Review and Comments "Composition, Emissions, and Air Quality Impacts of Hazardous Air Pollutants in Unburned Natural Gas from Residential Stoves in California," 2022

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In October 2022, the Environmental Science & Technology journal published "Composition, Emissions, and Air Quality Impacts of Hazardous Air Pollutants in Unburned Natural Gas from Residential Stoves in California" (Lebel et al., Oct. 2022).[1] The following Review and Comments present several points, observations, and issues for further scrutiny. The authors appear to have used an extreme, beyond "worst case" scenario to model potential exceedances of benzene in atypical circumstances. Furthermore, if these scenarios did occur, the odorants in the natural gas would alert the building occupants before the elevated benzene levels were encountered (based on the authors' own numbers in a prior study). Further investigation of the underlying methods, assumptions, and results is required to develop a full and fair exposition of the pertinent facts.

Overview of Study Conclusions

- The gas industry routinely tests natural gas to determine its constituents, including methane, ethane, propane, and butane content. Prior research has shown that natural gas contains only trace amounts of volatile organic compounds. The data from this new study is generally consistent with these earlier studies.
- The study measured samples of natural gas taken from end-use appliances and did not conduct direct measurements of fugitive natural gas emissions.
- The study then reported indoor ambient air concentrations that were *model*ed*, not measured,* and subject to underlying assumptions.
- Most of the model simulations, including *all* of the median-value simulations of indoor benzene concentrations attributable to natural gas stoves and ovens, were below the state 8-hour screening level (the California Environmental Protection Agency Office of Environmental Health Hazard Assessment 8-h reference exposure level [REL] of 0.94 ppbv) ("OEHHA guideline").

[1] Lebel, Eric D., et. al. "Composition, Emissions, and Air Quality Impacts of Hazardous Air Pollutants in Unburned Natural Gas from Residential Stoves in California" Environmental Science and Technology. October 20, 2022. https://pubs.acs.org/doi/10.1021/acs.est.2c02581

- The estimates of indoor air concentrations included contributions from other sources unrelated to indoor appliance use. The authors included an assumed 0.174 ppb of benzene from outdoor air. The outdoor air contributions represent nearly 20% of the conservative screening level used by the authors as a point of comparison.

- It is only when worst-case modeling inputs were stacked on top of one another (the highest regional 95th percentile benzene levels in natural gas combined with the 95th percentile natural gas leakage rate) that the authors found that "certain parameter combinations have the *potential*" to lead to modeled indoor air benzene concentrations exceeding the OEHHA guideline (emphasis added).

- All the modeled simulations were based on very conservative assumptions, including using air change rates (the frequency of the air replaced in a room) much lower than typical homes based on current U.S. Environmental Protection Agency (USEPA) literature.

- The assumptions used are so conservative that these scenarios would be very unlikely actually to occur in the real world. Furthermore, if these scenarios did occur, the odorants in the natural gas would alert the building occupants before the elevated benzene levels were encountered (based on the authors' own numbers in a prior study).[2]

- Moreover, it is uncertain how well the measured benzene concentrations in the natural gas samples represent long-term average trace gas concentrations. The authors acknowledge that their sampling design focused on capturing geographic rather than temporal variability.

- Findings are based on a limited one-time study and do not appear to be adequate to conclude that the volatile organic compound (VOC) "content in unburned [natural gas] observed in our study is representative of California's transmission and distribution segments of the supply chain." The sample sizes for each region were small, including some as low as eight samples.

- The study used natural gas leakage rates from an earlier 2022 Lebel study to *model* the benzene concentrations in indoor air.[3] An AGA review of that earlier study raised

[2] Michanowicz, Drew R., et. al. "Home is Where the Pipeline Ends: Characterization of Volatile Organic Compounds Present in Natural Gas at the Point of the Residential End User" Environmental Science and Technology. June 28, 2022. https://pubs.acs.org/doi/full/10.1021/acs.est.1c08298

[3] AGA review of Lebel et. al. January 2022: https://www.aga.org/globalassets/research--insights/american-gas-association-review-and-comments-lebel-et.-al-2022-rev2022.4.14.pdf (reviewing Lebel, Eric D., et. al. "Methane

questions regarding the test methods, measuring instrumentation, emissions sampling, physical and operating conditions, and other issues. The data distribution for leakage rates from the earlier study was also highly skewed, and yet in the current study, the authors used the 95th percentile value from the skewed data set as an upper bound estimate. Reliance on that prior study, including the 95th percentile natural gas leakage rate, thus introduces additional uncertainty into these modeling scenarios.

