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Clearing the Air: Gas Stove Emissions and Direct Health Effects

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Pollutant levels spike as soon as the stove is switched on. In a minivan parked at a two-story home in the wealthy enclave of Piedmont, California, researchers watch as their instruments display rapid increases inside the home in carbon monoxide (CO), methane (CH_4), nitrous oxide (N_2O), and nitrogen dioxide (NO_2).

The researchers with Stanford University and the nonprofit PSE Healthy Energy are watching that last one most closely. NO_2, a pulmonary irritant that can have a variety of impacts on the respiratory system, is one of six air pollutants for which well-documented health effects have led to strict monitoring and regulation by the US Environmental Protection Agency (EPA)[1]—in outdoor air, that is. Indoor air, like that inside this California home, is effectively off-limits for the agency.[2]

A Cloud of Chemicals in Kitchen Air

Decades of research[3,4] have established that in some settings, particularly kitchens with poor ventilation or where range hoods are turned off or do not vent to the outdoors, just a few minutes of gas stove use can cause indoor NO_2 levels to surpass current 1-hour standards for outdoor air[5]—with potentially serious implications for the occupants' respiratory health. A 1992 meta-analysis[6] concluded, and a 2013 systematic review and meta-analysis[7] later agreed, that NO_2 emissions from gas cooking are associated with an increased risk of asthma and wheeze in children, based on data from observational studies.

NO_2 receives the most attention, but it is not the only chemical emitted by gas stoves during typical operation. In addition to those being measured inside the Piedmont home's kitchen (CO, CH_4, and N_2O), recent research has established that the stoves also produce formaldehyde (CH_2O),[8] a respiratory irritant and known human carcinogen.[9] And just this past June, a study[10] from the Stanford–PSE Healthy Energy team showed gas stoves also generate the carcinogen benzene (C_6H_6)[11] at levels that can exceed US EPA[12] and World Health Organization (WHO)[13] benchmarks.

It now seems possible that gas stoves, found in 38% of US homes in 2020,[14] could pose a greater health risk than researchers have long thought. A December 2022 paper[15] estimated that 12.7% of all current childhood asthma cases in the United States are attributable to gas stove use. These surprising findings spurred Richard Trumka, Jr., of the US Consumer Product Safety

The production and use of natural gas and propane in gas-powered appliances have been implicated in climate change. However, gas stove emissions can also have direct health effects. Image: © Keith Getter/Getty Images.

A 2013 review of population studies concluded that “gas cooking increases the risk of asthma in children, and indoor nitrogen dioxide increases the risk of current wheeze in children.”[7] Image: © Dragon Images/Shutterstock.com.

Commission (CPSC) to remark in an interview that gas stoves are hazardous and could potentially be prohibited.[16] Days later, addressing public concern about the commissioner’s comments, CPSC chair Alex Hoehn-Saric stated that even though “research indicates that emissions from gas stoves can be hazardous” and the commission is indeed actively investigating the issue, it has no plans to ban gas stoves.[17]

Yet the clarification was too little, too late to stem the impact of the original comment: a cultural debate around government regulation, climate change, and the safety and value of gas stoves[18,19] that continues today.[20]

