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*Comment Received From: Southern California Gas Company  
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**Comments on Sept 30, 2020, IAQ Workshop**

*Additional submitted attachment is included below.*



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October 16, 2020

Commissioner Andrew McAllister  
California Energy Commission  
Dockets Office, 19-BSTD-03  
Ninth Street Sacramento, CA 95814-5512

**Subject: Comments on Commissioner Hearing on Indoor Cooking, Ventilation and Indoor Air Quality**

Dear Commissioner McAllister:

Southern California Gas Company (SoCalGas) appreciates the opportunity to provide comments on the September 30, 2020, California Energy Commission (CEC) workshop on Indoor Cooking, Ventilation and Indoor Air Quality. SoCalGas supports the CEC's efforts to compile a robust, scientific record on indoor air quality (IAQ) and inform the development of effective strategies to mitigate emissions from indoor cooking. To that end, we offer the following comments which are intended to: (1) provide additional scientific literature on IAQ, not just the University of California Los Angeles (UCLA) and the Rocky Mountain Institute (RMI) reports; (2) offer viable solutions to address indoor cooking emissions and IAQ; (3) provide additional, technical information about gas cooking and potential health impacts; and, (4) address environmental justice concerns.

**1. CEC Must Consider Additional Scientific Literature on IAQ**

Although IAQ has been studied for many years around the country and internationally, much of the literature on IAQ focuses on potential triggers for asthma and other health conditions. The Center for Disease Control (CDC) and the United States Environmental Protection Agency (EPA) both cite to a variety of common indoor asthma triggers including environmental tobacco smoke (secondhand smoke), dust mites, mold, cockroaches and other pests, and household pets<sup>1</sup>.

While there have been numerous studies on asthma and potential triggers, it is still difficult to draw specific conclusions other than the need for ventilation regardless of the source of indoor air quality concerns. For example, EPA notes, "[i]ndoor pollution sources that release gases or

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<sup>1</sup> Centers for Disease Control and Prevention (CDC). Common Asthma Triggers. Available at: <https://www.cdc.gov/asthma/triggers.html> [cdc.gov] [October 15, 2020]

US EPA. Asthma Triggers: Gain Control. Available at: <https://www.epa.gov/asthma/asthma-triggers-gain-control> [epa.gov] [October 15, 2020]

particles into the air are a primary cause of indoor air quality problems in homes. Inadequate ventilation can increase indoor pollutant levels by not bringing in enough fresh outdoor air to dilute emissions from indoor sources and by not carrying indoor air pollutants out of the home.”<sup>2</sup> Further, the CEC has been a leader in adopting standards for mechanical ventilation and appliance venting that have reduced potential exposure to indoor pollution sources for new construction and improved indoor air quality in newer homes.

Additionally, it should be recognized that contemporary reviews by the federal agencies with expertise and responsibility for protecting consumer safety, including the EPA and the Consumer Product Safety Commission (CPSC), have not identified concerns related to use of gas cooking appliances.

There have been two recent reports that exaggerate the scientific evidence that natural gas cooking, per se, leads to health impacts.<sup>3</sup> First, the Sierra Club funded a report by the UCLA Fielding School of Public Health, titled “Effects of Residential Gas Appliances on Indoor and Outdoor Air Quality and Public Health in California” (UCLA report). Several weeks later, the RMI and Sierra Club issued a report (RMI report) that amplified the UCLA report and selectively cited to additional studies to advance their unsupported conclusion that gas appliances create emissions that cause health risks to advance the perception that electric appliances should replace natural gas appliances.

Both reports largely reflect a selective literature review of existing studies and reach conclusions that are not supported by the data or underlying studies. While the UCLA report does include some independent modeling of hypothetical health benefits from residential building electrification, neither the UCLA report nor the RMI report is peer reviewed.<sup>4</sup> Instead, these reports represent the viewpoints of the authors, rather than a balanced examination of the science behind indoor air quality and potential health impacts of different cooking appliances.

The September 30<sup>th</sup> IAQ workshop included a presentation on the UCLA report and statements from the RMI report were the basis of the public comments made by several parties. In response, SoCalGas seeks to address several of the claims made during the workshop and offers additional technical analysis based on the body of unbiased scientific literature as it relates to natural gas appliances. At SoCalGas’s request, Ramboll has provided a technical review of the UCLA and RMI reports and provides additional insight on indoor air quality and cooking. Their technical assessment is attached as Appendix A.

## **2. *Cooking Produces Emissions Regardless of the Energy Source and Ventilation Effectively Mitigates Emissions***

Cooking is a well-recognized source of particulate matter in homes. The particulate matter is primarily formed due to the cooking process (e.g. frying, sautéing, toasting) and is similar whether the energy source is gas or electric. To a lesser extent, nitrogen dioxide (NO<sub>2</sub>) and carbon monoxide (CO) emissions can be produced as a byproduct of cooking.

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<sup>2</sup> US EPA website, <https://www.epa.gov/indoor-air-quality-iaq/protect-indoor-air-quality-your-home>

<sup>3</sup> One of these reports, prepared by UCLA on behalf of the Sierra Club, was presented at the September 30<sup>th</sup> workshop.

<sup>4</sup> Neither report was published in a peer reviewed journal.

Ventilation has been recognized as a key factor in mitigating emissions associated with cooking. In older homes, historical guidance was to open a door or window while cooking to increase air flow and diffuse the emissions. Over time, ranges have become more likely to provide a hood to direct the emissions away from the kitchen. In many regions across the country, including California, new construction requires mechanical venting of stoves and ovens outside of the home to limit exposure.

During the September 30<sup>th</sup> workshop, several speakers, including CEC staff, noted that stove hoods are not consistently used during cooking and there is an ongoing concern about cooking and IAQ. While inconsistent usage of stove hoods is concerning and must be addressed, the stakeholder proposal to eliminate gas ranges and ovens does not address the underlying health concern – particulate matter emissions caused by cooking. Adequate ventilation effectively mitigates emissions from all cooking and does not differentiate between energy sources. If you merely replace a natural gas stove with an electric stove, you will continue to have exposure to particulate matter during the process of cooking.

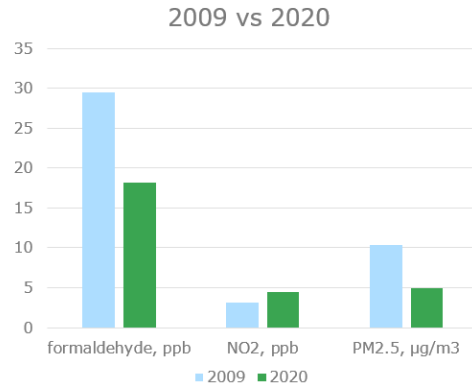
Particulate matter (PM<sub>2.5</sub>) is the more concerning pollutant, posing a greater health concern and a more significant cause of asthma. The Ramboll letter in Appendix A provides additional citations on the importance of addressing PM emissions and proper use of ventilation systems. Eliminating gas stoves will not change the important health benefits of properly maintained appliances and ventilation systems.

*A. Recent Studies Demonstrate the Effectiveness of Ventilation to Mitigate Potential Health Impacts Due to Cooking*

A comparison of two studies of new homes in California illustrates the effectiveness of proper ventilation. These CEC-funded studies published in 2009 and 2020 illustrate the effectiveness of mechanical ventilation and other building codes in reducing the emissions in new homes. The two studies, 2009 California New Home Study (CNHS) by Offermann and the 2020 Healthy Efficient New Gas Home (HENGH) by Chan, et al were both conducted by Lawrence Berkeley National Laboratories (LBNL). While both studies looked at new homes, there was an important difference in the 2009 and 2020 studies – the energy source of the cooking appliances. Almost all of the homes (98%) in the 2009 study had electric cooking, while all of the homes in the 2020 study had gas cooking. Among the key findings was a significant reduction in formaldehyde<sup>5</sup> and fine particulate matter (PM<sub>2.5</sub>), with little change in the NO<sub>2</sub> levels. Comparing these two studies illustrates that residences built after 2010 with gas cooking appliances do not have significantly elevated concentrations of these constituents.

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<sup>5</sup> As described in Appendix A, formaldehyde has declined largely due to CA composite wood product regulations. PM<sub>2.5</sub> has declined due to lower outdoor PM<sub>2.5</sub> levels, high efficiency air filters and mechanical ventilation requirements.



When asked about these studies at the workshop, Dr. Singer suggested the 2020 study looked at bigger homes where people did not cook as much. These observations were not part of the HENGH report. The study articulates clear criteria for homes to provide a balance between building size and design reflective of the variety of homes and climate zones in California. As noted in Appendix A, the median size of homes in the 2009 and 2020 studies were similar. While, it is true that new home sizes are generally larger than in the past, the findings are still informative to CEC for developing standards for new homes.<sup>6</sup>

### *B. CEC Should Consider Developing Additional Measures to Improve the Use of Ventilation*

We would also encourage staff to further examine the examples on automatic ventilation systems used in Japan as a way to address the concern that individuals are not using their range hoods while cooking.<sup>7</sup> This may be a consideration that requires further evaluation beyond the current code cycle. But, it does present an informative alternative to improve utilization of stove hoods during cooking.

### **3. Potential Health Impacts of Gas Cooking Are Unsupported and Overestimated**

The UCLA and RMI reports have made a variety of claims about the association of gas cooking with increased health risks, including the prevalence of asthma based upon false modeling or comparisons as noted below. First, the reports suggest NO<sub>2</sub> levels during cooking can exceed national ambient air quality standards for NO<sub>2</sub> and base this claim on modeling of peak NO<sub>2</sub> compared to the 1-hour standard for ambient NO<sub>2</sub>. This is a false comparison. Peak exposures do not typically extend for a full hour. Thus, it is incorrect comparison to the federal standard.

Second, the reports focus on the findings of a meta-analysis of health studies on asthma prepared by Lin, et al in 2013 (Lin Study). There are several concerning inconsistencies and questions raised by the Lin Study that are ignored in the RMI and UCLA reports. Ramboll has elaborated on these issues in Appendix A. Briefly, the following are key points that question the

<sup>6</sup> A September 2016 article in LA Weekly notes home sizes have grown 38% in Los Angeles over the past century. <https://www.laweekly.com/how-the-size-of-the-typical-l-a-home-has-grown-over-the-years/>

<sup>7</sup> Presentation by Kazukiyo Kumagai at September 30, 2020, workshop

underlying methodologies of the Lin Study and its conclusion that there is a direct relationship between gas cooking and asthma.

