Issues that Render the Sierra Club/UCLA Study of *Effects of Residential Gas Appliances on Indoor and Outdoor Air Quality and Public Health in California* Not Useful for Decision-Making Purposes

Daniel Tormey, Ph.D., P.G., Steve Huntley

Catalyst ENVIRONMENTAL SOLUTIONS

CALIFORNIA RESTAURANT ASSOCIATION

Introduction

The report *Effects of Residential Gas Appliances on Indoor and Outdoor Air Quality and Public Health in California* (UCLA Report), published in April 2020, was prepared on behalf of the Sierra Club by the UCLA Fielding School of Public Health. Several cities in California have passed electrification policies for new construction, and such programs are being considered Statewide. Most of the focus on electrification efforts has been on reducing greenhouse gas emissions in general. The UCLA Report takes a different perspective and focuses on potential health effects rather than greenhouse gas emissions. The UCLA Report advocates that replacing natural gas-fired stoves and ovens with electric appliances would have public health benefits and continued use of natural gas-fired appliances will result in adverse health effects. The discussion of these effects is divided into two main sections: (1) indoor air quality and health effects and (2) outdoor air quality and health effects.

As discussed in this Technical Memorandum, there are several significant flaws in the UCLA Report that undermine its use in decision-making on the topic of the health effects of natural gas stoves and ovens. We identify five major issues and three other issues for this conclusion. The major issues are as follows:

Issue 1: Indoor air modeling results presented in Table 2-2 of the UCLA Report are incorrectly compared to NAAQS and CAAQS. Had the UCLA Report made the correct comparisons, it would have concluded that there are no adverse health impacts from indoor use of natural gas appliances.

Issue 2: The UCLA Report cites several references that conclude that indoor air quality is more a function of what is being cooked, rather than the fuel used for cooking. Emissions from cooking oils and foods would remain in indoor air whether or not there is a transition from natural gas to electric cooking appliances.

Issue 3: The UCLA Report does not consider unanticipated consequences of replacing natural gas with electric stoves and ovens. The focus is solely on combustion of natural gas. Considering the UCLA Report advocates for eliminating natural gas for stoves and ovens, the consequences of electrification (cost and disproportionate adverse impacts to disadvantaged communities, availability, hazards) are certainly relevant and belong in the decision-making process.

Issue 4: The results of the UCLA Report depend upon a sequential series of assumptions, some of which are unsupported by the literature. The approach of the paper leads to compounding (increasing) these uncertainties rather than reducing them.

Issue 5: Numerous statements throughout the UCLA Report are not supported by the data provided or the references cited. Because the UCLA Report is built on data in the published literature, this problem indicates a flawed foundation for the findings.

The technical basis for each major issue, as well as the three other issues, are described in the next sections.

Major Issues

Issue 1: Indoor air modeling results presented in Table 2-2 of the UCLA Report are incorrectly compared to NAAQS and CAAQS. Had the UCLA Report made the correct comparisons, it would have concluded that there are no health impacts from indoor use of natural gas appliances.

Table 2-2 in the UCLA Report presents the key results for the indoor air modeling exercise. The results are divided into two categories for indoor air appliance emissions: (1) stoves and ovens and (2) stoves only. In both cases, indoor air modeling was conducted assuming no venting of appliance emissions to the outside. Within each of these two categories, indoor air concentrations of CO, NO_2, and NO_x are presented under four cooking time scenarios: (1) peak (maximum) concentration, (2) 15-minute cooking time, (3) 1-hour cooking time, and (4) 2-hour cooking time. The following discussion focuses on the three purported exceedances of NAAQS and/or CAAQS as presented in Table 2-2.

Note that of the chemicals presented in Table 2-2, NAAQS and CAAQS are only available for CO and NO_2. NAAQS and CAAQS have not been developed for NO_x. For CO, specific NAAQS and CAAQS are only available for 1-hour and 8-hour averaging times. For NO_2, specific NAAQS and CAAQS are only available for 1-hour and annual arithmetic mean averaging times. Table 2-2 of the UCLA Report did not present modeling results for either 8-hour or annual arithmetic mean averaging times. Therefore, the only relevant comparisons that can be made using UCLA modeling results are CO and NO_2 1-hour average concentrations as compared to their respective 1-hour time-averaged NAAQS and CAAQS; these comparisons are presented in the table below.

