventilated, resulting in a higher concentration of pollutants indoors.[29] In addition, individuals have greater exposure to gas combustion pollutants when they use gas ovens to supplement their home heating.[30] Low-income communities and communities of color are already living with higher levels of outdoor air pollution[31]; their consequent health disparities may be further exacerbated by cumulative exposures to pollution from indoor sources such as gas stoves.

Lack of policies and programs addressing gas stoves and indoor air quality: While outdoor air pollution has received much policy attention, indoor air pollution—including that caused by gas appliances—is entirely unregulated at the federal level. Unlike Canada and WHO, the EPA does not establish health standards or guidelines for indoor air quality. While the EPA does not currently issue air quality guidelines, it does recommend American National Standards Institute (ANSI)/American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 62.2 (which details whole-home ventilation guidelines for acceptable indoor air quality[32]) in a number of its guidelines for construction, including Indoor AirPLUS construction specifications[33] and single-family[34] and multifamily renovations.[35] Similar to the EPA, the U.S. Department of Housing and Urban Development (HUD) does not regulate indoor air quality in its buildings, although it recommends using ANSI/ASHRAE Standard 62.2. It also establishes smoke-free policies in public housing and multifamily properties funded by HUD.[36] The U.S. Air Force does indoor air quality building inspections and recognizes that combustion can cause NO_2 pollution. It recommends venting combustion appliances if NO_2 levels are above the NAAQS.[37] In contrast to other gas appliances, which must be externally vented according to building codes, there is a lack of consistent regulation of gas stove ventilation. Some state and local new construction building codes may require more ventilation through the adoption of voluntary ANSI/ASHRAE standards that can reduce gas stove pollution but do not eliminate it.[14] Some jurisdictions (Washington State, New York City, the District of Columbia, and 60 cities in California and towns in Oregon and Colorado) have also recently established building codes that require installation of electric appliances in new construction,[38] but otherwise indoor air pollution is not regulated at the state or local level.

Several existing healthy homes programs address ventilation of gas stoves but do not warn people about gas stove emissions and their association with respiratory illnesses or provide emission reduction strategies beyond ventilation. Examples include HUD's Healthy Homes Principles,[39] the EPA's Asthma Home Environment Checklist,[40] and the CDC's Healthy Housing Reference Manual.[41] These interventions depend on people understanding the health risks gas stoves pose and regularly using an exhaust hood vented outdoors. However, building codes do not uniformly require adequate ventilation,[14] and current data suggest that most people do not use ventilation regularly.[11,42,43]

The costs of transitioning to electric stoves, both at a household and a national level, will require large-scale policy changes and government investments to ensure a just transition away from gas cooking.

Stoves are a crucial piece of kitchen equipment that support household nutrition, and given that many households lack the financial means or property owner permission to choose an electric stove, we must simultaneously advocate for and ensure access to other lower-cost, shorter-term solutions that help mitigate indoor cooking pollution. Additional research on the health harms of gas stoves and assessments of the available health interventions will help support this advocacy and policy change.

Evidence-Based Strategies to Address the Problem

As with successful public health programs and policies that have reduced exposure to household smoke[44] and radon,[45] reducing exposure to gas stove pollution will require a multipronged approach that includes indoor air quality guidelines, education of consumers and the public health and medical community, uptake of exposure reduction strategies, and creation of new policies and programs.

Indoor air quality guidelines: More policy attention should focus on indoor air pollutant guidelines. While the Clean Air Act requires the EPA to set NAAQS for common air pollutants outdoors,[46] there are no similar standards or guidelines for indoor air, resulting in less regulation and consequent unsafe levels of indoor pollution. The Clean Air Act has successfully reduced levels of U.S. outdoor air pollution and prevented hundreds of thousands of early deaths and millions of cases of health effects,[47] demonstrating the benefits of such standards. Although EPA indoor air quality guidelines would not have the same legal force under the Clean Air Act as EPA's NAAQS, they would play a valuable role in informing consumers about risks related to indoor air pollution and helping state regulators and voluntary standard-setting bodies assess these risks. Similarly, the EPA develops criteria for determining when surface water is unsafe for people and wildlife. State and tribal governments can use these criteria to develop their own guidance and regulations.[48] Health Canada[3] and WHO[4] have both set indoor air quality guidelines to guide health-based assessments. States do not regulate indoor air quality but can set indoor air quality guidelines. The California Air Resources Board (CARB) passed a resolution in 2020 supporting the electrification of appliances and citing the "urgent need to update CARB's indoor air pollution guidelines to provide agencies, researchers, and the public guidance on safe levels for indoor air pollutant exposures."[49]

Exposure reduction strategies: Replacing existing gas stoves with electric or induction stoves is the most effective strategy for gas stove emissions mitigation. In a randomized study that explored the intervention options of ventilation, running an air purifier, or switching to electric stoves, electric stoves improved air quality the most, reducing the median kitchen concentration of NO_2 by 51% and the bedroom

concentration by 42%.[11] The switch to an electric stove is often most feasible in new construction and at the end of existing gas stoves' life, when replacement is already needed, although some households (i.e., those with the financial means and control over their environment) may choose to replace sooner than that for immediate benefits to their indoor air. There are cases in which a complete replacement is not feasible, such as lack of financial means or property owner permission or structural limitations posed by limited electrical panel capacity. In these cases, households may choose to shift some of their cooking from a gas stove to other small electric appliances they already own, such as microwave ovens, electric kettles, and toaster ovens.