- The Lin Study did not perform a critical review of potential confounding and systematic bias in the underlying studies, which may bias the findings.
  - When adjusting for mold and/or dampness, several of the studies showed no effect of gas stoves on IAQ.
  - One of these studies noted a strong statistically significant association for gas cooking and common asthma triggers – dampness, mold, pets, second-hand smoke. Noting, “..when studying a specific indoor exposure, one should also take into account other potential indoor factors.”<sup>8</sup>
- The Lin Study did not find an association with measured NO<sub>2</sub>, which is typically associated with gas cooking.
- Further, the Lin Study did not find an association between gas cooking and wheeze, which is a symptom of asthma.
- The Lin Study is largely based on older studies. Notably, fourteen of nineteen studies were conducted before 2000. Appliance efficiencies have improved significantly and emissions are lower for the appliances after 2000 and those appliances that will be placed in new homes.

As discussed further in Appendix A, Ramboll’s literature search found additional recent studies on asthma and indoor air quality that came to different conclusions from the Lin Study. Moreover, the largest study cited by Ramboll is the Wong et al (2013) report based on the International Study of Asthma and Allergies in Childhood (ISAAC)<sup>9</sup>. This study included 250,000 children in 31 countries through independent academic and national health studies. Wong et al reported no association between gas cooking and lifetime asthma or current asthma in children when compared to children who lived in households that used electric stoves for cooking.

Another study discussed in the Ramboll letter explicitly looked at the effectiveness of ventilation at reducing the incidents of asthma in children. Kile et al 2014 noted asthma was statistically significantly decreased by 36% for children who lived in households where gas stoves for cooking were used only with ventilation when compared to children who lived in households where gas stoves were used without ventilation.<sup>10</sup> This finding is consistent with other literature on mitigating indoor air pollution.

#### *A. The CEC Should Evaluate Other Safety Risks Including Fire Safety*

During the workshop, a question was asked about fire safety of electric versus gas cooking. Dr.

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<sup>8</sup> Casas L, Tischer C, Tiesler C et al. 2012. Association of gas cooking with children’s respiratory health: results from GINIplus and LISAPLUS birth cohort studies. *Indoor Air* 22:476–82. At p. 481. Casas et al was one of the studies included in the Lin meta-analysis.

<sup>9</sup> Wong GW, Brunekreef B, Ellwood P, et al. Cooking fuels and prevalence of asthma: a global analysis of phase three of the International Study of Asthma and Allergies in Childhood (ISAAC). *The Lancet. Respiratory Medicine*. 2013 Jul;1(5):386-394. DOI: 10.1016/s2213-2600(13)70073-0.

<sup>10</sup> Kile ML, Coker ES, Smit E, Sudakin D, Molitor J, Harding AK. 2014. A cross-sectional study of the association between ventilation of gas stoves and chronic respiratory illness in US children enrolled in NHANES III. *Environ Health* 13:71.

Singer noted there may be higher incidence of fires in homes with electric cooking because there are more homes with electric cooking. However, the statistics reported by the National Fire Protection Agency are normalized to show the incidence of fire, injury and death per million households. Below are the key findings on fire safety and cooking based on all reported home fires during 2014-2018.<sup>11</sup>

- Cooking was responsible for 49% of all reported home fires.
- Ranges or cooktops were involved in
  - 61% of all reported home cooking fires
  - 87% of deaths and
  - 78% of injuries associated with home cooking fires.
- Electric range/cooktops were involved in 1,165 fires per million households
- Gas ranges/cooktops were involved in 445 fires per million households
- Although 60% of households cook with electricity, electric ranges or cooktops were involved in four out of every five reported cooking fires.
- The risk of fire from electric cooktops is 2.6 times greater than from gas cooktops
  - the associated death rate (per million households) was 3.4 times greater for electric cooking
  - the associated injury rate (per million households) was 4.8 times greater for electric cooktops

While, CEC is focused on the IAQ health risks associated with cooking, we recommend that CEC evaluate additional, relevant health and safety risks including fire safety.

#### **4. Environmental Justice Concerns Should Be Addressed**

Throughout the CEC Workshop, the issue of susceptibility of low income and minority populations to health issues was raised. This is a very important issue, as multiple stressors that affect health and poor housing conditions disproportionately impact low income and minority populations. Much of the discussion around low income communities seemed to relate more to existing housing stock. While, Title 24 focuses on new construction, SoCalGas supports further examination by the CEC on pathways to improve indoor air quality in existing homes, as well.

Replacing gas appliances with new, electric appliances will not, however, address the broader mechanical ventilation deficits that underlie most of the findings on poor indoor air quality. Improving mechanical ventilation would improve all indoor air quality issues, including the host of other indoor air pollutants that can adversely impact health. Poorly ventilated homes have increased concentrations of many of the asthma triggers: secondhand smoke, mold, dust mites, concentrations of volatile organic chemicals from cleaning products, off-gassing of formaldehyde from fabrics and composite wood products, and particulate emissions (including PM<sub>2.5</sub> and ultrafine particles) from cooking food regardless of the heating source. The UCLA report investigators concur with the importance of improving ventilation, particularly for vulnerable populations.

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<sup>11</sup> Ahrens M. July 2020. Home Cooking Fires. National Fire Protection Agency. Report available at: <https://www.nfpa.org/News-and-Research/Data-research-and-tools/US-Fire-Problem/Home-Cooking-Fires>



## Conclusion

SoCalGas supports CEC's efforts to improve the indoor air quality for new and existing buildings. SoCalGas appreciates the opportunity to provide additional information to expand the Commission's understanding on cooking and the importance of ventilation to mitigate any potential health effects from particulate matter generated during cooking and any emissions from the use of gas. The UCLA and RMI reports provide a limited and biased look at existing health studies on the potential association between asthma and cooking with gas. SoCalGas encourages staff to review the studies underlying these reports to get a more complete understanding of the results and uncertainties in these results. SoCalGas will also provide copies of the studies identified by Ramboll to the docket to further inform CEC's understanding of these issues.

Additionally, SoCalGas requests that CEC staff conduct another technical workshop before issuing their report to further examine the important questions on ventilation capacity efficiency and air flow rate. Dr. Singer's presentation provides one viewpoint on these issues. It is important to include industry experts on ventilation to provide their perspective on the effectiveness and costs of these different approaches.

Finally, SoCalGas notes much of the public comment at the workshop focused on the lack of ventilation in existing homes, rather than new construction. SoCalGas supports additional evaluation of programs for enhancements to existing home ventilation regardless of energy source as an important opportunity to improve the comfort and health of Californians, especially in disadvantaged communities.

Sincerely,

*Tim Carmichael*

/s/ Tim Carmichael  
State Agency Relations Manager  
Southern California Gas Company

# **APPENDIX A**

## MEMORANDUM

To: Allison Smith, Southern California Gas Company

From: Linda Dell MS, Ramboll  
Debra A. Kaden PhD, Ramboll  
Yi Tian CIH, Ramboll  
Julia Lester PhD, Ramboll

Subject: **Comments on the CEC 2020 Energy Code Docket 19-BSTD-03**

### EXECUTIVE SUMMARY

Date: October 16, 2020

#### Summary/Highlights

- The act of cooking, regardless of energy source, generates indoor air pollutants such as fine particulate matter and ultrafine particles;
- To reduce indoor air pollutants in residences, ensure proper ventilation (including vented appliances);
- Proper ventilation reduces all indoor air pollutants;
- Residences built after the 2008 California Energy Standards went into effect do not have high nitrogen dioxide (NO<sub>2</sub>) concentrations;
- NO<sub>2</sub> originating from residential natural gas appliances does not contribute in meaningful way to ambient concentrations;
- Although a meta-analysis published in 2013 reported increased asthma in children who lived in households with gas stoves, there was not an association between measured NO<sub>2</sub> and asthma or between gas stove use and wheeze (a hallmark symptom of asthma). These results are internally inconsistent;
- A large, global study also published in 2013 reported that use of gas stoves was not associated with asthma diagnosis or asthma symptoms in children. Given the size and global geographic distribution of participants in this study, this is an important study that should be considered; and
- Researchers have consistently pointed to the importance of proper ventilation to improve indoor air quality and reduce potential health impacts.

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## INTRODUCTION

On September 30, 2020, California Energy Commission (CEC) held a workshop “Advances in Scientific Understanding of the Impacts of Indoor Cooking and Associated Ventilation on Indoor Air Quality” (the CEC Workshop) to support staff in developing their recommendations for amendments in the 2022 Energy Code. The 2019 Energy Code included requirements for updates to air filtration standards applicable to all buildings. The 2022 Energy Code will apply to newly constructed commercial and residential buildings, and additions and alterations to existing buildings. The goal of the CEC Workshop was to “bring together public health and air quality experts and examine the current science and standards relating to kitchen equipment and ventilation;” and to “solicit input from experts and feedback from stakeholders and members of the public ahead of staff work in amending standards, reach consensus on the scientific record, and establish the factual foundation necessary for amending the Energy Code.” The CEC Workshop included presentations by Dr. Yifang Zhu (University of California, Los Angeles (UCLA)), Dr. Brett Singer (Lawrence Berkeley National Laboratory), Marian Goebes (TRC), Pat Wong and Qunfang Zhang (California Air Resources Board (CARB)), Susan Wilhelm (CEC), and Kazukayo Kumagai (California Department of Health). As such, the consensus on the state-of-the-science following the CEC Workshop will have important implications for the minimum standards for kitchen equipment, ventilation, and range hoods following passage of the 2022 Energy Code.

Some scientists have cited health concerns (primarily related to respiratory health) as providing the primary rationale for amending the Energy Code. Epidemiological studies have reported associations between air pollutants found inside residences and health effects, such as premature mortality and asthma or asthma exacerbations. Separately, improvements in energy efficiency have led to tighter buildings. In the absence of ventilation, indoor air pollutants remain inside the house. Mechanical ventilation is critical to help control indoor air pollutants and control moisture, and exhaust air pollutants from gas appliances.

In addressing the question posed by the CEC on whether there should be separate standards for electric stoves and gas stoves, we (1) discuss cooking as a source of particulate matter emissions, and discuss other indoor air pollutants for which ventilation would help improve indoor air quality; (2) discuss existing reports by CEC that indicate that indoor air quality is improving which may be a result of the ventilation requirement introduced by Title 24 Building Energy Efficiency Standards;<sup>1</sup> (3) comment on CARB inventory information submitted to the docket and discussed in the workshop related to natural gas appliances on indoor and outdoor air quality; and (4) provide scientific analysis and critique of recent reports and peer-reviewed published research related to gas stoves that should be considered when establishing new building codes related to addressing indoor air quality.

