Review and Comments
"Methane and NOx Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes," Environmental Science & Technology, 2022

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In January 2022, the journal *Environmental Science & Technology* published "Methane and NOx Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes" (Lebel et al. 2022). The following Review and Comments present several points, observations, and questions based on an AGA review of the study. A review of the study raises several issues and questions regarding the test methods, measuring instrumentation, emissions sampling of the natural gas cooking appliance types, physical and operating conditions, and other issues. Further investigation and analysis of testing and test results by individuals with the appropriate expertise are needed to sufficiently develop a full and fair exposition of the pertinent facts to enable the public to understand how the authors came to their conclusions or to form independent conclusions.

- The article claims "methane emissions from all gas stoves in U.S. homes have a climate impact comparable to the carbon dioxide emissions of 500,000 cars." The assumptions and calculations for this extrapolation are subject to question. Still, they would translate into only 0.09% of the annual methane emissions in the U.S. (Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks | USEPA).
    - The U.S. Environmental Protection Agency (USEPA) estimates a typical passenger vehicle emits about 4.6 metric tons of carbon dioxide (CO2) per year (Source: Greenhouse Gas Emissions from a Typical Passenger Vehicle | USEPA); for 500,000 cars, that equates to 2.3 million metric tons of CO2 per year; which equates to 26,700 metric tons of methane per year using USEPA's Greenhouse Gas Equivalencies Calculator, which is 0.09% of annual methane emissions.

- The study states, "In addition to methane emissions, co-emitted health-damaging air pollutants such as nitrous oxides (NOx) are released into home air and can trigger respiratory diseases." However, the study did not measure representative nitrogen oxides (NOx) levels in room air. The rate of NOx emissions were measured rather than a direct measurement of NOx in the breathing zone under conditions representative of a normal kitchen.

- The article "found that ovens could produce enough NO_2 to exceed the 1-h ambient standard (100 ppb) within a few minutes." This claim improperly compares instantaneous peak concentrations during the first few minutes of stove usage to a threshold based on 1-hour time-averaged data and has no scientific basis. The shortest

measurement time interval that should be used to evaluate against the outdoor air guideline is 1 hour.

- To make strong inferences about the nation, or even just California, requires a larger sample size of no less than 385 homes, preferably not all in the same region. This assumes a 95% confidence level, 5% margin of error, and at least 1.3 million gas stoves in use. Loosening the confidence level to 90% and a 10% margin of error would require 68 sites. (Both cases assume a 0.5 standard deviation.)

- The study did not include emissions from the cooking process, which is just as important, if not more so, than emissions from the burner or heat source operation. Indoor air quality studies have consistently found that emissions from the cooking process can be significant for various classes of pollutants such as particulate matter and volatile organic compounds.

- The Federal Interagency Committee on Indoor Air Quality (CIAQ), which is comprised of two dozen federal agencies led by the U.S. Environmental Protection Agency (EPA), routinely addresses indoor air quality issues of public importance. The CIAQ has not identified natural gas cooking emissions as an important issue concerning asthma or respiratory illness. Furthermore, the U.S. Consumer Product Safety Commission and EPA do not present gas ranges as a significant contributor to adverse air quality or health hazards in their technical or public information literature, guidance, or requirements.

- Federal agencies such as the Consumer Product Safety Commission (CPSC) and the Environmental Protection Agency (EPA) closely monitor and have evaluated homes with natural gas piping and natural gas appliances and have never taken action to limit their use on methane emissions as suggested in this study.

- The appliance manufacturers recommend the installation and use of gas piping and gas appliances in accordance with national consensus standards.

- Natural gas appliances are required to be design certified for safety to appropriate National American National Standards in order to be installed.

- The study does not isolate the methane leakage to the appliance, and the article could not confirm where the leaks originated.

    - The appliance was not isolated from the gas supply equipment as part of this investigation. Specific sources for the leaks were not identified.

    - The tests were performed on gas-leaking appliances or where gas leaks existed in the home gas piping or at the connection of these two, making it impossible to determine which component contributed.
    - There is no indication in the article that the appliances underwent periodic maintenance as specified by the appliance manufacturer.

- The study mentions ignitor issues, indicating the appliances were in disrepair.
    - Consequently, when a correctly functioning gas appliance is properly installed, there should not be any gas leaks.
    - Further, with a properly functioning gas appliance, there is no methane released into the atmosphere when the burner is operating. The combustion chemical reaction does not allow it, meaning that all of the gas being supplied to the burner, including the raw gas being released during the four seconds safety standards allowance during ignition, will burn during the combustion process, and nothing will be liberated as raw gas to the environment.

- There is no indication in the article that the building's gas distribution system, including connections in the piping and connections to the appliances, was verified as properly functioning and sealed before testing.

- The reported leak rates are skewed by a few possible outliers. Even so, the reported average leak rate when stoves are off is only 0.00005 cubic feet per minute.

- There are some potential methodological issues with the study. The measured methane and NOx results were adjusted for dilution caused by leak rates from the test enclosure reported to be 1 to 3 air changes per hour (ACH). That is about five to ten times more dilution than expected for a sealed-off test area.