The Climate Question

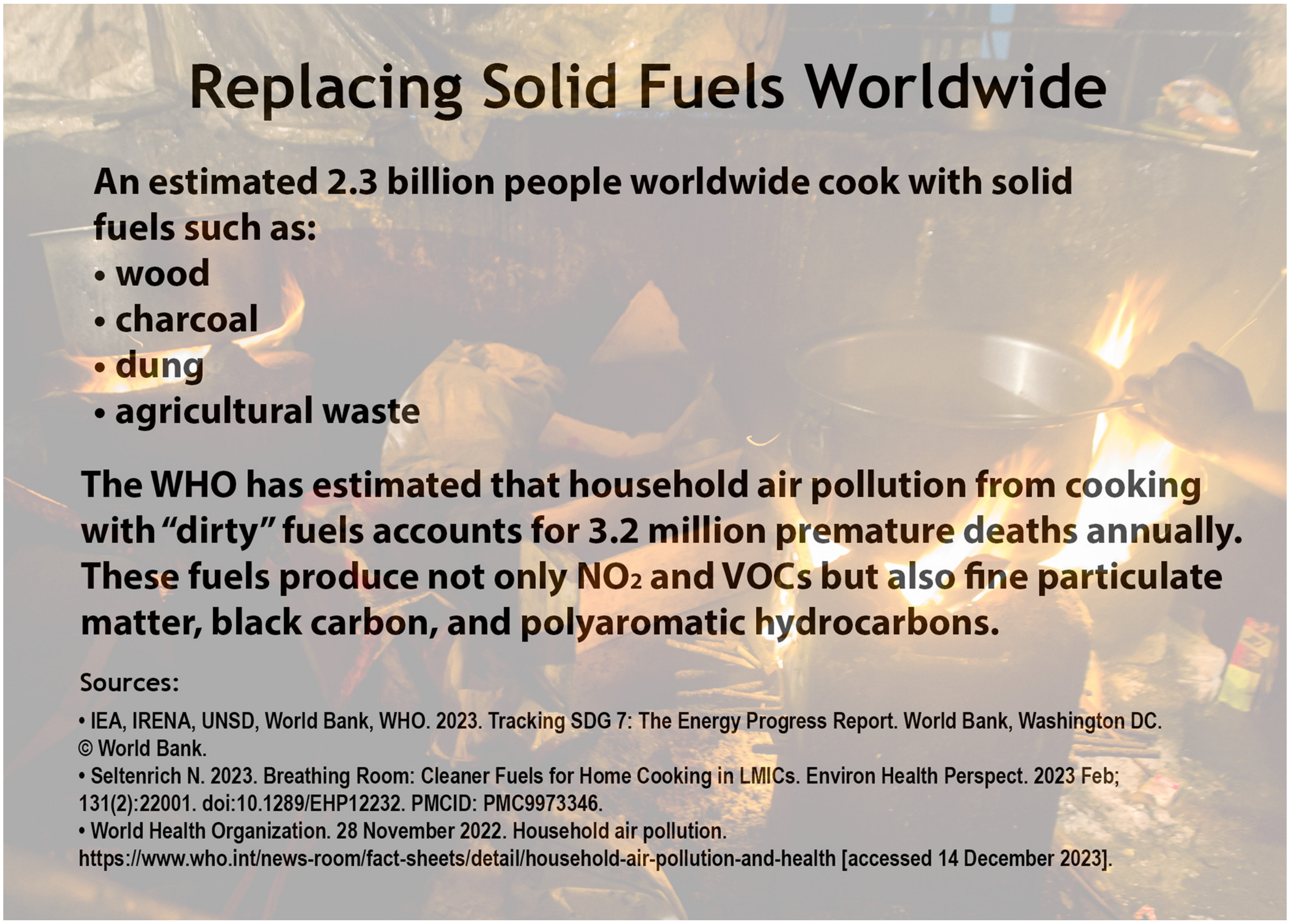
In high-income countries, including the United States[21] and Canada,[22] natural gas use in buildings and homes—not only for stoves, but also for water heaters, furnaces, and clothes dryers—is being targeted for a reason wholly unrelated to indoor air quality: It is a fossil fuel. Organizations including the United Nations[23] and the International Energy Agency[24] are calling for the reduction in use of fossil fuels and their replacement by renewable, carbon-free energy[25] to help meet greenhouse gas reduction goals and mitigate climate change.

Accordingly, a small but growing number of US cities and states[26] have banned natural gas connections in new residential and commercial construction (and in some cases, renovations) explicitly to reduce carbon emissions and combat climate change.

But these policies have met with considerable controversy of their own.[27] The first such ban, passed by the city of Berkeley, California, in 2019,[28] was challenged by the California Restaurant Association and overturned by a federal appeals court in April 2023.[29,30] The city’s subsequent appeal to reinstate it[31] was struck down in January 2024.[32] Meanwhile, well over half of US states have passed or introduced legislation preemptively prohibiting future bans on new gas connections.[33]

Taking a global view, the status of natural gas today becomes even more complex. At the same moment that some countries are considering a move away from gas, others are moving toward it. In regions where most cooking is still done using solid fuels, gas stoves are seen largely as a boon to both public health and climate change mitigation efforts.[34,35] Studies in low- and middle-income countries have documented reduced pollutant exposures and improved health outcomes in households burning gas vs. biomass.[36–39] Yet many clean-cooking advocates still view gas only as a stepping-stone on the way to electric cooking—and a step that can be skipped altogether in some cases—not the final destination.[40]

In the United States, the subject is often politicized, polarized, and stripped of nuance. At the very least, recent reports about new health findings, the CPSC commissioner’s public comments, and dueling gas-ban laws may lead some people who enjoy cooking on gas stoves to wonder: How much longer can (or should) I hold on to mine?