### Cooking and Particulate Matter (PM)

Cooking food is a well-known source of PM emissions, including particulate matter with diameter less than 2.5 microns (PM<sub>2.5</sub>) and ultrafine PM, due to broiling, baking, sautéing, toasting, and barbecuing (Abt et al., 2000<sup>2</sup>). A Canadian study of 132 households concluded that cooking contributed about 22% to the total daily PM<sub>2.5</sub> exposure in the participating homes (Sun & Wallace, 2020<sup>3</sup>). In a study examining emissions

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<sup>1</sup> California Title 24, Part 6, Building Energy Efficiency Standards.

<sup>2</sup> Abt E, Suh HH, Allen G, Koutrakis P. 2000. Characterization of indoor particle sources: A study conducted in the metropolitan Boston area. *Environmental Health Perspectives*, 108(1), 35-44.

<sup>3</sup> Sun L, Wallace LA. 2020. Residential cooking and use of kitchen ventilation: the impact on exposure. *Journal of the Air & Waste Management Association*. 24 September.

and source strengths from the cooking of complete meals, mean emission rates and source strengths of PM<sub>2.5</sub> varied between 0.54-3.7 mg/min and 15-68 mg, respectively (O'Leary et al., 2019<sup>4</sup>). Using a range hood and frying in non-stick pans were found to significantly reduce emissions. The authors concluded that using these two mitigation habits as well as cooking methods that avoid the browning or charring of food will reduce PM exposure, and are especially important in airtight dwellings where ventilation may be inadequate.

In a study designed to evaluate the influence of the food, cooking temperature, type of oil, and stove type on emissions of PM<sub>2.5</sub> and ultrafine particles, when grilling or frying, emission rates and aerosol characteristics were determined for a variety of cooking methods (Buonanno et al., 2009<sup>5</sup>). Overall, more particulate matter was emitted with increased cooking temperatures, and cooking fatty foods produced more particulate matter than vegetables. Emissions also varied dependent on the type of oil used. Importantly, while gas stove had slightly higher particle number-based emission factors compared to electric stoves, the majority of the particles appeared to come from the cooking process itself. The type of food used for grilling was very important, with fatty foods producing the most particles. Cooking temperature was also found to influence particle emissions for both gas and electric stoves.

### Other Important Indoor Air Pollutants

There are many relevant indoor air pollutants that have been associated with health impacts such as premature mortality, asthma and other respiratory effects, including mold, pests, pet dander, secondhand smoke, PM<sub>2.5</sub>, ultrafine PM, polycyclic aromatic hydrocarbons, volatile organic compounds (VOC), NO<sub>2</sub>, and others.

When considering the health impact of any indoor pollutant, it is important to consider its impacts relative to all other indoor air pollutants and their sources. This allows for the identification of the most appropriate risk management option to reduce exposures and effectively reduce potential health impacts. Many scientists report that improved ventilation within residences will improve air quality for all indoor air pollutants, including NO<sub>2</sub>.<sup>6</sup> The UCLA investigators note the importance of this topic<sup>7</sup> but stated that

<sup>4</sup> O'Leary C, Kluzenaar YD, Jacobs P, Borsboom W, Hall I, Jones B. 2019. Investigating measurements of fine particle (PM<sub>2.5</sub>) emissions from the cooking of meals and mitigating exposure using a cooker hood. *Indoor Air*, 29(3): 423-438.

<sup>5</sup> Buonanno G, Morawska L, Stabile L. 2009. Particle emission factors during cooking activities. *Atmospheric Environment*, 43(20): 3235-3242.

<sup>6</sup> For example, see Lin et al. 2013: "In outdoor air pollution studies, NO<sub>2</sub> often is used as a marker of a complex, traffic-related air pollution mixture, which makes extrapolation of our results to outdoor air pollution difficult. Indoors, gas cookers can be replaced by electric cookers, and gas cooking fumes can be removed by using ventilation hoods."

See Dekker et al. 2016: "Our results are consistent with those of others in showing that home dampness is associated with both current asthma and wheezing syndromes. However, the results do not allow identification of causal mechanisms. Home dampness reflects inadequate ventilation which may cause increased concentration of various contaminants. House dust mites and fungi are both known to be more prevalent in damp homes, and they are also both known to produce substances that may trigger allergic reactions."

See Melia et al. 1977: "The relation between gas cooking and respiratory disease seems to be stronger and more consistent for girls than for boys, as would be expected if girls spent more time in the family kitchen. If this is the case, and the difference between the sexes is purely the result of differing exposure, it seems likely that increased ventilation might be sufficient to dispel any risk."

<sup>7</sup> For example, see Zhu et al. p. 16: "Ventilation (and AER) significantly influence indoor air quality. Inadequate ventilation has been associated with higher concentrations of indoor air pollutants, including NO<sub>2</sub>, PM<sub>2.5</sub>, and VOCs, as well as adverse health outcomes." See Zhu et al. 2020 p. 30: "Finally, there are indoor air quality issues

providing a comprehensive comparison of the relevant importance of indoor air pollutants was outside of the scope of their report. They agree, however, that improving ventilation is incredibly important, particularly for vulnerable populations (which they do highlight within the report).<sup>8</sup>

### Indoor Air Quality in California Homes

CEC-commissioned a set of studies designed to examine indoor air quality in new California homes (Offermann 2009;<sup>9</sup> Chan et al., 2020<sup>10</sup>). The first study, "Ventilation and Indoor Air Quality in New Homes" (Offermann 2009), known as the California New Home Study (CNHS), examined 108 new homes in California, including only single-family, detached homes built after January 2002. All homes were owner-occupied primary residences for at least one year, and all homes had only non-smoking occupants. Of the 108 homes, 17 were from the South Coast region, 42 were from the Central Valley region, and 29 were from the remainder of the State. Within each region, half were sampled in the summer month, and half in the winter months. The selection process required at least 20 homes have mechanical ventilation; others could have a range of ventilation methods, including opening windows and doors, mechanical exhaust air systems, mechanical outdoor air systems, mechanical nighttime cooling systems, and occupant use of forced air unit systems. Overall, 98% of the homes had electric ranges, and only 2% had gas ranges. Eighty-five percent of the cooking ranges had exhaust fans vented to the outdoor air. Overall, 73% of the ovens were electric and 27% were gas. Only a small percentage (2%) of the ovens were vented to the outdoor air. The majority of the homes (98%) had gas-powered water heaters, and 61% of the homes had decorative fireplaces; all were vented to outdoor air. The median square footage of the homes was 2,703 ft<sup>2</sup> (range 1,283-5,064 ft<sup>2</sup>).

The second study, "Ventilation and Air Quality in New California Homes with Gas Appliances and Mechanical Ventilation" (Chan et al., 2020), known as the Health Efficient New Gas Homes (HENGH) study, examined 70 homes built after the 2008 California Building Energy Efficiency Standards<sup>11</sup> required mechanical ventilation, to evaluate the impacts of those mechanical ventilation standards on indoor air quality. Part of this requirement is the presence of either a venting range hood or an exhaust fan in the kitchen. All homes were single-family detached homes, located in California, and built in 2011 or later. All homes had natural gas appliances and mechanical ventilation. All homes were owner-occupied, and all homes had only non-smoking occupants. The majority of the homes had 3-5 bedrooms, and the median square footage was in the 2,500-2,900 ft<sup>2</sup> range. The Chan et al. (2020) study also contrasted their findings with the earlier Offerman (2009) study.

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*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."*

See Zhu et al. 2020 p. 41: "We echo other researchers in this space with the recommendation that proper ventilation technology, such as effective, low-noise range hoods, be implemented to reduce exposure and protect public health."

<sup>8</sup> Docket Number 19-BSTD-03. UCLA additional hearing questions and answers.

<sup>9</sup> Offermann FJ. 2009. Ventilation and Indoor Air Quality in New Homes, California Energy Commission, November 2009 (CEC 2009 report).

<sup>10</sup> Chan WR, Kim Y-S, Less BB, Singer B, Walker IS. 2020. Ventilation and Air Quality in New California Homes with Gas Appliances and Mechanical Ventilation, California Energy Commission (CEC 2020 report) United States: N. p., 2019. Web. Available at: [https://eta-publications.lbl.gov/sites/default/files/walker\\_i\\_-\\_2001200.pdf](https://eta-publications.lbl.gov/sites/default/files/walker_i_-_2001200.pdf).

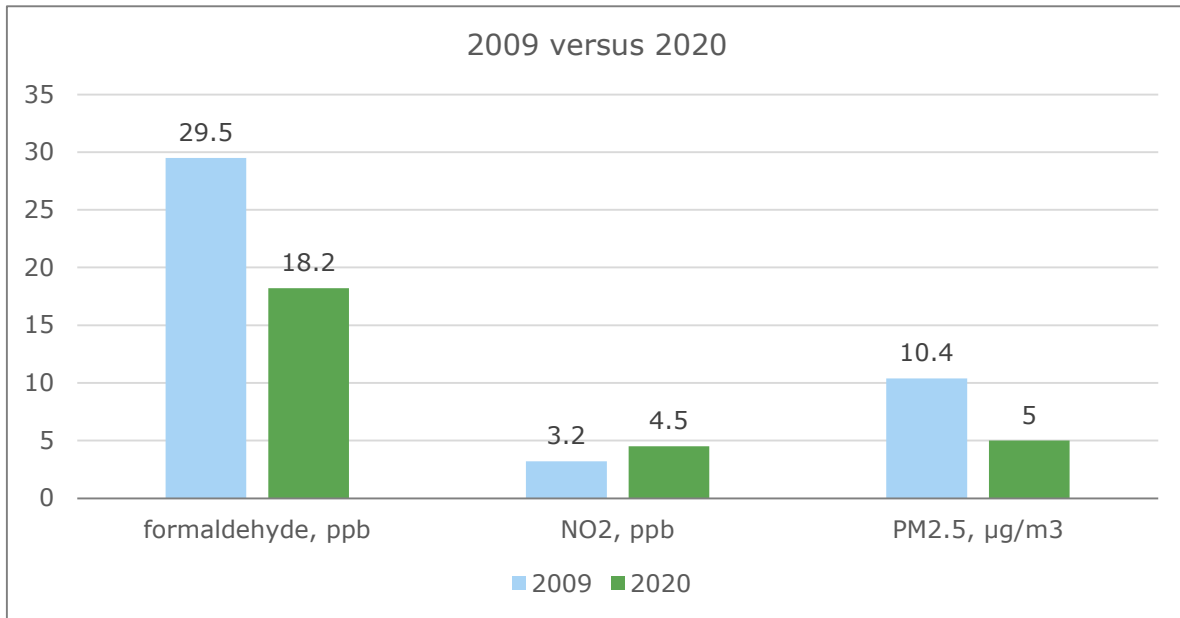
<sup>11</sup> California Title 24, Part 6, Building Energy Efficiency Standards.