When implemented correctly, filtration may be an effective and lower-cost strategy to mitigate indoor air pollution from gas appliances already present in homes across the nation.[50] In the same randomized interventional study described above, installing a ventilation hood was not shown to significantly change NO_2 concentrations from gas stove use. However, high-efficiency particulate absorbing air purifiers with carbon filters placed in kitchens with gas stoves resulted in a 27% reduction in median kitchen NO_2 levels and a 20% reduction over 3 months.[11]

Ventilation may be a strategy to reduce gas emissions, but it has limitations. There are two types of ventilation: whole-home/whole-building ventilation and source ventilation (e.g., exhaust hood). ANSI/ASHRAE Standard 62.2 details whole-home ventilation guidelines for acceptable indoor air quality.[32] In an NCHH study of ANSI/ASHRAE Standard 62.2 in comparison with standard ventilation, whole-building ventilation was shown to reduce $PM_{2.5}$ and carbon monoxide from gas stoves. However, it was inadequate to expel NO_2 pollution. The researchers concluded that, to ensure healthy indoor air quality, gas stoves should be removed from homes.[14] Source ventilation can remove gas stove emissions but is not as effective as whole-home ventilation. Many people do not frequently use source ventilation; one survey revealed that respondents used their exhaust hoods only a third of the time, citing noise and forgetfulness.[42] The hoods currently on the market also vary in effectiveness. Many hoods do not vent to the outdoors and simply circulate pollutants around the home, and most fail to capture more than 75% of pollutants.[43] In a study of households that reported using ventilation, children had better lung function and lower odds of respiratory symptoms.[30] Residents with gas stoves and without proper exhaust ventilation can ventilate naturally by opening doors and windows while cooking if weather, outdoor air quality conditions, and window operability permit. Considering the NCHH observation that ventilation is not sufficient to remove NO_2,[14] whole-home and source ventilation should be paired with other strategies that remove gas stoves or reduce their use.

Education: An effective way to inform the public of the risk of gas stove emissions and effective remediation strategies is to require disclosures at the point of sale or when rental and lease agreements are signed. Thirty-seven states require the presence of radon to be disclosed during real estate transactions, and four states require tenant disclosures.[51] HUD requires information about radon be provided for all Federal Housing Administration insured forward mortgages. This requirement is estimated to reach millions of people buying homes. When HUD-acquired single-family properties are sold, buyers receive information about the health harms of radon and mold as part of a release agreement and receive information about home repairs that can help minimize them. The home repairs suggested to mitigate radon are recommendations without associated funding to make the repairs.[52]

Education and recommendations on gas stove emissions control strategies beyond ventilation could be added to the outreach materials created by the EPA, HUD, and the CDC. Similarly, health profession curricula could better address environmental health risks such as gas stoves. Together, these education strategies could play a role in public education about gas stove emissions and mitigation.

CDC's EXHALE program recommends implementing six strategies to reduce asthma symptoms and uses health care visits in a home-based program to educate people caring for children with asthma about multiple asthma triggers. The Community Preventive Services Task Force recommends home-based multitrigger, multicomponent interventions with environmental remediation because they reduce symptoms and medical care needs and because they are cost effective.[53] These programs cover information on issues such as secondhand smoke and pest management.[54] Outreach workers could also provide information about unventilated gas stoves and offer low-cost remediation strategies that pair ventilation with source control based on individual household resources (e.g., presence of ventilation, operational windows, other electric appliances).

Other policy levers: Another policy lever is to better regulate gas stoves and ventilation. The Institute for Policy Integrity at the New York University School of Law, citing health-harming emissions of gas stoves, recently called upon the Consumer Product Safety Commission (CPSC) to develop mandatory performance standards for gas stoves and range hoods, require warning labels for gas stoves, and educate the public about the harms of gas stove emissions. These actions are within the agency's existing statutory authority.[55]

Air quality guidelines and nongovernmental standards, such as the internationally recognized ANSI/ASHRAE Standards 62.1 and 62.2,[32] can also be used to guide state and local building codes. Building codes can establish indoor pollutant concentration limits based on air quality guidelines and require effective ventilation aligned with ANSI/ASHRAE standards. The 2020 ASHRAE Position Document on Unvented Combustion Devices and Indoor Air Quality[56] specifically called for more research to investigate the effects of gas cooking combustion on indoor air quality in residential and commercial buildings, especially concerning NO_2, as well as a review and update of appliance standards and a revision of product information to include the risk of extended use.