Table 1. Comparison of UCLA 1-hour Average Modeled Air Concentrations to Relevant CAAQS and NAAQS

Carbon Monoxide	1-hour Average
CAAQS	20,000
NAAQS	35,000
Stoves and ovens¥	2,300¥
Stoves only¥	900¥

Nitrogen Dioxide	1-hour Average
CAAQS	180
NAAQS	100
Stoves and ovens¥	19¥
Stoves only¥	11¥

All concentrations in ppb.

¥ Modeled 1-hour average concentration as reported in Table 2-2 of the UCLA Report.

As shown in the above Table 1, for both CO and NO_2, the modeled indoor air concentrations for Stoves and ovens and for Stoves only are nearly 10-fold below their respective CAAQS and NAAQS, demonstrating a large margin of safety and absence of potential adverse health effects, even under the unrealistic assumption of no venting of stove and oven exhaust.

In contrast to the appropriate comparison presented in Table 1 (above), the UCLA Report presented several comparisons that are not appropriate nor realistic. For comparison to NAAQs and CAAQs, the UCLA Report compared peak (maximum) concentrations directly to 1-hour NAAQs and CAAQs. **The comparison of maximum peak concentrations to a 1-hour standard is not correct and certainly not relevant for assessing health risks.** The 1-hour NAAQS and CAAQS represent health effects thresholds associated with 1-hour time averaged exposures. It is meaningless to compare a maximum to an average. When the incorrect method of the UCLA

Report is applied, the maximum peak NO_2 concentrations for stoves and ovens (860 ppb) and stoves only (400 ppb) exceeded the 1-hour NO_2 NAAQS of 100 ppb and the 1-hour NO_2 CAAQS of 180 ppb. In contrast, when the average concentrations under the 1-hour and 2-hour cooking scenarios are compared to the 1-hour NAAQS and CAAQS, there are no exceedances. Therefore, the argument that natural gas appliances cause adverse health impacts because they exceed air quality limits is not supported by the data presented in the study.

The UCLA Report has a similarly incorrect comparison for assessing potential chronic exposures. The UCLA Report states on page 20, "[w]e compare the modeled 8-hour time-averaged CO concentrations to the 8-hour CO thresholds, and the 24- hour time-averaged NO_2 concentrations to the chronic NO_2 thresholds, under three cooking-time scenarios (15 minutes of cooking, 1 hour of cooking, and 2 hours of cooking." However, the only chronic exposure exceedance shown in Table 2-2 for NO_2 under the stoves and ovens scenario is apparently based on comparison of 1-year annual NAAQs (53 ppb) and CAAQS (30 ppb) to a calculated 24-hour time-averaged concentration (34 ppb). **A 24-hour time-weighted average concentration cannot properly be compared to 1-year annual standards.** While the calculated 24-hour time-weighted average concentration may be a reasonable estimate of exposure concentration over the course of 24 hours, it is not a reasonable estimate of exposure concentration over the course of an entire year. The unrealistic underlying assumption for this comparison is that cooking, using both stove and oven, without venting, would take place in a residence for 2-hours every single day for 365 days per year. This is contrary to available data on residential occupancy and appliance use and is inconsistent with standard risk assessment practices that recommend assessment of reasonable maximum exposures, often referred to as the RME (DTSC 2015[1]).

Based on data provided by the USEPA[2] for the amount of time spent indoors at a residence by age group, the age group that spends the most amount of time indoors is >65 years. Based on these data, this age group representing the upper-bound exposure spends on average 82% of their time indoors at their residence. Therefore, these maximally exposed individuals would experience no exposure 18% of the time or 66 days each year. Adjusting the 24-hour time-weighted NO_2 concentration of 34 ppb by this factor alone reduces the time-averaged NO_2 concentration to 28 ppb, which would eliminate any exceedances since it is below both NAAQs (53 ppb) and CAAQS (30 ppb). Even this comparison is considered to be highly conservative (and unrealistic) as it assumes that none of the stove and oven appliance emissions are vented to the outside and that these individuals >65 years in age cook every day using both stove and oven at full capacity for 2 hours each day.