Characteristics of the two studies are presented in Table 1.

<b>Table 1. Comparison of Homes in Two CEC-Commissioned Studies</b>	
<b>CNHS Offermann 2009</b>	<b>HENGH Chan et al. 2020</b>
108 residences	70 residences
98% electric cooktops 2% gas cooktops	0% electric cooktops 100% gas cooktops
Combination of windows/exhaust fans/other mechanical ventilation	All have mechanical ventilation
Floor Space: Median 2,703 ft <sup>2</sup>	Floor Space: Median 2,767 ft <sup>2</sup>

Field teams measured the concentrations in formaldehyde, NO<sub>2</sub>, and PM<sub>2.5</sub> in each of the two studies, as illustrated in Figure 1. Lower median concentrations of formaldehyde were observed in the 2020 study (18.2 ppb) compared to the 2009 study (29 ppb). Similarly, lower median concentrations of PM<sub>2.5</sub> were observed in the 2020 study (5 µg/m<sup>3</sup>) as compared to the 2009 study (10.4 µg/m<sup>3</sup>). While the median concentration of NO<sub>2</sub> was slightly higher in 2020 (4.5 ppb) compared to the 2009 study (4.5 ppb), 100% of the homes in the 2020 study had gas ranges as compared to only 2% of the homes in the 2009 study. Comparing the two studies illustrates that residences built after 2010 with gas cooking do not lead to elevated indoor NO<sub>2</sub>. This supports the conclusion that indoor air quality is acceptable in new California homes when mechanical ventilation is used.

**Figure 1. Median Concentrations of Indoor Pollutants in Two CEC-Commissioned Studies**



The Chan et al. (2020) study found improved ventilation was a significant factor for the better indoor air quality. The study recommended that labeling and controls for ventilation systems need to be improved, since about half of the homeowners did not know how to properly operate their mechanical ventilation system. Had all homeowners known and operated their ventilation systems properly, one would anticipate indoor air pollutant concentrations would have been even lower.

When questions were raised about these studies at the CEC Workshop Dr. Singer speculated that the Chan et al. (2020) study looked at larger homes. However, the Chan et al. (2020) study describes that homes were selected per the study criteria (as described above), and there is no evidence that the study disproportionately sampled larger homes.

### **Indoor Air Quality is Improving**

Other studies over the past 30 years have demonstrated a continuing downward trend in the concentrations of multiple indoor air pollutants (PM<sub>2.5</sub>, formaldehyde, CO and NO<sub>2</sub>). This is illustrated in Figure 2, which examines indoor air trends over the years. The two graphics on the left-hand part of Figure 2 present median concentrations of formaldehyde and PM<sub>2.5</sub> in the Offermann (2009) and Chan et al. (2020) studies discussed above. In Figure 2, these concentrations are plotted as the difference between indoor and outdoor air concentrations (the delta). This is a useful way of viewing the trends, as both indoor and outdoor concentrations of these pollutants decreased during this period of time.

The two graphics on the right side of Figure 2 plot pollutant concentrations in indoor air over the years. Because it is not appropriate to use studies with different energy sources to reflect these trends, we chose to use the 1994 versus 2020 to show the NO<sub>2</sub> trends. The Chan et al. (2020) study did not measure CO, so Figure 2 examines studies from 1994 (Wilson et al., 1994a)<sup>12</sup> and 2012 (Mullen et al., 2012);<sup>13</sup> both studies were in California homes with gas appliances. The Mullen et al. (2012) study did not measure outdoor CO, so only indoor concentrations are displayed. In order to only make comparisons for homes with gas appliances, the Chan et al. (2020) study is compared to an earlier study in homes with gas appliances, Wilson et al. (1994b).<sup>14</sup> Again, only indoor air concentrations are displayed. For all four pollutants, a clear downward trend in concentrations is observed.

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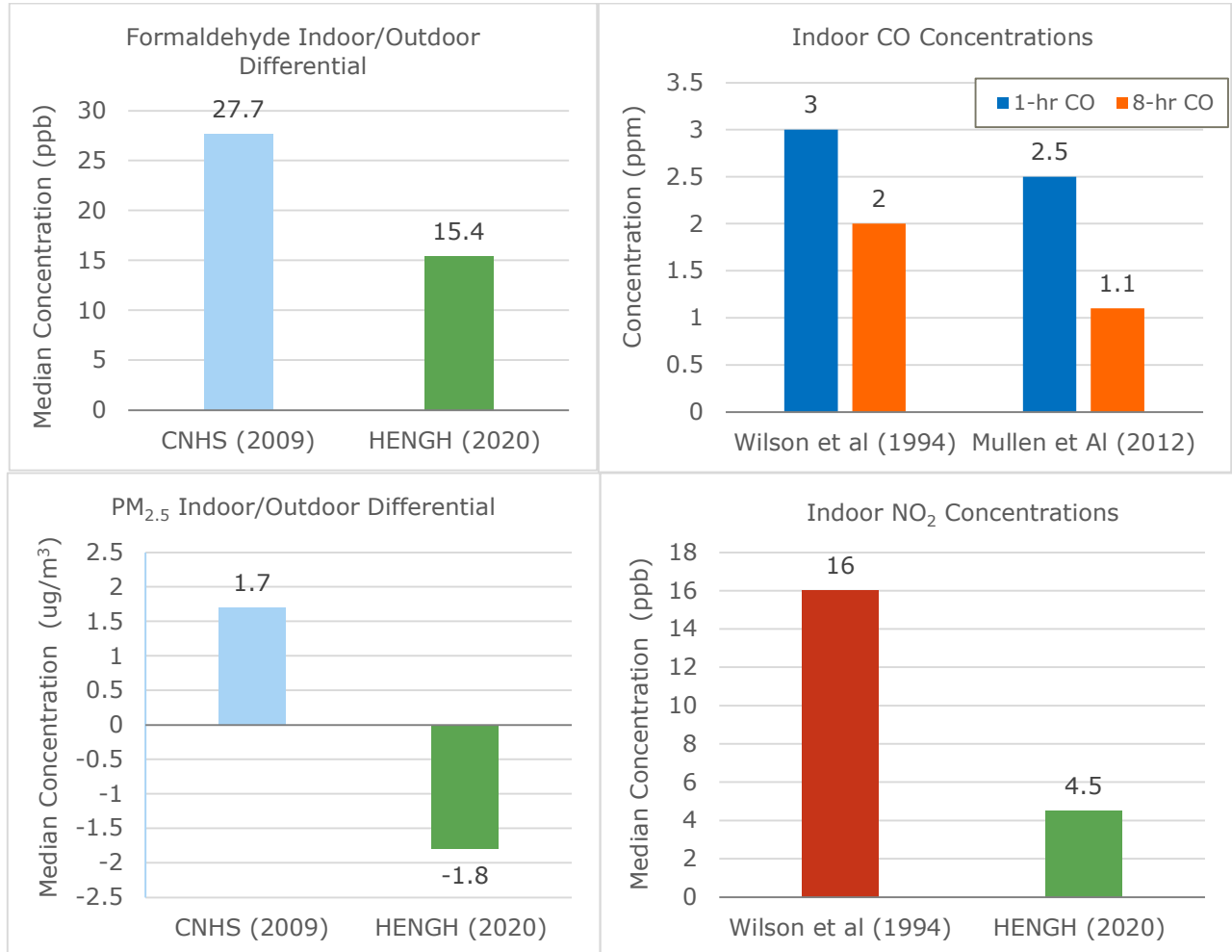
<sup>12</sup> Wilson AL, Colome SD, Tian Y, Becker EW, Behrens DW, Billick IH, Garrison CA (A&WMA 94-WP90.04). Carbon Monoxide Concentrations Inside and Outside of Homes in California, 1994.

<sup>13</sup> Mullen NA, Li J, and Singer BC. 2012. Impact of natural gas appliances on pollutant levels in California homes. 2012. (No. LBNL-5970E). Lawrence Berkeley National Laboratory (LBNL), Berkeley, CA (United States).

<sup>14</sup> Wilson AL, Colome SD, Tian Y, Garrison CA. 1994. Formaldehyde and nitrogen dioxide concentrations inside and outside of homes in California (A&WMA 94-WP90.01).



**Figure 2. Temporal Trends in Indoor Air Pollutants**



The trend for decreasing indoor air concentrations of formaldehyde are driven largely by the California composite wood product regulations in effect in more recent years. For PM<sub>2.5</sub>, downward trends are driven by both the decreasing outdoor concentrations of PM<sub>2.5</sub>, as well as high efficiency air filters in central forced air systems and mechanical ventilation systems present in the more modern homes. Downward trends for NO<sub>2</sub> are driven by both decreased outdoor concentrations of NO<sub>2</sub>, and mechanical ventilation systems present in the more modern homes. Lower CO concentrations largely reflect lower CO concentrations in the outdoor air. Thus, ventilation is key for all of these downward trends in indoor air pollutants, although other factors contribute as well.

### Personal Exposure Versus Indoor Air Concentrations

An individual's proximity to the source of air pollutants is an important factor when assessing their exposure (personal exposure). As such, indoor air pollutant concentrations, which may reflect the average pollutant concentrations at some central location indoors may underestimate personal exposures. Studies have demonstrated that for some pollutants, personal exposure concentrations as measured by a sensor

worn by the individual is greater than indoor air exposure concentrations (e.g., Wallace 2000<sup>15</sup>, Weisel et al. et al., 2005<sup>16</sup>). Since individuals cooking may spend more time standing near the source of cooking-related pollutants, this may also be true for PM<sub>2.5</sub>, NO<sub>2</sub>, and other pollutants associated with cooking. Removing pollutants at the source through ventilation would therefore be especially important for cooking-related pollutants.

**Ambient Air: CARB’s Workshop Presentation of the Emission Inventory Does Not Accurately Represent Residential Building Emissions Alone**

During the Indoor Cooking and Air Quality Panel Discussion and Workshop held on September 30, 2020, CARB staff presented a slide showing oxides of nitrogen (NO<sub>x</sub>) and greenhouse gas (GHG) emissions inventories for buildings (Slide 2 of CARB presentation). The slide stated that NO<sub>x</sub> emissions from light-duty vehicles (LDVs) and natural gas usage in buildings are similar. While these numbers are consistent with CARB’s CEPAM database, it is important to note that the NO<sub>x</sub> emissions from natural gas usage in buildings shown on this slide represents emissions from “all buildings” rather than the emissions “residential buildings” which was the focus of the workshop. As shown in the Table 2 below, residential Natural Gas use makes up only 44 of the 82 tons per day of NO<sub>x</sub> emissions from buildings. This represents only 3% of the entire statewide NO<sub>x</sub> inventory. Further, emissions from LDVs make up only 8% of the statewide NO<sub>x</sub> inventory. The heavy-duty vehicle (HDV) sector is the largest source of NO<sub>x</sub> emissions representing 28% of the statewide NO<sub>x</sub> inventory.