Government-funded new construction and retrofits: The Boston Department of Neighborhood Development requires developers receiving funds from the city for new construction affordable housing projects to build to a zero emissions standard with respect to electric appliances.[57] Electrification programs focusing on retrofitting existing buildings are also becoming more popular across the United States,[58] and the replacement of gas stoves could potentially be an additional element of these programs. California and Philadelphia combined a variety of government funding sources to address the core components of a healthy home into one program. “One-stop-shop” models such as these provide funding for whole-home retrofits and address four key components: health and safety, weatherization and energy efficiency, appliance electrification, and energy assistance.[59] Maine has a successful heat pump adoption program that covers the cost of heat pumps for low-income residents and provides tiered rebate financing. Maine’s program resulted in 25% to 30% growth in uptake of heat pumps in each of the past 3 years.[60] This model could be applied to electric stoves, prioritizing installation in low-income homes. To minimize displacement that may result from building upgrades, government agencies can protect renters by including stipulations on electrification funding. A recent report focused on Los Angeles identified several housing policies that can be used to minimize the impact of building electrification and efficiency programs on renters. These policies included prohibiting pass-through costs for decarbonization retrofits to affordable housing tenants and targeting decarbonization subsidies to low-income communities. In addition, local municipalities can strengthen tenant’s rights laws.[61]

Other programs: ENERGY STAR, a national program administered by the EPA, rates the efficiency of appliances and has been successful in reducing energy consumption from appliances.[62] Some states provide rebates for ENERGY STAR rated appliances, and ENERGY STAR appliances are required for several green building certification programs, including the U.S. Green Building Council’s Leadership in Energy and Environmental Design (LEED) certification program. Electric stoves and induction stoves are

more efficient than gas stoves,[63] and adding electric and induction stoves to the ENERGY STAR program may help create a preference for them. Some governments, as part of local zoning laws or building codes, require LEED certification for building permits, suggesting that providing ENERGY STAR ratings could help with the uptake of electric stoves in new building construction.

Opposing Arguments/Evidence

One opposing argument is that there are no stated risks to respiratory health from regulatory and advisory agencies and organizations responsible for consumer health and safety. On the contrary, the EPA and CPSC have been aware of and have publicized health risks of combustion appliances in buildings for more than 35 years.[64] The EPA currently recommends source control for gas stoves (i.e., proper adjustment) and ventilation to the outdoors to reduce exposure to indoor air pollution.[65] Through its indoor air quality guidelines, the agency recommends whole-home ventilation according to ANSI/ASHRAE Standard 62.2 and further recommends that occupants be educated about the importance of using ventilation in the kitchen and bathroom. One of the leading medical associations in the United States, the American Medical Association, passed a resolution in 2022 recognizing the associations among gas stoves, indoor NO_2 concentrations, and pediatric asthma.[66]

A small number of studies and reports also refute the evidence on the health risks of gas stoves. In one global survey study, no association was found between gas cooking and lifetime or current asthma among children.[67] However, this single study was not based on measured concentrations of NO_2 in the home; rather, it was based on a self-reported global survey of household cooking fuels and asthma symptoms in which the respondents were children 13–14 years of age and parents of children 6–7 years of age. Because the study combined data from 31 countries, differences across countries in housing characteristics, ambient temperatures, ventilation, and other factors may have masked the association between gas cooking and asthma. Without better isolation among geographies, types of housing, and ventilation, it is problematic to assume that this study's global findings are applicable to the United States.

A 2021 report sponsored by the California Restaurant Association (CRA) critiqued a 2020 report by the University of California, Los Angeles (UCLA), on indoor and outdoor pollution from gas appliances.[68] The CRA's arguments primarily addressed the UCLA study's modeling assumptions and scenarios as opposed to the actual public health impacts reported. The UCLA study was not included in this policy statement, but a few CRA assertions are discussed here because they have been raised elsewhere. In

addition to arguments around the cost and effectiveness of ventilation, the CRA report asserts that indoor air pollution is more a function of what is being cooked than what fuel is used. In response to that claim, there are several pollutants emitted from gas that are not emitted from cooking food or from using electric stoves, namely NO_2, carbon monoxide, and formaldehyde. Cooking food inevitably produces $PM_{2.5}$, which is why ventilation is still recommended even when an electric stove is used. However, replacing a gas stove with an electric stove will remove the source of NO_2 and other health-harming combustion pollutants. It will also remove some $PM_{2.5}$, as research shows that gas stoves can produce twice as much $PM_{2.5}$ as electric stoves.[69] In addition, gas stoves produce higher concentrations of ultrafine particles even when no cooking activities take place.[70]