Issue 2: The UCLA Report cites several references that conclude that indoor air quality is more a function of what is being cooked, rather than of the fuel used for cooking. Emissions from cooking oils and foods would remain in indoor air whether or not there is a transition from natural gas to electric cooking appliances.

The available data indicates that indoor air quality is more a function of what is being cooked than the fuel used for cooking. The UCLA Report's conclusions gloss over this fact. The UCLA Report does not include this fact in the summarized major issues. Yet the Report is forced to acknowledge this issue repeatedly: it notes that "there are indoor air quality issues associated with the use of gas cooking appliances that will remain despite the implementation of electrification, and we do not account for this. Some PM emissions are associated with cooking oils and foods, and there are no mitigation methods for this, other than the use of ventilation devices such as range hoods. We do not claim that the transition to electric appliances would make a substantial difference in terms of emissions from cooking oils and food.[3]" It also notes that "although many studies have measured $PM_{2.5}$ and UFP [ultrafine particle] emissions from cooking with various types of food

[1] DTSC. 2015. PEA Guidance Manual. October.

[2] USEPA. 2011. Exposure Factors Handbook: 2011 Edition. September. EPA/600/R-090/052F

[3] Page 30 of UCLA Report

and cooking oil, these particulate emissions were often attributed to the food and cooking method rather than the operation of gas appliances.[4]" The UCLA Report also acknowledges that "[o]ne caveat mentioned previously is that cooking can be a significant source of exposure to $PM_{2.5}$ due to heating and combustion of food and cooking oil, resulting in indoor concentrations far in excess of the NAAQS 24-hour threshold.[5]"

The UCLA Report[6] further states, "Gas stoves have been associated with increased levels of indoor CO in California homes, but these increases in concentrations are generally negligible,[27,49,51,52]" and "studies measuring PM2.5 emissions found that increases attributed solely to gas kitchen appliances (with no cooking of food involved, though sometimes a pot of water was heated) were negligible.[49,52]"

While it is clear that what is cooked can have a significant effect on indoor air quality, the UCLA Report buries this beneath the headline statement[7] that natural gas stoves and ovens exceed NAAQS and CAAQS. Moreover, while it is clear that the emissions of some pollutants (in particular CO and PM) from home appliance natural gas usage are negligible, the UCLA Report attempts to implicate these very same pollutants in the context of health effects associated with residential natural gas appliance use. As generally concluded by the references cited in the UCLA Report, PM emissions from gas stoves and ovens are elevated during food cooking but are negligible when burners are on without food cooking, and therefore provide no basis for inferring adverse health effects.

Issue 3: The UCLA Report does not consider unanticipated consequences of replacing natural gas with electric stoves and ovens. The focus is solely on combustion of natural gas. Considering the UCLA Report advocates for eliminating natural gas for stoves and ovens, the consequences of electrification (cost and disproportionate adverse impacts to disadvantaged communities, availability, hazards) are certainly relevant and belong in the decision-making process.

The UCLA Report correctly notes that it does not provide any sort of cost benefit comparison between electric and natural gas stoves and ovens. The UCLA Report notes "[w]e also did not assess any exposures or other dangers associated with electrification, as we focus on combustion pollutants in this report…[t]his report does not compare the benefits and costs of electrification versus improving range hood use and efficiency in terms of reducing indoor air pollution. This is an important consideration that needs to be included in any full-scale assessment of indoor air pollution mitigation techniques.[8]" The UCLA Report notes other studies do provide such cost-benefit analysis, but the citation it provides did not do so.[9]

Another unintended consequence of following the advice of the UCLA Report is that it fails to address the disproportionate economic impact on low-income individuals and families resulting from the higher cost of electrification and elimination of natural gas as an economically efficient energy source. A recent study published in January 2021 by the Berkeley and UCLA Schools of Law[10] has proposed a policy resolution for the

---

[4] Pages 9 and 12 of UCLA Report

[5] Page 13 of UCLA Report

[6] Pages 12 and 13 of UCLA Report

[7] A statement that is incorrect, as described in Issue 1 of this Technical Memorandum.