**Table 2. 2019 Statewide NO<sub>x</sub> Emission Inventory from CARB CEPAM Database**

<b>Emission Source</b>	<b>NO<sub>x</sub> Emissions (tons/day)</b>	<b>Percentage of Total</b>
HDVs	359	28%
Off-Road Equipment (not including recreational)	123	10%
Light-duty Vehicles (LDVs)	97	8%
Trains	75	6%
Farm Equipment	74	6%
Industrial Processes	64	5%
Marine Vehicles	64	5%
Industrial – Fuel Combustion	57	5%
Aircraft	54	4%
<b>Residential NG Use</b>	<b>44</b>	<b>3%</b>
Medium-duty vehicle (MDV)	41	3%

<sup>15</sup> Wallace L. 2000. Correlations of personal exposure to particles with outdoor air measurements: a review of recent studies. *Aerosol Science & Technology*, 32(1): 15-25.

<sup>16</sup> Weisel CP, Zhang J, Turpin BJ, Morandi MT, Colome S, Stock TH, Spektor DM, Korn L, Winer AM, Kwon J, Meng QY. 2005. Relationships of Indoor, Outdoor, and Personal Air (RIOPA). Part I. Collection methods and descriptive analyses. *Research Report (Health Effects Institute)*, 130(Pt 1): 1-107.

**Table 2. 2019 Statewide NO<sub>x</sub> Emission Inventory from CARB CEPAM Database**

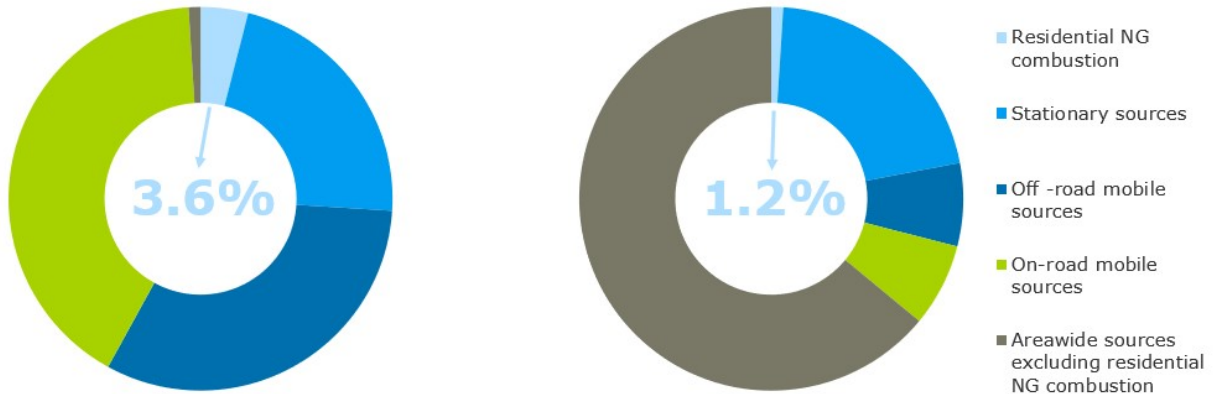
<b>Emission Source</b>	<b>NO<sub>x</sub> Emissions (tons/day)</b>	<b>Percentage of Total</b>
Commercial NG Use	38	3%
Buses	36	3%
Petroleum Refining and Production	24	2%
Electric Utilities	21	2%
Cogeneration	18	1%
Areawide Sources (excluding Residential NG)	17	1%
Service and Commercial (excluding Commercial NG Use)	11	1%
Food and Agricultural Processing	10	0.8%
Other On-Road Vehicles	10	0.8%
Oil and Gas Production (Combustion)	9	0.7%
Other Fuel Combustion	9	0.7%
Waste Disposal	5	0.4%
Off-Road Recreational	1	0.07%
Cleaning and Surface Coating	0.1	0.01%
<b>Total CA NO<sub>x</sub> Emissions</b>	<b>1262</b>	<b>100%</b>

On the same slide, CARB staff presented statistics on the greenhouse gas emissions from (“all”) building use. The GHG emissions from buildings reported in the slide do not match the output for residential and commercial buildings from CARB's 2000-2017 Data Query Tool or the EIA's CA state GHG emission database. We respectfully request that CARB provide the source for the GHG emissions data included on their slide and update the analysis so that it is representative of “residential buildings” rather than “all buildings.” Figure 3 presents this information from the current inventory (2020).

**Figure 3. Contribution of Residential Natural Gas Combustion to the 2020 Statewide NO<sub>x</sub> and PM<sub>2.5</sub> Emission Inventory**

**2020 STATEWIDE MANMADE NO<sub>x</sub> EMISSIONS: 1,200 TONS/DAY**

**2020 STATEWIDE MANMADE PM<sub>2.5</sub> EMISSIONS: 375 TONS/DAY**



### Hood Design

We understand that CEC is considering a capture efficiency (CE) standard for the upcoming 2022 code revision. CE is defined as the fraction of airborne contaminants generated by a source that is captured by the hood. During the workshop, Dr. Singer presented a study on capture efficiency and concluded that it would be necessary to “use hoods with CE up to 65 to 75% needed to protect indoor air quality in all new homes, particularly in those <1000 sf.”

While we agree that CE is an important parameter, capture velocity is equally important in hood design. Capture velocity is the air velocity at any point beneath the hood necessary to overcome opposing air currents and capture the contaminant at that point causing it to flow into the hood. The capture velocity required to control particulate matter emissions is much higher than that of gaseous compounds such as NO<sub>2</sub> since particulates have higher density than that of gaseous compounds and can be generated from all stove types plus the cooking process itself.

### Recent Reports

Two reports have recently been released that draw conclusions that using gas stoves (in particular) lead to quantifiable adverse health impacts from mortality, chronic bronchitis, and asthma. In April 2020, a UCLA team led by Dr. Yifang Zhu released a report “Effects of Residential Gas Appliances on Indoor and Outdoor Air Quality and Public Health in California<sup>17</sup>” (the UCLA Report). This report sought to better understand health concerns of natural gas appliance use and purported to analyze the health benefits of phasing out residential gas appliances in California. However, there are a number of overly simplistic assumptions made in the report, and several of these have been amplified by others citing the report.

<sup>17</sup> Zhu Y, Connolly R, Lin Y, Mathews T, Wang Z. 2020. Effects of Residential Gas Appliances on Indoor and Outdoor Air Quality and Public Health in California. UCLA Fielding School of Public Health, Department of Environmental Health. Sierra Club Agreement 20184996.

Seals and Krasner (2020<sup>18</sup>) co-authored “Health Effects from Gas Stove Pollution” selectively cite research to conclude that gas stoves “can lead to unhealthy levels of indoor air pollution.”

**UCLA Report Hazard identification is not the same as risk.** The first step in a risk assessment process is to identify chemicals which may be toxic at *some* concentration – the hazard identification step. However, this is simply a first step, and by itself is not informative about risk. Everything is toxic at some concentration, even beneficial items like aspirin.<sup>19</sup>

The second step in a risk assessment process is to understand exposures. To do this, the UCLA Report uses a model that is based on a number of conservative and sometimes unreasonable assumptions. For example, in modeling indoor air exposures, the authors we compared two indoor environments, one with the use of gas appliances and one without, where the second environment represented “an electrification scenario.” In other words, they assumed there were no emissions of combustion pollutants with the use of electric appliances. Models assumed that stoves and ovens were used at the same time and were vented directly into the kitchen (not vented outside), although many of the ranges and ovens would have had hoods to vent outdoors. In other calculations, models allowed for drafting (the backward movement of exhausted gas through the venting system) and resulting spillage (leakage of exhausted gases from the appliance into the indoor environment). The latter was assumed even though the report cites a LBNL study suggesting that few instances of sustained back drafting or spillage were found.<sup>20</sup>

**A peak exposure represents a very transient event. It is not the same thing as a 1-hr exposure.**

Based on all of the above assumptions, authors modeled the use of kitchen appliances under three cooking scenarios: 15 minutes, 1 hour, and 2 hours per day. The model also produced an estimate of the highest concentration value reflecting emissions while cooking. Authors used this to estimate the peak NO<sub>2</sub> concentrations. This latter estimate, peak concentration, was then compared to the 1-hour California and National Ambient Air Quality Standards. However, it is highly unlikely that peak concentrations would persist for an entire hour, especially as authors cite that the entire cooking time over the course of a day is likely 1-hour cumulative. It is not clear why the peak concentration estimates were compared to the Ambient Air Quality Standards, as opposed to the more appropriate modeled 1-hour average estimates.

In their response to questions, the UCLA team confirmed that they did not specifically simulate the length of peak exposures and acknowledge that they would expect 1-hour averages to be lower than peaks.<sup>21</sup>

**The assumption that gas appliances are used for supplemental heating is not universal.**

Section 2.2 of the UCLA Report discusses use of gas appliances for supplemental heating of the home. Although the authors premise their discussion by stating that there is limited information on the supplemental use of stoves and ovens for heating residences, they nevertheless include a scenario where cooking appliances are used to heat for 4 hours. Furthermore, many of the references they cite in support of their analysis are in regions of the country or world where temperatures are colder (such as Boston or England).

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<sup>18</sup> Seals B, Krasner A. 2020. Health Effects from Gas Stove Pollution. Rocky Mountain Institute, Physicians for Social Responsibility, Mothers Out Front, and Sierra Club, 2020, Available at: <https://rmi.org/insight/gasstoves-pollution-health>. Accessed: October 2020.

<sup>19</sup> Miller RR, Jick H. 1977. Acute toxicity of aspirin in hospitalized medical patients. American Journal of the Medical Sciences, 274(3), 271-279.

<sup>20</sup> Rapp VH, Singer BC, Stratton JC, Wray CP, Less B. 2015. Assessment of Literature Related to Combustion Appliance Venting Systems. As cited by Chan et al., 2020.

<sup>21</sup> Docket Number 19-BSTD-03. UCLA additional hearing questions and answers.