- The authors may have been testing emissions from commercial appliances, which by code require that vent hoods be installed.
    - The authors noted in the article that the stoves' ages ranged between 3 and 30 years of age, with heat output for each burner ranging from 4500 to 25,000 Btu/h.
    - Commercial burners have higher heat output ranges (25,000 Btu/h), and the fuel gas codes (IFGC & NFGC) require that vent hoods be installed. Using both residential and commercial appliances in this study is inappropriate.
    - Commercial burners are designed, tested, and certified with a specified air exchange rate.

- No uncertainty analysis was conducted, and no independent tests of the method were presented.

Further observations and discussion points

- The scope of the study focused on gas stoves, cooktops, and ovens and includes measurements of these appliances in 53 California homes during all phases of appliance operations.
    - The study sampled a range of appliance brands (18) and ages (3 to 30 years), including appliances with pilot lights or electronic ignition.
    - No appliances in multi-family buildings were sampled.
    - The approach involved partitioning the kitchen with plastic sheets from the rest of the house.
    - This effectively formed a source enclosure where methane and NOx concentrations were sampled from within while the stove was in various states of operation.

- In the U.S., an organic foul-smelling non-toxic gas called mercaptan is added to natural gas to odorize it so that people can effectively detect any natural gas presence.
    - Humans can detect mercaptan at 1.6 ppb (0.0016 ppm) concentrations; therefore, in a typical home, gas leaks in appliances and their connecting gas lines/piping will be very easily detected by the home occupants. The reported concentrations in the study are well below levels that would likely be detected by smell. Nevertheless, it is unclear if the five ranges studied, or any range for that matter had detectable leaks that had not been remedied.

- All certified gas ranges are tested for leaks [with the Manufacturing and Productions Tests required by Section 6 of the ANSI Z21.1 · CSA 1.1 Standard, where subsections 6.1 b) and c)], and common multiple leak points are evaluated during factory manufacture.

- Fuel-fired appliances are designed and installed with the knowledge that there is air movement. The test area was sealed, preventing any normal air movement.

- The article does not indicate if the cavity ring-down spectrometer readings were corrected or adjusted for the presence of volatile organic compounds (VOCs) (due to the presence of common household items), hydrogen sulfide (present in trace amounts in gas), or other interferents

- Tested gas cooking appliances were not indicated as checked for proper operating rates.
    - The article indicates that nitrogen dioxide (NO_2) was measured directly. However, the instrumentation cited typically is used to measure NOx and nitric oxide (NO), with NO_2 calculated by difference rather than actually being directly measured.
    - The article does not state if the NOx results were corrected or adjusted for the presence of nitrous acid or other interferents. Correspondence with the authors indicates that they did not correct for the presence of HNO_2.

Statistical observations

Summary of mean CH4 emission rates of residential stoves, cooktops and ovens.

Source	Number	Mean Emission Rate mg/hr	Lower Confidence Limit (5%)	Upper Confidence Limit (95%)	Comment
steady state stove off	53	57.9	36.3	84	9% of stoves = 49% of emissions
single cooktop burner on	180	259	151	408	9% of burners = 51% of emissions
burner on/off	180	45.9	33.1	64.8	
burner on/off w pilot light	8	258	166	382	estimated ranges
burner on/off electronic	180	38	24	56	estimated ranges
oven pre heat	40	663	408	1030	
oven at temperature	40	759	435	1310	
broiler steady on	31	112	50	186	less on /off cycling

- As shown in the Table, the measured emission rates were characterized by highly skewed, fat-tailed distributions with relatively large confidence limits. Oven operations had the highest emission rates, while single burner emission pulses for pilot light burners were much higher than electronic ignition units. The data for steady-state-off measurements were long-tail skewed, with the top five stoves (9% of sampled units) emitting half (49%) of all steady-state-off emissions. Steady-state-on emission measurements were also long-tailed skewed. The top 5 stoves (9%) emitted 51% of all steady-state-on emissions.
    - The article does not indicate which stoves skewed the results.
    - Did the five appliances in the steady-state off measurements producing 49% of the emissions have standing pilots?
    - Were any of these appliances commercial-grade appliances and not residential?

- The extrapolation of the mean (58 mg/hr) test results to calculate an emission level for the entire country is problematic with the known skewness of the dataset. The median (24 mg/hr) leakage value from the dataset may have been a more representative value. Using the median result would not penalize the national emissions calculation based on a small number of ranges with potential special causes that were not fully investigated.

- It is noted in the report that bootstrapping was performed on the original data set.
    - There are several forms of bootstrapping. Which type was conducted is not indicated, nor were the number of replicate data sets generated in the bootstrapping process.

Regarding Figures

- 5S:
  - The data set appears to be exponential with severe right-sided skewness, yet the graph indicates mean & confidence intervals based on a normal data set.
  - In this, the average will be higher than the median in such a skewed data set. What is the median of this data set?

- S8, S9, S10:
  - The data set appears to be non-normal, yet the data presented assumes a normal distribution using the mean (average) and corresponding confidence intervals.
  - What distribution are the data sets and resulting medians?