Concerns about consumer costs of replacing gas stoves and installing ventilation or filtration are often raised as reasons why the public health implications of gas stoves cannot be prioritized. The priority of a public health program is to recognize a problem. Funding for secondhand smoke education programs followed the medical and scientific community's recognition of health harms. As with radon programs, information can be given to consumers about the health effects of gas stoves without the obligation to replace every gas stove in use. The cost of replacing a gas stove with an electric stove (a $650 average cost plus an installation cost of $100–$200)[71] is similar to average radon remediation costs ($771–$1,179).[72] However, the upfront cost of the stove, ventilation, and filtration technology, as well as the operating costs (including utility bills), can be minimized. In new buildings, all-electric homes are often less expensive to construct than all-gas homes or homes with a mix of fuels.[73] In the case of existing homes, state or local programs can offer point-of-purchase rebates for electric or induction stoves and ventilation and filtration devices through energy efficiency programs. For example, MassSave offers rebates for ENERGY STAR rated appliances.[74] While rebate programs are least effective for renters, they do meet the needs of middle-income homeowners. State-funded electrification programs could offer electric or induction stoves and ventilation and filtration devices according to a means-tested benefits scale, as Maine has done with heat pumps.[60] Although electricity currently costs more than gas for many consumers, electric stoves are more efficient than gas stoves, meaning that once the electric stove has been installed, the annual energy cost differential of operating an electric stove is minimal and should not burden low-income households.[63] In contrast, the average cost of an asthma diagnosis in a household is estimated to be more than $3,000 a year, illustrating the importance of quantifying the health care costs of gas stoves.[75]

Concerns that tenants could be displaced after upgrades have been made to homes are not unique to replacing gas stoves. They are legitimate concerns for all building improvement programs, including energy efficiency and electrification programs. States and municipalities should be encouraged to develop a suite of anti-displacement policies to complement funding for building upgrades and include stipulations on funding to minimize displacement.[61]

Consumer preference for gas stoves has been suggested as a reason not to adopt electric stoves. However, consumer preference is largely driven by advertising. Surveys have shown that people have no preference for whether gas or electricity heats their home, so the gas industry has focused on marketing gas stoves to sell more gas for entire homes.[76] While marketing campaigns may claim that gas stoves provide a better cooking experience, Consumer Reports compared various gas and electric stove models and found that electric stoves outperformed gas.[77] A study that considered the efficiency of gas stoves in comparison with electric and induction stoves revealed that gas stoves were least efficient.[63] Recent polling data show that gas stove interest has declined by 5%.[78]

For people in substandard housing, replacing a gas stove may not be a household priority. None of the recommended interventions require anyone to prioritize switching out a gas stove over radon, mold, or lead abatement or other household priorities. As with national radon education programs, educating consumers about gas stove emissions allows some people (i.e., those who have the financial means and control over their environment) to make choices based on their specific circumstances. Many mitigation strategies do not require any investment, including using other appliances or opening windows, or require minimal investment, such as using induction burners that plug into existing electrical outlets (estimated to cost less than $100).

Instead of asking households to prioritize, the recommendation is that electrification be included in a suite of healthy home upgrades. Electrifying appliances are often excluded from typical weatherization and energy efficiency programs. One solution (as noted) is to create one-stop-shop models for whole-home retrofits that address health and safety, weatherization and energy efficiency, appliance electrification, and energy assistance. This solution is being successfully modeled in California and Philadelphia, where unique funding sources are combined.[59]

Action Steps

Based on this evidence, APHA:

1. Calls upon the EPA, HUD, and the CDC to formally recognize the links among gas stove emissions, NO_2 pollution, and increased risk of illness in children, older adults, people with underlying conditions, and environmental justice communities. Furthermore, the public and health care practitioners should be educated on the health harms of gas stove emissions and promotion of mitigation solutions should be expedited.
2. Calls upon the EPA to set health-protective indoor air quality guidelines for all indoor residential settings, drawing on the Clean Air Act and the current EPA recommendations to utilize ANSI/ASHRAE Standard 62.2 in indoor air quality guidance in new construction specifications and renovations.
3. Calls upon the EPA to support the 2020 ASHRAE position document, which recommended additional research on gas stove emissions, review of appliance standards, and revision of product information.
4. Calls upon the CPSC to set mandatory or voluntary performance standards for gas stoves and range hoods and to launch a public awareness campaign.
5. Calls upon state legislatures and HUD to require disclosure during real estate transactions and tenant disclosures that gas stoves emit harmful levels of pollutants without proper ventilation and to provide source control and mitigation strategies for improving air quality (similar to the approach for radon education programs).
6. Calls upon HUD to adopt policies with preferences for the installation of electric appliances in new and retrofitted buildings that are federally funded. Furthermore, HUD should update its Healthy Homes program to provide educational information about gas stove emissions and mitigation strategies, including source control and ventilation.
7. Calls upon public and affordable housing agencies and providers, including those receiving HUD funding, to develop and implement strategies to ensure that residents do not experience unsafe levels of gas stove pollution. New units and retrofitted units can be fitted with appropriate ventilation, filtration, and electric stoves.
8. Calls upon state and local authorities responsible for building codes to legislate the inclusion of whole-home ventilation and outdoor-venting exhaust hoods in all new buildings and remodels, adhering to ANSI/ASHRAE Standard 62.2.
9. Calls upon local and state legislative and regulatory bodies to adopt residential building codes with preferences for installing electric appliances and to require electric appliances for building projects receiving municipal or state funding. Funding for retrofits or building upgrades should include stipulations that minimize displacement.