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A Question of Chemistry

To better understand why gas stoves raise indoor air concerns, it helps to consider the underlying chemistry. What we call natural gas is 60%–90% methane mixed with varying levels of other volatile organic compounds (VOCs), depending on the source and processing methods.[41]

Another fuel commonly burned in gas stoves is liquefied petroleum gas (LPG). Usually called "propane," it is actually a blend of propane (C_3H_8) with lesser amounts of butane (C_4H_{10}) and trace amounts of ethane, methane, pentane, and other VOCs.[42,43]

No matter the specific composition, when these fuels are combusted by an open flame—whether on a range-top or in the oven—their constituents transform into other compounds and interact with elements in the air to produce still more chemicals. The heat of the flame itself triggers reactions right at the source, including, most notably, production of NO_2. Indeed, the Stanford researchers confirmed in a 2022 study[5] that NO_2 production during stove use has a linear association with gas flow: the more gas burned, the more NO_2 released to the indoor environment.

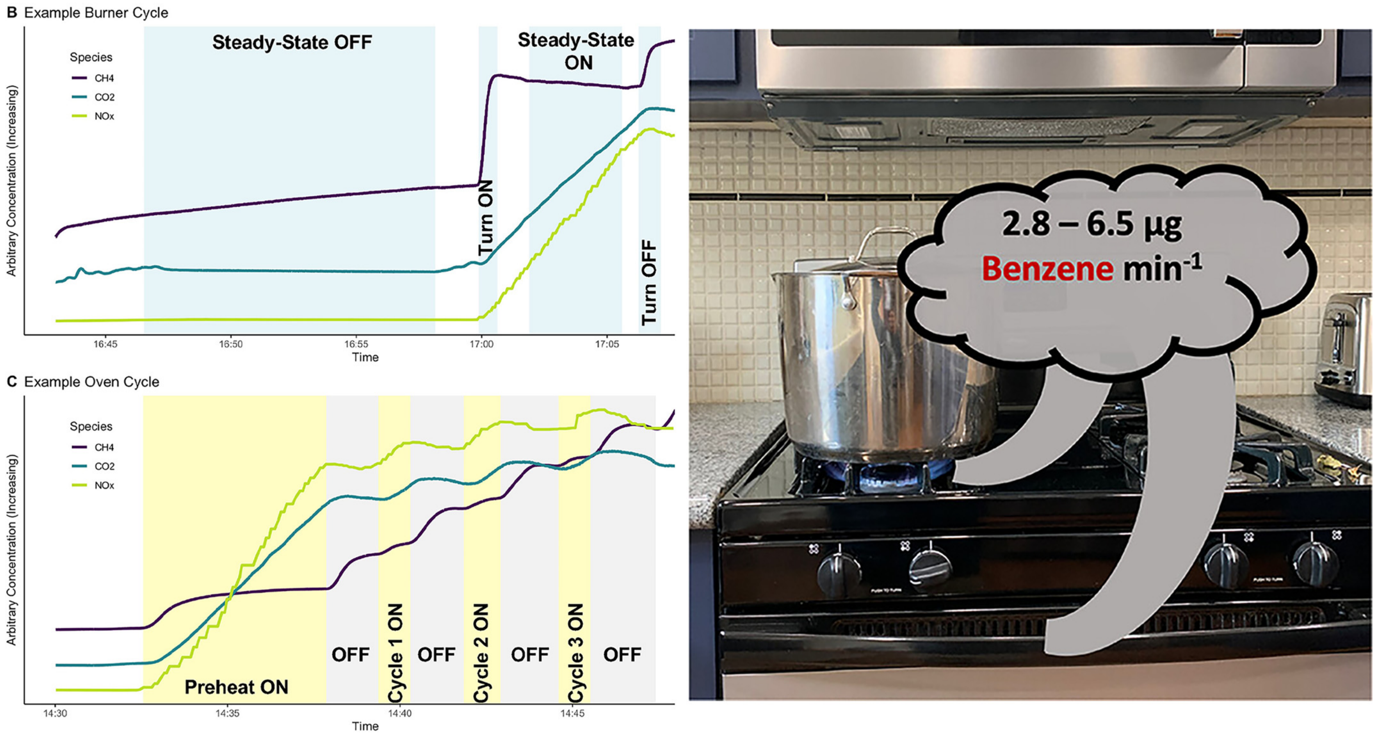
Yannai Kashtan, a graduate student researcher at Stanford University and lead author of the Stanford–PSE Healthy Energy C_6H_6 paper,[10] notes that the vast majority of our atmosphere is composed of nitrogen in the form N_2, which is nontoxic, and oxygen in the form O_2, which we need to survive. "At high temperatures, however, a lot of messy things happen," Kashtan says. "Chemical bonds can break, and things can rearrange. And if you are dealing with N_2 and O_2 in a high-temperature situation, one of the products you will get is NO_2."