[8] Page 30 of UCLA Report

[9] Page 42 of UCLA Report. The citation, reference 15, is to a National Renewable Energy Lab (NREL) report that does not include the words "stove" or "oven" in it, but is a broader view of electrification. No EPRI reference was evident.

[10] Berkeley Law Center for Law, Energy, and the Environment; UCLA School of Law Emmett Institute on Climate Change and the Environment. 2021. Building Toward Decarbonization. Policy Solutions to Accelerate Building Electrification in High-Priority Communities.

higher cost of electric appliances compared to natural gas appliances: raise the cost of natural gas. While this resolution would make the cost comparable, it seeks to shift the cost burden to low-income individuals and families who rely on natural gas as an affordable energy source by artificially increasing natural gas rates to conform with higher electric rates. The effect of this policy would be to reduce demand for natural gas while financially impacting low-income individuals and families.

Even in the absence of focused policy efforts to increase the cost of natural gas to align with electricity costs, as discussed in the Berkeley/UCLA Schools of Law study, the overall shift away from natural gas usage to full electrification will over time result in gradual increased costs to those dependent on natural gas. As discussed in the National Bureau of Economic Research (NBER) working paper recently published by Davis and Hausman (2021)[11], during the period of this shift from natural gas to electrification, historical capital cost recovery, pipeline and other infrastructure maintenance, and operating costs will remain the same, yet natural gas revenues based on declining consumer usage will decrease. Consequently, the shortfall in revenues will need to be resolved by increasing natural gas usage rates to remaining consumers. Since low-income individuals and families have less financial capabilities to shift from natural gas appliances to electric appliances, it is these disadvantaged subpopulations that will be forced to bear the majority of these increased costs of natural gas.

The UCLA Report also notes that eliminating combustion of natural gas in stoves and ovens will typically lead to increased natural gas combustion at power plants: "One aspect to keep in mind throughout this analysis, which will be mentioned again in the Results and Discussion section, is that electricity generation at gas power plants emits both GHGs and criteria air pollutants. Even if all residential gas appliances were transitioned to electric appliances, the electricity required to power these appliances must still be generated by some form of fuel, and gas power plants currently produce almost half of the electricity generation in the state.[12]"

As illustrated in Figure B-5 of the UCLA Report, the contribution of NO_x from residential gas appliances to outdoor air as compared to the total NO_x emissions from all sources in California is very small. Therefore, the relative net beneficial impact of reduced NO_x to outdoor air from the elimination of residential gas appliances is very likely close to zero given the need to supplement electrical generation with other fuel-dependent power sources. This is also likely the case for the other gas combustion by-products evaluated in the UCLA Report such as CO, PM, and NO_2.

Overall, these unintended consequences of following the advice in the UCLA Report undermines the purported benefits highlighted in the report.

Issue 4: The results of the UCLA Report depend upon a sequential series of assumptions, some of which are unsupported by the literature. The approach of the paper leads to compounding (increasing) these uncertainties rather than reducing them.

The UCLA Report acknowledges that the literature and underlying data are uncertain and inconclusive, and that they collected no new data, and yet their approach was to apply an uncertain model in order to address the uncertainty in the literature data. That is, the underlying data on all these issues is inconclusive, lacking, or in some cases contradictory, yet the Report purports to "analyze" it to draw "clear" conclusions. By relying on the same uncertain data, the model simply compounds this uncertainty with model-related uncertainty:

Page 17: "While there is clear evidence of a relationship between indoor air quality and health, and combustion falls under that domain, there is some inconclusive literature related to gas appliance use and

[11] Davis, L.W. and C. Hausman. 2021. Who Will Pay for Legacy Utility Costs? NBER Working Paper 28955.