10. Calls upon ENERGY STAR to provide ratings for electric and electric induction cooking stoves.
11. Calls upon health care practitioners (including physicians, nurses, public health nurses, community health workers, and many others) to inform patients of the risks of gas stove emissions and the measures they can take to mitigate exposure, similar to the approach to home exposures to tobacco. This workforce will be best prepared to address risks such as gas stoves if health professions increase the amount of environmental health content in curricula.
12. Calls upon CDC's National Asthma Control Program to add gas stove emission education, source control, and ventilation strategies to its EXHALE program.
13. Calls upon researchers and funders to broaden the scope of health impacts and populations studied in relation to gas stove pollution and assess the risks to households cooking with gas. Other research priorities include identifying the most effective intervention options and monetizing the health costs and benefits of interventions.

References

1. Seals BA, Krasner A. Health effects from gas stove pollution. Available at: https://rmi.org/insight/gas-stoves-pollution-health. Accessed November 12, 2021.

2. US Environmental Protection Agency. Integrated science assessment for oxides of nitrogen: health criteria (final report, 2016). Available at: https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=310879. Accessed November 12, 2021.

3. Health Canada. Residential indoor air quality guideline: nitrogen dioxide. Available at: https://www.canada.ca/en/health-canada/services/publications/healthy-living/residential-indoor-air-quality-guideline-nitrogen-dioxide.html. Accessed July 28, 2022.

4. World Health Organization. WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Available at: https://apps.who.int/iris/handle/10665/345329. Accessed July 28, 2022.

5. Krasner A, Jones TS, LaRocque R. Cooking with gas, household air pollution, and asthma: little recognized risk for children. J Environ Health. 2021;83(8):14–18.

6. Jarvis DJ, Adamkiewicz G, Heroux ME, Rapp R, Kelly FJ. Nitrogen dioxide. Available at: https://www.ncbi.nlm.nih.gov/books/NBK138707/. Accessed July 28, 2022.

7. Lebel ED, Finnegan CJ, Ouyang Z, Jackson RB. Methane and NOx emissions from natural gas stoves, cooktops, and ovens in residential homes. Environ Sci Technol. 2022;56(4):2529–2539.

8. U.S. Environmental Protection Agency. Integrated science assessment for oxides of nitrogen: health criteria (final report, 2008). Available at: https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=194645. Accessed November 12, 2021.

9. Mullen NA, Li J, Russell ML, Spears M, Less BD, Singer BC. Results of the California Healthy Homes Indoor Air Quality Study of 2011–2013: impact of natural gas appliances on air pollutant concentrations. Indoor Air. 2016;26(2):231–245.

10. Baxter LK, Clougherty JE, Laden F, Levy JI. Predictors of concentrations of nitrogen dioxide, fine particulate matter, and particle constituents inside of lower socioeconomic status urban homes. J Expo Sci Environ Epidemiol. 2007;17(5):433–444.

11. Paulin LM, Diette GB, Scott M, et al. Home interventions are effective at decreasing indoor nitrogen dioxide concentrations. Indoor Air. 2014;24(4):416–424.

12. Belanger K, Holford TR, Gent JF, Hill ME, Kezik JM, Leaderer BP. Household levels of nitrogen dioxide and pediatric asthma severity. Epidemiology. 2013;24(2):320–330.

13. Singer BC, Pass RZ, Delp WW, Lorenzetti DM, Maddalena RL. Pollutant concentrations and emission rates from natural gas cooking burners without and with range hood exhaust in nine California homes. Building Environ. 2017;122:215–229.

14. National Center for Healthy Housing. Studying the optimal ventilation for environmental indoor air quality. Available at: https://nchh.org/resource-library/report_studying-the-optimal-ventilation-for-environmental-indoor-air-quality.pdf. Accessed July 28, 2022.

15. Logue JM, Klepeis NE, Lobscheid AB, Singer BC. Pollutant exposures from natural gas cooking burners: a simulation-based assessment for southern California. Environ Health Perspect. 2014;122(1):43–50.

16. Klepeis NE, Nelson WC, Ott WR, et al. The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. J Expo Sci Environ Epidemiol. 2001;11(3):231–252.

17. Levy JI, Lee K, Spengler JD, Yanagisawa Y. Impact of residential nitrogen dioxide exposure on personal exposure: an international study. J Air Waste Manag Assoc. 1998;48(6):553–560.