Other pollutants produced by gas burners are similarly hard to avoid, but for a different reason, Kashtan says. They are products of what is termed incomplete combustion. During complete combustion, all the carbon and hydrogen atoms in the fuel combine with oxygen in the atmosphere to produce carbon dioxide (CO_2) and water (H_2O).[44] Yet this requires a perfect ratio of air and fuel that is difficult to sustain. During incomplete combustion—observed even with newer, properly functioning stoves, says Kashtan—a wide variety of VOCs can form (or reform) instead. This explains how we get CO, CH_2O, and, as the Stanford team established, C_6H_6 in indoor air.[10]

"Basically, if you do not get all the way from methane to carbon dioxide, you get a panoply of these different compounds," he says. "Some of these compounds are perfectly harmless. And others, like benzene, are toxic."

Without Vents or Open Windows

Back inside the home in Piedmont, the researchers ignite a single burner to heat a large pot of water. The spacious, normally open kitchen has been sealed off with plastic sheeting and tape to accurately measure emission rates. The overhead range hood is off, but a floor fan circulates the air. And a narrow plastic tube elevated about 6 feet (1.8 m) off the ground sips that air and sends it outside to the instruments in the minivan.



Incomplete combustion of natural gas during normal operation of home appliances generates measurable levels of methane, carbon dioxide, and nitrous oxides, left, and benzene, right. Images: Lebel et al. (2022), left[5]; Kashtan et al. (2023), right[10]; both CC-BY-NC-ND 4.0. [https://creativecommons.org/licenses/by-nc-nd/4.0/].

Quickly, the concentration of NO_2 reaches 66 ppb, then 116 ppb, then 244 ppb and beyond. In a matter of minutes, the level in the kitchen has exceeded both US EPA (100 ppb)[45] and California Air Resources Board (180 ppb)[46] regulatory limits for outdoor 1-hour average exposures. And it has surpassed by an order of magnitude the WHO's more stringent 24-hour outdoor guideline of 25 ppb.[47]

The sealed-off kitchen represents a truly worst-case scenario, with no ventilation or air exchange whatsoever. For people in small apartments without a range hood that vents to the outdoors and few or no windows to open, or in a climate or season that makes opening windows impracticable, this worst-case scenario can be pretty close to reality, says Misbath Daouda, an assistant professor at the University of California (UC), Berkeley.

Daouda has preliminary data to support that claim. In 2022 she contributed to a pilot study[48] in a New York City Housing Authority apartment building involving a 10-month monitoring period in 10 apartments that received electric induction stoves and 10 control apartments that retained their gas stoves. Led by the community-based organization WE ACT for Environmental Justice, the study was designed to assess the feasibility and benefits of switching from gas to electric stoves in urban public housing.

In three apartments from each group, the team conducted controlled cooking tests involving a standardized meal of spaghetti, tomato sauce, steamed broccoli, and chocolate chip cookies. In the units with gas ranges, NO_2 levels inside the kitchens spiked from a median background of 18 ppb to an average 197 ppb. In one case, NO_2 slightly exceeded 400 ppb, four times the US EPA's 1-hour outdoor limit.

By contrast, in the apartments outfitted with new electric induction stoves (later provided to all study participants), NO_2 levels ranged from an average 11 ppb before the test to 14 ppb during the test. No apartment tested in the pilot had a functioning range hood above the stove to help with ventilation.

A Closer Look at Asthma

Most of the research on the relationship between gas stove use and acute irritant effects of NO_2 is observational in nature. But a team of researchers based at Lawrence Berkeley National Laboratory (LBNL), UC San Francisco, and the Central California Asthma Collaborative (CCAC), an organization that provides direct services to low-income families with cases of asthma, has just launched the first randomized controlled trial evaluating connections between gas cooking and childhood asthma.[49]

Called Cooking Electrification and Ventilation Improvements for Children's Asthma (CEVICA),[50] the study is set in California's Central Valley, a region with poor air quality and high childhood asthma rates.[51] CCAC's co-founder and co-executive director, Tim Tyner, serves as one of three CEVICA co-principal investigators, along with Stephanie Holm of UC San Francisco and Brett Singer of LBNL.

