Research Brief

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Stanford | Woods Institute for the Environment

The Elevated Health Risks from Nitrogen Dioxide and Benzene in Homes

Gas stoves are a leading cause of indoor air pollution in homes because of emissions of nitrogen dioxide and benzene that increase health risks. Switching to electric stoves eliminates these risks while improved ventilation reduces them.

Background

The link between air pollution and health has been clear for decades, prompting such laws as the U.S. Clear Air Act to protect people from the more severe effects of exposure to poor air quality outdoors. In the United States, approximately 100,000 premature deaths are estimated to occur annually due to heart attack, stroke, lung cancer and other diseases associated with exposure to poor air quality. However, while the U.S. population spends about 90% of its time indoors on average, the air quality in our homes is largely unmonitored and unregulated.

Prolonged exposure to poor indoor air quality can reduce productivity, health and well-being. Combustion-based cooking from gas and propane stoves is one of the largest contributors of indoor air pollution. In the United States, approximately 38% of households — about 47 million households — cook with gas and hundreds of millions of households cook with gas stoves globally. Combustion produces numerous pollutants, including nitrogen dioxide (NO_2), ultrafine particulate matter, carbon monoxide, and carcinogenic formaldehyde and benzene. Long-term exposure to NO_2 is associated with serious health risks, including childhood asthma, chronic obstructive pulmonary disease (COPD) and preterm births. Benzene is classified as a human carcinogen by the United States Environmental Protection Agency (USEPA), and the United States Department of Health and Human Services (DHHS) has similarly determined that benzene causes cancer in humans. Chronic exposure to elevated benzene levels increases the risk of developing leukemia, a cancer of the blood-forming organs, as

POINTS FOR POLICYMAKERS

- **Gas and propane combustion in stoves is a substantial source of NO_2 exposure indoors relative to outdoor sources and can significantly elevate benzene concentrations in homes:** Across the United States, gas and propane stoves represent a quarter of total residential NO_2 exposure on average for people who use gas stoves, with outdoor exposure making up the remaining three quarters. Exposure from gas and propane stoves varies across ZIP codes.

- **Gas and propane stoves in the United States are responsible for substantial long-term NO_2 exposure and virtually all short-term NO_2 exposures exceeding the WHO and US EPA's guidelines.** For households owning gas stoves, the Stanford-led study estimates that gas and propane stoves contribute roughly one quarter of long-term residential NO_2 exposure. It also estimates that gas and propane stoves in the United States are responsible for virtually all estimated NO_2 exposures that exceed the WHO and US EPA's short-term guideline, primarily because NO_2 exposure from gas stoves occurs as relatively brief bursts at high concentrations.

- **Exposure to benzene attributable to gas stove use in homes can raise the risk of leukemia, especially childhood leukemia:** The cumulative Incremental Lifetime Cancer Risks (ILTCR), a measure used in environmental risk assessments to evaluate the potential health impacts of exposure to hazardous substances, often exceeded the World Health Organization's safe threshold. The risk is particularly concerning for children, whose cancer risk was 85% higher than for adults in most of the high and medium gas stove usage cases.

- **Good ventilation plays a critical role in reducing indoor air pollution concentrations:** In the benzene study, higher efficiency ventilation systems, such as outdoor-venting range hoods with a 75% capture efficiency, decreased exposure when used. In contrast to outdoor-venting hoods, recirculating hoods, as found in many U.S. homes, do not reduce overall benzene concentrations indoors. Studies show that only one-quarter to one-third of residents use their ventilation hoods when they cook.

well as acute non-cancerous effects such as aplastic anemia, a deficiency in red and white blood cells and platelets.

Primary sources of outdoor NO_2 include natural sources such as lightning as well as human activities that include vehicle exhaust, fossil fuel combustion for electricity, and natural gas flaring. Indoors, NO_2 is primarily generated by gas and propane stoves. Despite the availability of detailed outdoor NO_2 concentration maps that have helped identify high-risk areas for diseases such as pediatric asthma, these maps fall short in estimating actual human exposure because they do not account for indoor sources or differences in building ventilation and climate. As a result, outdoor concentrations alone are poor predictors of total personal NO_2 exposure.

To address the gap in understanding of indoor NO_2 and benzene exposure, a team of researchers led by Stanford University studied emissions of both pollutants indoors. For nitrogen dioxide, they developed new models that integrate indoor NO_2 emissions with zip code level data on outdoor NO_2 levels, housing characteristics, and regional climate. Their approach provides the first nationally representative estimates of total long- and short-term residential NO_2 exposure. For benzene, the researchers measured the emissions and movement of benzene emitted from gas stoves in various rooms of the home, in different housing and floor plan types and under various levels of gas stove usage and scenarios of ventilation.

The new NO_2 exposure maps provide a much more accurate picture of how Americans are affected by NO_2 and related pollutants in their homes. Their work offers policymakers powerful tools to prioritize and target electrification initiatives, ventilation improvements, and public health campaigns in areas with the highest estimated exposures. The research on benzene shows that gas stove emissions significantly elevate cancer risks in homes with medium to high gas stove usage coupled with inadequate ventilation. Because benzene and NO_2 travel quickly beyond the kitchen and throughout the home, their presence affects all members of the household, not just people who cook. Their presence in bedrooms even after the stove is turned off is especially concerning for children and other vulnerable groups.

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ABOUT THE RESEARCH

This brief is based on the **Exposure and health risks of benzene from combustion by gas stoves: A modelling approach in U.S. homes** published in *Journal of Hazardous Materials* and **Integrating Indoor and Outdoor Nitrogen Dioxide Exposures in U.S. Homes Nationally by ZIP Code** published in *PNAS Nexus*

POINTS FOR POLICYMAKERS CONTINUED

- **Mitigation approaches are needed to reduce nitrogen dioxide and benzene sources in both indoor and outdoor air:** Strategies to reduce chronic health risks include switching to electric stoves, which eliminates the risk, to enhancing ventilation (such as opening windows in areas with low outdoor pollution), and requiring outdoor-venting hoods with high efficiency. California, for instance, now requires outdoor-venting hoods when purchasing new gas stoves.

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