18. Downen SR, Dong Q, Chorvinsky E, et al. Personal NO_2 sensor demonstrates feasibility of in-home exposure measurements for pediatric asthma research and management. J Expo Sci Environ Epidemiol. 2022;32(2):312–319.

19. U.S. Energy Information Administration. Residential Energy Consumption Survey (RECS) 2020 Tables HC3.5, HC3.7, and HC3.8. Available at: https://www.eia.gov/consumption/residential/data/2020. Accessed July 20, 2022.

20. Hansel NN, Breysse PN, McCormack MC, et al. A longitudinal study of indoor nitrogen dioxide levels and respiratory symptoms in inner-city children with asthma. Environ Health Perspect. 2008;116(10):1428–1432.
21. Lin W, Brunekreef B, Gehring U. Meta-analysis of the effects of indoor nitrogen dioxide and gas cooking on asthma and wheeze in children. Int J Epidemiol. 2013;42(6):1724–1737.
22. Climate Council of Australia. Kicking the gas habit: how gas is harming our health. Available at: https://www.climatecouncil.org.au/wp-content/uploads/2021/05/Kicking-the-Gas-Habit-How-Gas-is-Harming-our-Health.pdf. Accessed July 28, 2022.
23. Bateson TF, Schwartz J. Children's response to air pollutants. J Toxicol Environ Health. 2007;71(3):238–243.
24. Moshammer H, Hutter HP, Neuberger M. Gas cooking and reduced lung function in school children. Atmos Environ. 2006;40(18):3349–3354.
25. Garcia E, Berhane KT, Islam T, et al. Association of changes in air quality with incident asthma in children in California, 1993–2014. JAMA. 2019;321(19):1906–1915.
26. WE ACT for Environmental Justice. Out of Gas, In with Justice. Available at: https://www.weact.org/campaigns/out-of-gas/. Accessed July 28, 2022.
27. California Energy Commission. Randomized trial study to investigate the impact of gas stove interventions on children with asthma. Available at: https://www.energy.ca.gov/solicitations/2021-09/gfo-21-301-randomized-trial-study-investigate-impact-gas-stove-interventions. Accessed July 28, 2022.
28. Qian Y, Li H, Rosenberg A, et al. Long-term exposure to low-level NO_2 and mortality among the elderly population in the southeastern United States. Environ Health Perspect. 2021;129(12):127009.
29. Spengler JD, Schwab M, McDermott A, Lambert WE, Samet JM. Nitrogen dioxide and respiratory illness in children. Part IV: effects of housing and meteorologic factors on indoor nitrogen dioxide concentrations. Res Rep Health Eff Inst. 1996;58:1–29.
30. Kile ML, Coker ES, Smit E, Sudakin D, Molitor J, Harding AK. A cross-sectional study of the association between ventilation of gas stoves and chronic respiratory illness in U.S. children enrolled in NHANESIII. Environ Health. 2014;13:71.
31. Miranda ML, Edwards SE, Keating MH, Paul CJ. Making the environmental justice grade: the relative burden of air pollution exposure in the United States. Int J Environ Res Public Health. 2011;8(6):1755–1771.
32. American Society of Heating, Refrigerating and Air-Conditioning Engineers. ASHRAE releases updated versions of Standards 62.1 and 62.2. Available at:

https://www.ashrae.org/about/news/2019/ashrae-releases-updated-versions-of-standard-62-1-and-62-2. Accessed November 12, 2021.

33. U.S. Environmental Protection Agency. Indoor AirPlus construction specifications. Available at: https://www.epa.gov/sites/default/files/2018-03/documents/indoor_airplus_construction_specifications.pdf. Accessed July 28, 2022.

34. U.S. Environmental Protection Agency. Energy savings plus health: indoor air quality guidelines for single-family renovations. Available at: https://www.epa.gov/sites/default/files/2021-05/documents/epa-oria_singlefamilyprotocols_2021_final_508.pdf. Accessed July 28, 2022.

35. U.S. Environmental Protection Agency. Energy savings plus health: indoor air quality guidelines for multifamily renovations. Available at: https://www.epa.gov/sites/default/files/2021-05/documents/epa-oria_multifamilyprotocols_2021_final_508.pdf. Accessed July 28, 2022.

36. U.S. Department of Housing and Urban Development, Office of Lead Hazard Control and Healthy Homes. Change is in the air: an action guide for establishing smoke-free public housing and multifamily properties. Available at: https://www.hud.gov/sites/documents/SMOKEFREEACTIONGUIDE.PDF. Accessed July 28, 2022.

37. Arceo E. Technical guide for indoor air quality surveys. Available at: https://apps.dtic.mil/sti/pdfs/ADA607657.pdf. Accessed July 28, 2022.

38. Louis-Prescott L, Golden R. How local governments and communities are taking action to get fossil fuels out of buildings. Available at: https://rmi.org/taking-action-to-get-fossil-fuels-out-of-buildings/. Accessed August 9, 2022.