**The assumption of no venting or hood range use for cooking is an unreasonable oversimplification, leading to over-estimated benefits of electrification.** Over-conservative assumptions about lack of any venting/range hood use over-estimated indoor air pollutant concentrations. As noted in the Report: *"This report does not compare the benefits and costs of electrification versus improving range hood use and efficiency in terms of reducing indoor air pollution."* By not comparing the benefits and costs of electrification versus improving range hood use and efficiency in terms of reducing indoor air pollution, the report is biased to the conclusion they reach. Improving range hood use and efficiency would be an easier and less costly mitigation. This is an important consideration, whether appliances are electric or gas, to reduce particulates generated while cooking food, as cooking food also emits particulates. These assumptions should be corrected and the analyses re-run before any of the Report's indoor air quality results are cited or used.

**The ventilation scenario for natural gas space and water heaters is unrealistic.** The UCLA Report (Table 2-7) estimates mean peak indoor concentrations of CO, NO<sub>2</sub>, and NO<sub>x</sub> associated with 0%, 25%, 50%, and 75% CE for space and water heaters. These scenarios are highly unrealistic, as residential natural gas space heaters and water heaters are required to be vented outdoors. The UCLA Report itself acknowledges this fact on Page 14 where it states that the National Fire Protection Association 54: National Fuel Gas Code requires gas space heaters and water heaters to be vented outdoors and that the California Health and Safety Code prohibits the sale of unvented gas heaters.

**Assumptions overestimate air quality changes and resulting health benefits of electrification.** The UCLA Report appreciably over-estimated changes in air quality resulting from use of natural gas appliances and thus the resulting calculated health benefits of electrification due to (1) overestimates of natural gas space and water heaters and (2) neglect of emissions from electric generation. The Report did not account for current air district regulations for natural gas space and water heaters. Based on the California Residential Appliance Saturation Survey, these sources are collectively 86% of the natural gas consumption in households. The air district regulations reduce baseline emissions by 2-20% for space heaters and 6-75% for water heaters in air districts that cover 89% of California's population, reducing any benefit of electrification calculated by the Study.

Specifically, the emission factors for natural gas appliances used in the Report did not meet the district specific regulatory requirements, as the Study methodology differed from the CARB methodology for residential fuel combustion that applies control factors to reflect emission reductions due to rules and regulations in each air district for space heaters and water heaters. For example, SCAQMD Rule 1111 for NO<sub>x</sub> emissions from natural-gas-fired space heaters has a NO<sub>x</sub> emission factor limit of 40 nanograms per joule (ng/J) for manufacture date April 1, 1984 to September 30, 2012 and 14 ng/J for manufacture date October 1, 2012 and beyond. The UCLA Report used a mean emission factor of 37 ng/J, which would indicate that most of the residential natural gas furnaces operating in the South Coast Air Basin are more than 8 years old. Another example is SCAQMD Rule 1121, which has a NO<sub>x</sub> emission factor limit for residential gas water heaters of 10 ng/J. The UCLA Report used an emission factor 25 ng/J, which is higher than the rule requirement. Similar examples can be made for the Bay Area Air Quality Management District (BAAQMD) (i.e. Reg 9 Rule 6 NO<sub>x</sub> emissions from natural gas-fired boilers and water heaters).

Table 3 shows the control factors that should be applied to the NO<sub>x</sub> emissions by air district based on the CARB methodology for residential natural gas combustion.<sup>22</sup>

<b>Table 3. Air District Specific Control Factors for Natural Gas Appliances</b>		
<b>District</b>	<b>Space Heating NO<sub>x</sub> Control Factor</b>	<b>Water Heating NO<sub>x</sub> Control Factor</b>
Antelope Valley <sup>23</sup>	0.89	0.81
Bay Area <sup>24</sup>	--	0.57
Mojave Desert <sup>25</sup>	0.89	0.81
Placer County <sup>26</sup>	--	0.74
Sacramento Metro <sup>27</sup>	--	0.34
San Diego County <sup>28</sup>	--	0.94
San Joaquin Valley <sup>29</sup>	0.98	0.54
South Coast <sup>30</sup>	0.80	0.25
Yolo-Solano <sup>31</sup>	0.91	0.61

Besides the issues with the NO<sub>x</sub> emission factors stated above, the UCLA Report assumes that NO<sub>2</sub> emissions from residential gas water heaters are approximately 13.6% of the total NO<sub>x</sub> emissions

<sup>22</sup> CARB. Section 7.2 Residential Natural Gas Combustion. Available at: [https://ww3.arb.ca.gov/ei/areasrc/fullpdf/residential\\_natural\\_gas\\_methodology\\_nov2019.pdf](https://ww3.arb.ca.gov/ei/areasrc/fullpdf/residential_natural_gas_methodology_nov2019.pdf). Accessed: May 2020.

<sup>23</sup> Antelope Valley APCD. Rule 1111: NO<sub>x</sub> Emissions from Natural-Gas-Fired, Fan-Type Central Furnaces. Available at: <https://avaqmd.ca.gov/files/6af0b6851/AV1111.pdf> and Rule 1121: Control of Nitrogen Oxides from Residential-Type Natural-Gas-Fired Water Heaters. Available at: <https://avaqmd.ca.gov/files/8f521eaea/AV1121.pdf>. Accessed: May 2020.

<sup>24</sup> Bay Area AQMD. Regulation 9 Rule 6: Nitrogen Oxides Emissions from Natural Gas-Fired Boilers and Water Heaters. Available at: <https://www.baaqmd.gov/~/media/dotgov/files/rules/reg-9-rule-6-nitrogen-oxides-emissions-from-natural-gas-fired-water-heaters/documents/rg0906.pdf?la=en>. Accessed: May 2020.

<sup>25</sup> Mojave Desert APCD. Rule 1157 Boilers and Process Heaters. Available at: <https://www.mdaqmd.ca.gov/home/showdocument?id=4704>. Accessed: May 2020.

<sup>26</sup> Placer County APCD. Rule 246 Natural Gas-Fired Water Heaters. Available at: <https://www.placerair.org/DocumentCenter/View/2217/Rule-246-PDF>. Accessed: May 2020.

<sup>27</sup> Sacramento Metro AQMD. Rule 414 Water Heaters, Boilers and Process Heaters Rated Less Than 1,000,000 BTU Per Hour. Available at: <http://www.airquality.org/ProgramCoordination/Documents/rule414.pdf>. Accessed: May 2020.

<sup>28</sup> San Diego County APCD. Rule 69.5.1 Natural Gas-Fired Water Heaters. Available at: [https://www.sdapcd.org/content/dam/sdc/apcd/PDF/Rules\\_and\\_Regulations/Prohibitions/APCD\\_R69-5-1.pdf](https://www.sdapcd.org/content/dam/sdc/apcd/PDF/Rules_and_Regulations/Prohibitions/APCD_R69-5-1.pdf). Accessed: May 2020.

<sup>29</sup> San Joaquin Valley APCD. Rule 4905 Natural Gas-Fired, Fan-Type Central Furnaces. Available at: <https://www.valleyair.org/rules/curnrules/Rule4905.pdf> and Rule 4902 Residential Water Heaters. Available at: <https://www.valleyair.org/rules/curnrules/r4902.pdf>. Accessed: May 2020.

<sup>30</sup> South Coast AQMD. Rule 1111 Reduction of NO<sub>x</sub> Emissions from Natural-Gas-Fired, Fan-Type Central Furnaces. Available at: <http://www.aqmd.gov/docs/default-source/rule-book/reg-xi/rule-1111.pdf?sfvrsn=4> and Rule 1121 Control of Nitrogen Oxides from Residential Type, Natural Gas-Fired Water Heaters. Available at: <http://www.aqmd.gov/docs/default-source/rule-book/reg-xi/rule-1121.pdf?sfvrsn=4>. Accessed: May 2020.

<sup>31</sup> Yolo-Solano AQMD. Rule 2.44 Central Furnaces. Available at: <https://ww3.arb.ca.gov/ei/rules/RuleID4234.pdf> and Rule 2.37 Natural Gas-Fired Water Heaters and Small Boilers. Available at: <https://ww3.arb.ca.gov/ei/rules/RuleID4227.pdf>. Accessed: May 2020.

(Table 2-1) based on the Singer study<sup>32</sup>. The Singer study, however, shows that the NO<sub>2</sub> fraction of NO<sub>x</sub> emissions from water heaters could vary greatly depending upon the technology. NO<sub>2</sub> fraction of NO<sub>x</sub> emissions for storage water heaters average 5%, while that of tankless water heaters average 37%. It is not clear how the UCLA Report chose the 13.6% value to represent all water heaters.

Since all of the quantified health benefits in the UCLA Report are related to outdoor air quality impacts, it is crucial that electrification of residential sources be evaluated by exactly the same criteria as other emission control measures. The UCLA Report however overestimates electrification emissions reductions, mortality/morbidity reductions, and monetized health benefits, due to the UCLA Report's assumption of a 100% renewable electric grid with no emissions. This is clearly false for the UCLA Report's analysis year and for at least several years to come. Estimates of projected emissions from the changing mix of electrical generation are available and should be used.

**The lack of accuracy in geographic distribution of NO<sub>x</sub> emissions leads to inaccurate and misleading outcomes for the health impact analysis presented in the UCLA Report.** Though the overall statewide NO<sub>x</sub> residential natural gas combustion emissions presented in the UCLA Report align with the CARB inventory (California Emission Projection Analysis Model, CEPAM), the basin level distribution of NO<sub>x</sub> emissions from residential natural gas usage presented in the UCLA Report is inconsistent with the CARB inventory, thus misrepresenting spatial distribution of NO<sub>x</sub> emissions. For example, the Mojave Desert Air Basin (MDAB) emissions, which encompasses desert portions of Kern, Los Angeles, Riverside and San Bernardino counties, were reported in the UCLA Report as the second-highest basin emissions for NO<sub>x</sub> (Figure 3-2 of UCLA Report) with ~24% of the statewide NO<sub>x</sub> emissions from gas appliances, whereas CEPAM NO<sub>x</sub> emissions from residential gas appliances in MDAB represent only 3% of the statewide emissions. The CEPAM NO<sub>x</sub> emissions are aggregated on a basin level based on the population of each county that resides within the basin, while the UCLA Report does not aggregate in this same manner. The lack of accuracy in geographic distribution of emissions across counties within California leads to inaccurate and misleading outcomes for the health impact analysis (performed using BENMAP) in the UCLA Report.