The study is supported by $4 million in state funding—not from a public health agency but, rather, the California Energy Commission (CEC),[50] a fact that exemplifies why there is confusion around the dual health and climate risks of gas stoves. "CEC is really tasked with trying to reduce fossil fuel combustion for energy generation in California," says retired UC San Francisco professor of medicine John Balmes, who is involved in the trial. "The commission hopes there would be health co-benefits from electrification of cooking for climate purposes."

The study's first phase, beginning in winter 2024, involves 80 homes provided with new electric induction stoves and another 80 using their existing gas stoves. Researchers will monitor indoor air quality along with childhood asthma incidence and lung function at baseline and after 3 months. For half the cohort, a second assessment will occur 6 months postintervention, "which is the more likely point that we could see possible changes in asthma outcomes," Tyner says. In the second phase, the 80 homes still using

In New York City, where 18.8% of childhood asthma is attributable to gas stove use,[15] investigators launched a pilot study on the effects of indoor cooking electrification.[48] Here, study participant Mary Rivera and daughter Francelli Reyes cook one of the standardized meals provided by the researchers. Image: Courtesy WE Act for Environmental Justice.

gas will receive induction stoves as well, and all outcomes will be monitored for 3 more months. Pending the approval of additional grant funding, Daouda hopes to add another arm of the study to analyze measures of pollutant exposures and respiratory outcomes among adults who do the primary cooking in the household.

The work may have significant real-world implications, according to Tyner. "The outcome of our study could determine whether or not California invests more money into replacing gas stoves [and] targets the most vulnerable populations," he says.

Using range hoods that exhaust to the outside, such as the one being installed above, and opening windows where feasible are ways to help reduce levels of harmful pollutants generated by even well-functioning gas stoves. Images: © Ungvar/Shutterstock.com.

Ventilate, Ventilate, Ventilate

Regardless of heat source, cooking food can release a variety of pollutants, including acrolein, polyaromatic hydrocarbons, and fine particulate matter.[52] These are most likely to be produced under high heat when sautéing, frying, or searing foods, especially those high in fat or oil.[53] Exposure to such pollutants can be reduced through kitchen exhaust ventilation, typically with the use of range hoods that are vented to the outside.[54]

"If you're going to have a gas or LPG stove, you need a vented hood to be able to reduce pollutants inside the home," says William Checkley, a professor of medicine, international health, and biostatistics at Johns Hopkins University who has studied cooking pollutants extensively. "That is for certain."

In California, Tyner says that Medi-Cal (the state's version of the federal Medicaid program that provides health care coverage to low-income residents) offers funding assistance to install range hoods in homes of residents with poorly controlled asthma as an intervention supporting respiratory health. More than one-third of Californians are covered by Medi-Cal.[55]

Those who do not have a range hood that exhausts to the outdoors, cannot add one, and cannot adequately ventilate with open windows (or live in a climate where this is impractical) may opt to replace their gas stove with an electric model, especially if there are adults with respiratory issues or any young children in the house. Even those buying a new stove for other reasons should consider making the switch, advises Balmes. The Inflation Reduction Act of 2022 funded rebates of up to $840 for the purchase of a new electric stove.[56]

However, for many people, none of these options are realistic. In a recent letter to the editor in the journal *Environmental Science and Technology*,[57] Daouda and colleagues noted several barriers for lower-income households, including up-front costs, cumbersome processes for recouping subsidies, and reliance on gas stoves for supplemental heat. In addition, renters have little say over which appliances are provided by landlords. "The onus should not be placed on individuals only," Daouda says.

For those who do have the desire, means, and freedom to replace their gas stove, induction models are touted as safer and more efficient—even compared with other types of electric stoves.[58,59] Indeed, Daouda says she heard only positive comments in the New York City pilot study. To ease the transition, participants were invited to attend live demonstrations of electric induction cooking with a local chef, preparing dishes the participants themselves had requested. They also were provided access to culturally appropriate, bilingual online cooking classes.[60]

"Participants were unanimous about one aspect of the pilot: they loved their new induction stoves," the study's final report reads.[7] "They cited different reasons for preferring the induction stove to the gas stove, including the ease of cooking, the time savings because the induction stove cooks faster and is easier to clean, the decreased reliance on other appliances, and the fact that the induction stove creates a safer cooking environment."

Nate Seltenrich covers science and the environment from the San Francisco Bay Area. His work on subjects including energy, ecology, and environmental health has appeared in a wide variety of regional, national, and international publications.

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