39. U.S. Department of Housing and Urban Development. Healthy homes for healthy families. Available at: https://www.hud.gov/program_offices/healthy_homes/healthyhomes. Accessed July 28, 2022.

40. U.S. Environmental Protection Agency. Asthma Home Environment Checklist. Available at: https://www.epa.gov/sites/default/files/2013-08/documents/home_environment_checklist.pdf. Accessed July 28, 2022.

41. Centers for Disease Control and Prevention. Healthy Housing Reference Manual. Available at: https://www.cdc.gov/nceh/publications/books/housing/housing_ref_manual_2012.pdf. Accessed July 28, 2022.

42. Klug V, Lobscheid A, Singer B. Cooking appliance use in California homes: data collected from a Web-based survey. Available at: https://www.osti.gov/servlets/purl/1050839. Accessed July 28, 2022.

43. Singer BC, Delp WW, Price PN, Apte MG. Performance of installed cooking exhaust devices. Indoor Air. 2012;22(3):224–234.

44. U.S. Environmental Protection Agency. Secondhand smoke and smoke-free homes. Available at: https://www.epa.gov/indoor-air-quality-iaq/secondhand-smoke-and-smoke-free-homes. Accessed July 28, 2022.
45. RadonLeaders. National Radon Action Plan. Available at: http://radonleaders.org/resources/nationalradonactionplan. Accessed July 28, 2022.
46. U.S. Environmental Protection Agency. Criteria air pollutants. Available at: https://www.epa.gov/criteria-air-pollutants. Accessed November 12, 2021.
47. U.S. Environmental Protection Agency. Benefits and costs of the Clean Air Act, 1970 to 1990: study design and summary of results. Available at: https://www.epa.gov/clean-air-act-overview/benefits-and-costs-clean-air-act-1970-1990-study-design-and-summary-results. Accessed July 28, 2022.
48. U.S. Environmental Protection Agency. Basic information on water quality criteria. Available at: https://www.epa.gov/wqc/basic-information-water-quality-criteria. Accessed July 28, 2022.
49. State of California Air Resources Board. California Indoor Air Quality Program update. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/board/res/2020/res20-32.pdf. Accessed July 28, 2022.
50. Hansel NN, Putcha N, Woo H, et al. Randomized clinical trial of air cleaners to improve indoor air quality and chronic obstructive pulmonary disease health: results of the CLEAN AIR Study. Am J Respir Crit Care Med. 2022;205(4):421–430.
51. Glass EAG, LeClair N. State radon laws. Available at: https://sosradon.org/files/sosradon/1_9_2017_State%20Radon%20Laws_Essential%20information.pdf. Accessed July 28, 2022.
52. U.S. Environmental Protection Agency. Radon and real estate resources. Available at: https://www.epa.gov/radon/radon-and-real-estate-resources. Accessed July 28, 2022.
53. Community Preventive Services Task Force. Asthma: home-based multi-trigger, multicomponent environmental interventions—children and adolescents with asthma. Available at: https://www.thecommunityguide.org/findings/asthma-home-based-multi-trigger-multicomponent-environmental-interventions-children-adolescents-asthma. Accessed July 28, 2022.
54. Centers for Disease Control and Prevention. Environmental policies or best practices to reduce asthma triggers. Available at: https://www.cdc.gov/asthma/exhale/environmental-policies.htm. Accessed July 28, 2022.
55. Figueroa LA, Lienke J. The emissions in the kitchen: how the Consumer Product Safety Commission can address the risks of indoor air pollution from gas stoves. Available at: https://policyintegrity.org/files/publications/Emissions_in_the_Kitchen_Report_v3_%281%29.pdf. Accessed July 28, 2022.

56. American Society of Heating, Refrigerating and Air-Conditioning Engineers. ASHRAE Position Document on Unvented Combustion Devices and Indoor Air Quality. Available at: https://www.ashrae.org/file%20library/about/position%20documents/unvented-combustion-devices-and-iaq-pd-6.29.2020.pdf. Accessed November 12, 2021.

57. City of Boston, Department of Neighborhood Development. Guidebook for zero emission buildings. Available at: https://www.boston.gov/sites/default/files/file/2020/03/200306_DND%20book_FOR%20WEB.pdf. Accessed July 28, 2022.

58. Cohn C, Wang Esram N. Building electrification: programs and best practices. Available at: https://www.aceee.org/research-report/b2201. Accessed July 28, 2022.

59. Kresowik M, Reeg L. Funding our future: creating a one-stop shop for whole-home retrofits. Available at: https://rmi.org/creating-a-one-stop-shop-for-whole-home-retrofits/. Accessed July 28, 2022.

60. Active Efficiency Collaborative. Beneficial electrification through the Efficiency Maine Trust. Available at: https://activeefficiency.org/project/beneficial-electrification-through-the-efficiency-maine-trust/. Accessed July 28, 2022.