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<sup>32</sup> Natural Gas Variability in California: Environmental Impacts and Device Performance. Experimental Evaluation of Pollutant Emissions from Residential Appliances. Available at: [https://eta-publications.lbl.gov/sites/default/files/lbnl-2897e\\_-\\_natural\\_gas\\_variability\\_in\\_california\\_environmental\\_impacts\\_and\\_device\\_performance\\_-\\_experimental\\_evaluation\\_of\\_pollutant\\_emissions\\_from\\_residential\\_appliances.pdf](https://eta-publications.lbl.gov/sites/default/files/lbnl-2897e_-_natural_gas_variability_in_california_environmental_impacts_and_device_performance_-_experimental_evaluation_of_pollutant_emissions_from_residential_appliances.pdf). Accessed: October 2020.



**Table 4. 2018 NO<sub>x</sub> Emissions Inventory in Tons per Year for Residential Natural Gas Appliances**

<b>Air Basin</b>	<b>UCLA Report<sup>1</sup></b>	<b>CEPAM<sup>2</sup></b>	<b>% Difference</b>
South Coast	3,900	4,878	-20%
Mojave Desert	3,750	429	775%
San Francisco Bay Area	2,870	5,103	-44%
San Joaquin Valley	1,450	1,920	-24%
Sacramento Valley	1,250	1,383	-10%
San Diego	940	765	23%
Other	1,740	1,691	3%
<b>Total</b>	<b>15,900</b>	<b>16,169</b>	<b>-2%</b>

Notes:

<sup>1</sup> Estimated from Figure 3-2 on Page 37 of the UCLA Report.

<sup>2</sup> Obtained from CARB 2016 State Implementation Plan Standard Emissions Tool. Available at: <https://www.arb.ca.gov/app/emsmv/fcmssumcat/fcmssumcat2016.php>. Accessed: May 2020.

**Policy implications of the UCLA report.** The UCLA Report does not provide any cost information for electrification and thus does not provide complete information needed by the public and regulators to assess the cost effectiveness of electrification compared to other control/mitigation measures. As such, policy makers or regulators cannot use the Report to assess whether electrification of residential appliances is the best use of either incentive or owner money to achieve the health benefits discussed in the Report. Regulators typically use cost effectiveness (e.g., dollars per ton of emission reductions) to assess what emission reduction strategies achieve the most benefit for a given amount of money. Emission reductions are maximized when the most cost-effective strategies are implemented first.

Air agencies calculate the cost effectiveness (dollars per ton of NO<sub>x</sub> or dollars per ton of PM<sub>2.5</sub>) for control measures in their State Implementation Plan submittals for most non-attainment areas. The general approach taken by most air districts such as the South Coast Air Quality Management District (South Coast AQMD) and San Joaquin Valley Air Pollution Control District is to implement the most cost-effective control measures, i.e., control measures that provide the highest NO<sub>x</sub> or PM<sub>2.5</sub> reductions per dollar. Previous South Coast AQMD analyses of natural gas residential appliance control measures have shown that non-electrification strategies (such as weatherization and the utilization of low- NO<sub>x</sub> burners, which are much less expensive than electrification) have a cost effectiveness of \$26,000-49,000/ton of NO<sub>x</sub> (Discounted Cash Flow Method) according to Table 2-4 of the 2016 AQMP Socioeconomic Report.

As noted in the UCLA Report (page 7), other emission reduction technologies besides electrification are available for residential appliances. The costs and emission reduction benefits of these technologies have been assessed, in part, by South Coast AQMD and others. Costs of electric appliances in new residential buildings (and appliance replacement in existing residential buildings) would also need to be done to compare costs and benefits of the different technologies, including any costs associated with supporting

infrastructure. The greatest reductions would be achieved by prioritizing the most cost-effective strategies, as the major air agencies do.

### **The RMI Report**

The RMI Report concludes that children are particularly at risk from pollutants associated with gas stoves. Both the UCLA Report and the RMI Report cite asthma as a health effect related to gas cooking, presumably assuming that gas cooking is a surrogate of nitrogen dioxide emissions. The RMI report, in particular, relied almost exclusively on the results from a meta-analysis conducted by Lin et al. (2013).<sup>33</sup> Below we discuss the Lin et al. (2013) analysis to provide context for the results cited in the RMI report.

### **The Lin et al. (2013) Meta-Analysis**

#### **The epidemiological evidence that gas cooking causes asthma symptoms (exacerbations) or newly diagnosed asthma is inconsistent.**

Lin et al. (2013) reported a 42% increased risk of asthma symptoms in children who live in homes with gas stoves, a 24% increased risk of being diagnosed with asthma by a physician and a 32% increased risk of asthma overall (accounting for both current asthma symptoms and lifetime asthma (Lin et al. 2013)). These results were statistically significant. Statistically significant results address random error (also known as the role of chance). Random error is the variation or uncertainty in the measured association that is due to sampling a subset of the population. A confidence interval (typically, 95%) provides a range of values for the true association for the population. The confidence interval also is used to describe the role of chance in explaining the results. For example, if a 95% confidence interval excludes 1, the result is considered "statistically significant." This means that the measured association is considered unlikely to have occurred by chance at a probability or significance level of 5%. Nevertheless, even when a result is statistically significant, it is critical to evaluate the quality of the study and determine whether systematic bias or confounding can explain the result.

Lin et al. (2013) separately analyzed measured indoor nitrogen dioxide and wheeze and reported that current wheeze was statistically significantly increased by 15% for each increase of 15 parts per billion of indoor NO<sub>2</sub>. However, gas cooking was not associated with current wheeze, and indoor NO<sub>2</sub> was not associated with asthma. These results are inconsistent because wheeze is a hallmark symptom of asthma, and gas cooking has been used in studies as a surrogate of indoor NO<sub>2</sub>. More importantly, these findings suggest that factors other than cooking with a gas stove may explain the results. These factors include the potential for systematic bias.

#### **Lin et al (2013) did not evaluate whether systematic bias or confounding possibly explained the results in the individual studies included in the meta-analysis.**

A meta-analysis does not explicitly address whether systematic bias or confounding in studies possibly explains the observed results. In epidemiology, methodological errors (or systematic bias) can lead to inaccurate and potentially invalid study results, even when findings are statistically significant. Most forms of bias can be grouped into three broad categories: selection bias, information bias and confounding bias. Selection bias refers to systematic differences in characteristics between individuals who participate and people who do not participate in an epidemiological study. Information bias refers to systematic difference in measuring exposure or the disease outcome. Ventilation characteristics were rarely considered in the studies included in the Lin et al. (2013) meta-analysis, leading to potential misclassification of exposure.

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<sup>33</sup> Lin W, Brunekreef B, Gehring U. 2013. Meta-analysis of the effects of indoor nitrogen dioxide and gas cooking on asthma and wheeze in children. *International Journal of Epidemiology* 42: 1724–1737.

The direction and magnitude of the bias from misclassification of exposure is difficult to predict because the misclassification is likely to affect both children with asthma and without asthma as well as children in the comparison group (that is, live in households that cook with electric stoves). After considering kitchen ventilation, Willers et al.<sup>34</sup> found no relationship between gas cooking and asthma, wheeze or other respiratory or allergy outcomes, except for nasal symptoms. Willers et al. observed “Often the kitchen ventilation characteristics are ignored, leading to potential misclassification of exposure to possibly relevant pollutants...in such cases, associations with medical endpoints derived while ignoring the ventilation characteristics can easily lead to incomplete and misleading advice considering the kitchen situation.”

Confounding bias refers to a distortion in the risk estimate from the presence of one or more unmeasured factors that “travel along” with the exposure and are also associated with the outcome. When confounding bias is present in a study, the results are inaccurate, and the conclusions drawn from a study are invalidated. For example, two recent meta-analyses of coffee drinking and lung cancer reported statistically significant associations between coffee drinking and lung cancer.<sup>35</sup> Galarraga and Boffetta<sup>36</sup> observed that the risk of lung cancer increased by 4% for each daily increase of one cup of coffee when smoking was not considered. After controlling for smoking, there was no association between coffee drinking and risk of lung cancer. In other words, smoking confounded the observed statistically significant association between coffee drinking and lung cancer. Confounding bias is a potential issue in the Lin et al. (2013) meta-analysis. Few of the studies included in the meta-analysis adjusted for common indoor asthma triggers such as mold/dampness, pets, and environmental tobacco smoke. These are potential confounders that may travel along with the exposure (gas stoves) and the outcomes (asthma exacerbations and wheeze). For example, 26% of the asthma and gas cooking studies adjusted for mold/dampness.<sup>37</sup> After adjusting for mold and/or dampness (among other variables), 3 of the 5 studies showed no association with gas stove<sup>38</sup> Only 21% of the studies adjusted for pets<sup>39</sup> and 53% of the studies adjusted for environmental tobacco smoke.<sup>40</sup>

**Lin et al. (2013) did not discuss whether exposure (gas stove use) preceded the asthma or the asthma preceded the exposure.**

Specifically, most of the studies included in the meta-analysis were cross-sectional study designs. In a cross-sectional study, exposure and disease are measured at the same time. As a result, whether exposure preceded the disease, or the disease preceded the exposure cannot be determined.

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<sup>34</sup> Willers SM, Brunekreef B, Oldenwening M et al. 2006. Gas cooking, kitchen ventilation, and asthma, allergic symptoms and sensitization in young children – the PIAMA study. *Allergy* 61:563–68.

<sup>35</sup> Tang N, Wu Y, Ma J, Wang B, Yu R. 2010. Coffee consumption and risk of lung cancer: a meta-analysis. *Lung Cancer*, 67:17–22. Galarraga V, Boffetta P. 2016. Coffee drinking and risk of lung cancer – a meta-analysis. *Cancer Epidemiol Biomarkers Prev*, 25(6):951–7.

<sup>36</sup> Galarraga V, Boffetta P. 2016. Coffee drinking and risk of lung cancer – a meta-analysis. *Cancer Epidemiol Biomarkers Prev*, 25(6):951–7.

<sup>37</sup> See Dekker et al. 1991, Hessel et al. 2001, Willers et al. 2006, Lin et al. 2013, Garrett et al. 1998, Casas et al. 2012.

<sup>38</sup> See Willers et al. 2006, Lin et al. 2013, Casas et al. 2012.

<sup>39</sup> See Willers et al. 2006, Lin et al. 2013, Garrett et al. 1998, Casas et al. 2012.

<sup>40</sup> See Dekker et al. 1991, Spengler et al. 2004, Behrens et al. 2005, Willers et al. 2006, Lin et al. 2013, Volkmer et al. 1995, Hoelscher et al. 2000, Ponsonby et al. 2000, Ponsonby et al. 2001, Casas et al. 2012.