[12] Page 33 of UCLA Report.

specific health effects. The broader relationship between NO_2 and adverse health effects is well-established but a recurrent theme in the literature is the uncertainty regarding the link between indoor NO_2 exposures from gas combustion and respiratory illness. [30,31,113,117]"

Page 29: "Due to the limited scope of this project, we did not conduct any primary data collection; we only analyzed existing literature and datasets. While we used as many relevant data sources as we could access, data paucity was a major limitation for this report. Particularly for conducting future quantitative analyses with regard to equity, the development of additional, publicly available databases to include more detailed and higher spatial resolution data would be a significant asset."

Page 17-18: "While several studies investigating gas appliances and asthma exacerbation produced mixed results, evidence supports a clearer association between gas appliances and asthma and respiratory symptoms in children with one meta-analysis reporting that children living in homes using gas for cooking have a 42% higher risk of having asthma.[33] While we did not estimate the association between specific health symptoms and use of gas appliances, our literature review and analysis aim to clarify the relationship between pollutants associated with gas appliance use and human health…To our knowledge, there are no existing literature review and secondary analysis studies that tie together indoor air quality modeling for various pollutants, housing types, and low-income vulnerability in California."

In conducting studies of the type presented in the UCLA Report, the uncertainties at each step compound, leading to even more uncertain results. While the UCLA Report purports to improve understanding of the effects of indoor combustion of natural gas for cooking, the study design leads to greater uncertainty and less understanding.

Issue 5: The UCLA Report contains numerous statements that are not supported by the data provided or the references cited. Because the UCLA Report is built on data in the published literature, this problem indicates a flawed foundation for the findings.

The UCLA study is a literature-based study; that is, it relies on studies in the published and at times peer-reviewed literature. However, many of the statements made in the report do not correspond to the cited literature. A few examples are provided, which call into question the foundation of this report.

***Example 1*:** In the first paragraph of Section 1.2 it states, "[h]owever, there are significant risks associated with the burning of gas in residences, due to the indoor emission of pollutants, such as CO and formaldehyde (from incomplete combustion), as well as nitrogen oxides (NO_X) such as NO_2 (caused by the oxidation of nitrogen during combustion). Other hazardous compounds emitted from the burning of gas inside homes include volatile organic compounds (VOCs), sulfur oxides, and PM.[20] "

The statement is misleading. The reference cited (Reference 20) is USEPA (1998) *Compilation of Emission Factors*, specifically Section 1.4 (Natural Gas Combustion). This document includes residential furnace and boiler emission factors for CO, formaldehyde, NO_x, NO_2, VOCs, sulfur oxides, and PM. However, there is no mention of potential health risks or the burning of gas in residences in this USEPA document. The UCLA Report provides no basis or specific reference for the statement that "there are significant risks associated with the burning of gas in residences, due to the indoor emission of pollutants…"

Furthermore, use of the term "significant" in scientific reports generally implies statistical significance. The phrase "statistically significant" is used several times in the UCLA Report, but never in the context of the actual evaluations. Not only does USEPA (1998) not refer to statistically significant health risks for any pollutant, as already noted, but in the two instances where the UCLA Report specifically discusses formaldehyde, it acknowledges that there is no statistically significant association between gas appliance use and indoor air

formaldehyde concentrations. On pg. 13, the UCLA Report states: "Gas appliances also emit formaldehyde,[27,44,62] but some studies did not find a statistically significant association between gas appliance use and indoor formaldehyde concentrations.[45,46,74]" In this instance, the reference is to the absence of statistical significance. And on pg. 14 of the UCLA Report, it states: "However, an LBNL study of California homes found that although 95% of homes tested had formaldehyde concentrations above the OEHHA chronic REL, these levels were not statistically significantly associated with gas appliances.[45]" and "Due to the lack of emission data and statistically significant evidence reported in the primary literature, we did not include formaldehyde or acetaldehyde in our quantitative analysis." In this instance, the reference is also to the absence of statistical significance. Despite acknowledging the *absence* of any statistically significant formaldehyde emissions associated with gas appliances, the UCLA Report nevertheless asserts "there are significant risks associated with the burning of natural gas in residences, due to the indoor emission of . . . formaldehyde."