Review of More Detailed Study Findings

- The study reported measurements of trace gas analyses and chemical composition from 159 natural gas samples collected directly from indoor distribution piping across seven geographic regions in California.
    - The study measured concentrations of different constituents of natural gas, including trace amounts of VOCs.
    - Measured benzene concentrations in these California natural gas samples were higher than reported concentrations in Massachusetts natural gas samples from a prior study.[4]
- This study conducted air modeling based on natural gas leakage data for stoves and ovens from the prior Lebel *et al*. (2022) paper to translate the observed benzene concentrations in natural gas samples into indoor air concentrations.
    - One hundred forty scenarios were modeled using different natural gas leakage rates, benzene concentrations (in unburned natural gas), and air exchange rates.
    - The modeling was based on very low air exchange rates, including the buildings' natural ventilation air change rate and the minimum recommended air change rate set by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE).
        - The range of values used for natural ventilation was 0.05 air changes per hour (ACH) (for apartments) to 0.11 ACH (for single-family homes). The authors indicate that these values have been empirically verified, but the supporting information fails to demonstrate any verification. These values appear consistent with the 5th percentile values for relatively new

and NOx Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes" Environmental Science and Technology. January 27, 2022. https://pubs.acs.org/doi/10.1021/acs.est.1c04707).

[4] Michanowicz, Drew R., et. al. "Home is Where the Pipeline Ends: Characterization of Volatile Organic Compounds Present in Natural Gas at the Point of the Residential End User" Environmental Science and Technology. June 28, 2022. https://pubs.acs.org/doi/full/10.1021/acs.est.1c08298

AGA review of Michanowicz et. al. 2022: https://www.aga.org/globalassets/research--insights/policy/american-gas-association-review-and-comments-michanowicz-et-al.-2022-rev-220629.pdf

construction in some cases.[5] For some scenarios, such as mobile homes, there does not appear to be any support for the ventilation value assumed in the study.

- The highest assumed air change rate was the ASHRAE minimum recommendation of 0.35 ACH. It should be noted that this is a minimum recommendation, yet the authors chose to use this as a maximum value. The worst-case modeling assumptions used air change rates 86% lower than the minimum recommendation.
- For comparison, the earlier Lebel study on leakage rates reported 1 to 3 ACH for the kitchens they tested (i.e., up to 60x higher than the assumed ventilation rate used in the modeling) even though they had attempted to seal off those spaces.
- Based on the literature, USEPA data demonstrates that a typical residence has about 0.46 ACH.[6] Using 0.35 ACH as a *maximum* air change rate, when that is below the *average* (geometric mean) air change rate, is unrealistic and appears to assume a "worst-case" scenario.

- Despite using an unreasonably low air change rate, the study found that "*[m]ost model simulations– including all median value simulations– did not result in ambient benzene concentrations* attributable to emissions of NG [natural gas] from gas stoves that are off above *the California Office of Environmental Health Hazard Assessment [OEHHA] 8-hour REL* of 0.94 ppbv" (emphasis added).
- While the study modeled some exceedances of the California guideline, those appear to only be for "95th percentile model runs" where the 95th percentile natural gas leakage rate was paired with the 95th percentile benzene natural gas concentration for one or two regions.
    - Thus, the study concluded that: "*Based on model results, an elevated leakage rate of benzene and a low ventilation rate are both requisite for indoor concentrations to exceed the OEHHA 8-h REL for benzene*" (emphasis added). The use of a 95th percentile methane emission rate combined with a 95th percentile benzene NG concentration does not represent a condition that would occur 5% of the time. These two factors could be expected to co-occur in only 0.25% of cases. This is <u>before</u> accounting for the additional low building ventilation rates that would also be necessary for an exceedance to occur. Thus, the "95th percentile model runs" where a small number of exceedances were observed reflect atypical residential conditions and do not represent conditions in most homes. As

[5] See Environmental Protection Agency. "Update for Chapter 19 of the Exposure Factors Handbook, Building Characteristics," Table 19-1 (recommending a median central estimate of 0.45 ACH for residential buildings based on multiple studies), https://www.epa.gov/sites/default/files/2018-07/documents/efh_-_chapter_19_update.pdf.
[6] See *id.*, Table 19-25.

previously noted, occupants would be alerted by odors before the elevated benzene concentrations would occur.

- None of the modeled benzene concentrations exceed the equivalent national EPA guideline.