61. Kirk C. Los Angeles building decarbonization: tenant impact and recommendations. Available at: https://www.saje.net/wp-content/uploads/2021/12/LA-Building-Decarb_Tenant-Impact-and-Recommendations_SAJE_December-2021-1.pdf. Accessed July 28, 2022.

62. Sanchez MC, Brown RE, Webber C, Homan GK. Savings estimates for the United States Environmental Protection Agency's ENERGY STAR voluntary product labeling program. Available at: https://www.sciencedirect.com/science/article/pii/S0301421508001092?via%3Dihub. Accessed July 28, 2022.

63. Sweeney M, Dols J, Fortenbery B, Sharp F. Induction cooking technology design and assessment. Available at: https://www.aceee.org/files/proceedings/2014/data/papers/9-702.pdf. Accessed July 28, 2022.

64. U.S. Environmental Protection Agency. A review of the Consumer Product Safety Commission's health effects and exposure assessment documents on nitrogen dioxide. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi/P1000J0G.PDF?Dockey=P1000J0G.PDF. Accessed July 28, 2022.

65. U.S. Environmental Protection Agency. Sources of combustion products. Available at: https://www.epa.gov/indoor-air-quality-iaq/sources-combustion-products. Accessed November 12, 2021.

66. American Medical Association. Business of the June 2022 meeting of the AMA House of Delegates. Available at: https://www.ama-assn.org/house-delegates/annual-meeting/business-june-2022-meeting-ama-house-delegates. Accessed July 28, 2022.

656 67. Wong GW, Brunekreef B, Ellwood P, et al. Cooking fuels and prevalence of asthma: a global analysis
657 of phase three of the International Study of Asthma and Allergies in Childhood (ISAAC). Lancet Respir
658 Med. 2013;1(5):386–394.
659 68. Tormey D, Huntley S. Effects of residential gas appliances on indoor and outdoor air quality and
660 public health in California. Available at: https://www.calrest.org/sites/main/files/file-
661 attachments/ucla_study_-_natural_gas_stoves_-_tormey_critical_review.pdf. Accessed July 28, 2022.
662 69. Hu T, Singer BC, Logue JM. Compilation of published $PM_{2.5}$ emission rates for cooking, candles, and
663 incense for use in modeling of exposures in residences. Available at:
664 https://www.osti.gov/biblio/1172959. Accessed July 28, 2022.
665 70. Wallace L, Wang F, Howard-Reed C, Persily A. Contribution of gas and electric stoves to residential
666 ultrafine particle concentrations between 2 and 64 nm: size distributions and emission and coagulation
667 rates. Environ Sci Technol. 2008;42(23):8641–8647.
668 71. Feininger D. How much does it cost to put in an electric stovetop? Available at:
669 https://www.housedigest.com/924631/how-much-does-it-cost-to-put-in-an-electric-stovetop/. Accessed
670 July 28, 2022.
671 72. Thorsby D. How much does a radon mitigation system cost? Available at:
672 https://realestate.usnews.com/real-estate/articles/how-much-does-a-radon-mitigation-system-cost.
673 Accessed July 28, 2022.
674 73. Billimoria S, Henchen M, Guccione L, Louis-Prescott L. The economics of electrifying buildings:
675 how electric space and water heating supports decarbonization of residential buildings. Available at:
676 http://www.rmi.org/ insights/reports/economics-electrifying-buildings/. Accessed July 28, 2022.
677 74. Mass Save. Appliances. Available at: https://www.masssave.com/save/appliances. Accessed July 28,
678 2022.
679 75. Nurmagambetov T, Kuwahara R, Garbe P. The economic burden of asthma in the United States,
680 2008–2013. Ann Am Thorac Soc. 2018;15(3):348–356.
681 76. Leber R. How the fossil fuel industry convinced Americans to love gas stoves. Available at:
682 https://www.motherjones.com/environment/2021/06/how-the-fossil-fuel-industry-convinced-americans-
683 to-love-gas-stoves/. Accessed July 28, 2022.
684 77. Hope P. Gas or electric range: which is better? Available at:
685 https://www.consumerreports.org/ranges/gas-or-electric-range-which-is-better-a1142956590/. Accessed
686 July 28, 2022.

20225- Gas Stove Emissions Are a Public Health Concern: Exposure to Indoor Nitrogen Dioxide Increases Risk of Illness in Children, Older Adults, and People with Underlying Health Conditions

78. Jenkins LM. Public interest in gas stoves, heating systems has inched down over the past year. Available at: https://morningconsult.com/2022/02/14/gas-electric-stoves-consumers-poll/. Accessed July 28, 2022.

20225- Gas Stove Emissions Are a Public Health Concern: Exposure to Indoor Nitrogen Dioxide Increases Risk of Illness in Children, Older Adults, and People with Underlying Health Conditions

---

20225- Gas Stove Emissions Are a Public Health Concern: Exposure to Indoor Nitrogen Dioxide Increases Risk of Illness in Children, Older Adults, and People with Underlying Health Conditions

---