Moreover, in Section 2.2.1 Emission Factor Database, and specifically the first subsection entitled *Results of Statistical Analyses*, the only reference to statistical analyses or statistical significance in this entire subsection is as follows: "Consistently, as the year of the publication from which EFs were gathered became more recent, the ng/J emissions decreased (e.g., a paper in 1995 would report higher emissions than a paper published in 2009, with a statistically significant difference); this indicates that emissions have reduced over time. For NO_X, there is a statistically significant increase in EFs for appliances designed to be vented outdoors (e.g., water heaters and home heating devices)." No references were provided for either the 1995 paper for the 2009 paper, and no reference is provided for the statistically significant increase in EFs for water heaters and home heating devices. Moreover, despite the misleading name of the subsection, there is no statistical analyses presented.

Example 2: In Section 1.2 (page 9) it states, "[t]he resulting indoor air pollution can have adverse effects on human health, as Americans spend almost 90% of their time indoors,[21]…" The statement is misleading. The reference cited (Reference 21; Klepeis et al. 2001) does not present any evaluation of potential adverse effects on human health resulting from indoor air pollution. Further, while the survey conducted by Klepeis et al. did report that Americans spend almost 90% (specifically 87%) of their time indoors, **the UCLA Report failed to indicate that only 67% of time is spent inside residences.** Since the focus on the UCLA Report is on residential exposure, 67% of time spent inside residences would be the appropriate metric to present.

Other Issues

Issue	Facts Supporting the Issue	Relevance
The UCLA Report advocates eliminating natural gas stoves and ovens for health reasons. The hypothetical risk, however, is already addressed through existing stove and hood design.	The UCLA Report did not model use of residential appliances under the scenarios of manufacturers' safety recommendations, state regulations, or local ordinances. Can natural gas usage be held accountable for improper use of appliances? Page 18: "Unsurprisingly, the EFs of gas appliances have declined over time, likely due to the technological advances of appliances and pollutant capture technology, which reduce emissions. Consistently, as the year of the publication from which EFs were gathered became more recent, the ng/J emissions decreased (e.g., a paper in 1995 would report higher emissions than a paper published in 2009, with a statistically significant difference); this indicates that emissions have reduced over time. "	The air concentrations of CO, NO_2, and NO_x as reported in Table 2-2 of the UCLA Report are incorrect (over-estimated) because the modeling scenario was not based on use according to manufacturer's requirements (nor on real-world conditions). Therefore, the corresponding health implications discussed in the UCLA Report are greatly exaggerated.
The section on outdoor air quality effects of indoor use of natural gas for stoves and ovens only serves to confuse the issues. For the indoor air emissions exposures, the UCLA Report assumed 0% venting to outdoors; for the outdoor air exposures the UCLA Report assumed 100% venting to outdoors. This is double counting and does not give any consideration to the available science on indoor air ventilation rates and similar relevant subjects. **Furthermore, most of the outdoor air section does not address actual stove and oven emissions, which are a small portion of GHG emissions; instead, it evaluates the effects of reducing fossil fuel emissions on GHG-forming compounds in general, not from stoves and ovens and not related to health effects.**	Page 32-33: "A study modeling the impact of future building electrification found that all-electric homes performed better than mixed-fuel buildings, in terms of both GHG emissions reductions and abatement costs associated with the construction of buildings compliant with the Title 24 California Building Standards.[269]" Page 38: "For the year 2018 (as described in Section 3.2.2), the improvement in outdoor air quality from residential building electrification alone would reduce approximately 354 deaths (all-cause mortality), 304 cases of chronic bronchitis, and 596 cases of acute bronchitis in California (see Table B-5 for confidence intervals for mortality). The most affected counties are the higher Population areas, i.e., Los Angeles County and Orange County, due to the nature of the concentration-response function."	The section on outdoor air quality impacts from indoor use of stoves confuses the issues because it in fact addresses overall GHG impacts and health effects of electrification in general, not solely due to cooking.