There are two basic epidemiological study designs useful for identifying associations between risk factors and disease: cohort studies in which disease rates are compared between groups of exposed persons and groups of unexposed persons; and case-control studies in which exposure history among individuals with disease (cases) is compared with exposure history among individuals without the disease (controls).

These study designs allow for hypotheses to be tested by analyzing differences in disease rates (i.e., cohort studies) or exposure prevalence (i.e., case-control studies) between the study population and appropriate comparison populations. Few of the studies included in the meta-analysis were cohort studies or case-control studies.

**Most of the studies in the Lin et al. (2013) meta-analysis were older studies (data collected before 2000) and included studies of single (and different) geographic regions.**

Gas appliances, like all appliances, have become more efficient over time. Lin et al. (2013) included studies of children who lived in England and Scotland,<sup>41</sup> Germany,<sup>42</sup> The Netherlands,<sup>43</sup> Australia,<sup>44</sup> Maryland,<sup>45</sup> Arizona,<sup>46</sup> California,<sup>47</sup> Washington,<sup>48</sup> Canada,<sup>49</sup> and Russia.<sup>50</sup> Appliances from different regions are likely to have different efficiencies and potentially emit different concentrations of pollutants.

**Since the meta-analysis by Lin et al. (2013) was published, additional studies have been published that found no association between cooking with gas stoves and asthma when compared to cooking with electric stoves.**

Wong et al.<sup>51</sup> studied approximately 250,000 children in 31 countries. The children were part of the global International Study of Asthma and Allergies in Children (ISAAC). Wong et al. (2013) found no association between gas cooking and asthma symptoms or asthma diagnosis when compared to children that lived in households that used electric stoves for cooking. The number of children in this study was many times

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<sup>41</sup> See Melia et al. 1977, Tavernier et al. 2005.

<sup>42</sup> See Behrens et al. 2005, Hoelscher et al. 2000, Casas et al. 2012.

<sup>43</sup> See Willers et al. 2006, Lin et al. 2013.

<sup>44</sup> See Volkmer et al. 1995, Garret et al. 1998, Ponsonby et al. 2000, 2001.

<sup>45</sup> See Diette et al. 2007.

<sup>46</sup> See Dodge et al. 1982.

<sup>47</sup> See McConnell et al. 2002.

<sup>48</sup> See Maier et al. 1998.

<sup>49</sup> See Dekker et al. 1988, Hessel et al. 2001, Carlsen et al. 2011.

<sup>50</sup> See Spengler et al. 2004.

<sup>51</sup> Wong GWK, Brunekreef B, Ellwood P et al. for the ISAAC Phase Three Study group. 2013. Cooking fuels and prevalence of asthma: a global analysis of phase three of the International Study on Asthma and Allergies in Childhood (ISAAC). *Lancet Respir* 1:386–94.

larger than the study populations included in the Lin meta-analysis.<sup>52</sup> Those study populations ranged from 148 children<sup>53</sup> to approximately 14,000 children.<sup>54</sup>

Three additional studies were published since 2013, and the results were inconsistent. Svendsen et al.<sup>55</sup> reported a statistically significant decrease of 22% in lifetime asthma for children that lived in households that used gas stoves when compared to children that lived in households that used electric stoves. Norbäck et al.<sup>56</sup> reported no association between gas cooking and current asthma. Huang et al.<sup>57</sup> reported a 2-fold statistically increased risk of current asthma in children who used gas stoves for cooking in China; however, there was no association between cooking with gas and wheeze.

**Neither the US EPA Integrative Science Assessment (ISA) nor the Canadian Residential Indoor Air Quality Guideline for NO<sub>2</sub> relied upon the conclusions of the Lin et al. (2013) meta-analysis.**

During the CEC Workshop, a participant pointed to the US EPA review of NO<sub>2</sub> in the National Ambient Air Quality Standards program. As part of its routine review of National Ambient Air Quality Standards every few years, the US EPA (2016) published the *Integrated Science Assessment for Oxides of Nitrogen – Health Criteria*. The US EPA (2016) concluded that there was a causal relationship between respiratory effects and short-term nitrogen dioxide exposure based on increased airway responsiveness and allergic inflammation in controlled human exposure studies of NO<sub>2</sub>. With respect to long-term exposure to NO<sub>2</sub>, the US EPA concluded that there is likely to be a causal effect; however, experimental evidence of this association is limited (US EPA 2016). Several workshop participants asserted that the ISA reviewed the most recent science on NO<sub>2</sub>; however, the US EPA (2016)<sup>58</sup> did not cite the Lin et al. meta-analysis or the Wong et al. global study of asthma in children related to cooking fuels. In fact, gas stoves were rarely mentioned in the ISA and primarily in the context of a variable that was (appropriately) adjusted for in a multivariate analysis of NO<sub>2</sub> and a health effect. The US EPA (2016) did not review studies of gas cooking as an independent exposure. This is not surprising, because the US EPA (2016) is largely focused on outdoor air pollutants, for which they have regulatory responsibility for setting appropriate standards for

<sup>52</sup> Interestingly, Lin et al. (2013) cited the Wong et al. (2013) study but did not include the findings regarding gas cooking and asthma in the meta-analysis. Lin et al. (2013) wrote: “Although the effects of gas cooking and indoor NO<sub>2</sub> on asthma and wheeze were found to be relatively small (all random-effects meta-odds ratios were less than 1.5) the public health impact may still be considerable because gas cooking is widespread. **A recent large population study found that 60–70% of European children lived in gas-cooking homes (Wong et al. 2013)** [*emphasis added*]. It is not clear to what extent the observed associations with gas cooking are attributable to NO<sub>2</sub> alone or also to other pollutants associated with the use of gas for cooking.”

<sup>53</sup> Garrett MH, Hooper MA, Hooper BM, Abramson MJ. 1998. Respiratory symptoms in children and indoor exposure to nitrogen dioxide and gas stoves. *Am J Respir Crit Care Med* 158:891–95.

<sup>54</sup> Volkmer RE, Ruffin RE, Wigg NR, Davies N. 1995. The prevalence of respiratory symptoms in South Australian preschool children. II. Factors associated with indoor air quality. *J Paediatr Child Health* 31:116–20.

<sup>55</sup> Svendsen ER, Gonzales M, Commodore A. 2018. The role of the indoor environment: Residential determinants of allergy, asthma and pulmonary function in children from a US-Mexico border community. *Sci Total Environ* 616-617:1513-1523.

<sup>56</sup> Norbäck D, Lu C, Zhang Y et al. 2019. Onset and remission of childhood wheeze and rhinitis across China – associations with early life indoor and outdoor air pollution. *Environment International* 123:61-69.

<sup>57</sup> Huang S, Garshick E, Weschler LB, et al. 2020. Home environmental and lifestyle factors associated with asthma, rhinitis and wheeze in children in Beijing, China. *Environmental Pollution* 256: 113426.

<sup>58</sup> US Environmental Protection Agency (US EPA). 2016. *Integrated Science Assessment for Oxides of Nitrogen – Health Criteria*. EPA/600/R-15/068 January 2016. Available at: <https://www.epa.gov/naaqs/nitrogen-dioxide-no2-primary-standards-integrated-science-assessments-current-review>. Accessed October 2020.

pollutants regulated under the Clean Air Act. The US EPA Ambient Air Quality Standard for NO<sub>2</sub> is 100 ppb (1-hr) and 53 ppb (annual).

During the CEC Workshop, the same participant pointed to the Canadian Residential Indoor Air Quality Guideline (RIAQG) for NO<sub>2</sub> (Health Canada, 2015)<sup>59</sup> as support for the Lin et al. 2013 study conclusions. The Canadian residential guidelines set a short-term RIAQG at 170 µg/m<sup>3</sup> (90 ppb) based on decreased lung function and increased airway responsiveness in asthmatics. The long-term RIAQG (24-hours or longer) is set at 20 µg/m<sup>3</sup> (11 ppb) based on higher frequency of days with respiratory symptoms and/or medication use in asthmatic children. Note that although the RIAQG notes gas appliances among the sources of indoor NO<sub>2</sub>, the guidelines are based on health effects of NO<sub>2</sub> and not gas appliances *per se*. The Canadian RIAQG does not refer to the Lin et al. (2013) meta-analysis directly. The Guidelines briefly discuss indoor epidemiological studies. In particular, the Guidelines note that epidemiological studies of respiratory effects in which gas stoves are used as a surrogate of NO<sub>2</sub> exposure have been inconsistent. The Guidelines state that these studies have greater potential for exposure misclassification because NO<sub>2</sub> is not directly measured.

Several strategies are outlined for reducing exposure to NO<sub>2</sub> indoors by Health Canada (2015). These strategies include controlling indoor emissions from combustion appliances and reducing infiltration of NO<sub>2</sub> from outdoor sources. Control measures include installation and maintenance of outdoor venting of combustion appliances used for heating, mechanical ventilation when cooking on a gas stove, not idling cars or using combustion-powered equipment in attached garages, and not using barbeque devices near open doors and windows.

### **Conclusion: Ventilation is Critical Regardless of the Indoor Exposures**

In this memorandum, we review relevant literature regarding indoor air quality and residential appliances, including cooking with the use of natural gas versus electric ranges or cooktops. We note the improving trends in indoor air quality, based in part on CEC's own studies. We then review some recent Reports (the UCLA Report and the RMI Report) and literature published since a meta-analysis relied upon in these Reports (Lin et al., 2013).

The "International Study of Asthma and Allergies in Children" (Wong et al. 2013), a large, global study published contemporaneously with the Lin et al. (2013) meta-analysis, reported that use of gas stoves was not associated with asthma diagnosis or asthma symptoms in children. Given the size and global geographic distribution of participants in this study, this is an important study that would have tempered the findings of a meta-analysis.

Furthermore, many of the authors of studies included in the Lin et al. (2013) meta-analysis explicitly discuss the importance of ventilation as an unmeasured factor potentially leading to exposure misclassification in their own studies. This exposure misclassification may have changed the association between exposure to gas stoves and health. The presence of other indoor pollutants, which were not taken into account in many of these studies, may have been responsible for the asthma attributed to gas stove use.

In fact, Kile et al. (2014) hypothesized that ventilation may reduce asthma in children. They reported asthma was statistically significantly decreased by 36% for children who lived in households where gas

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<sup>59</sup> Health Canada. 2015. Residential Indoor Air Quality Guideline: Nitrogen Dioxide. <https://www.canada.ca/en/health-canada/services/publications/healthy-living/residential-indoor-air-quality-guideline-nitrogen-dioxide.html>. Accessed October 13, 2020.

stoves for cooking were used only with ventilation when compared to children who lived in households where gas stoves were used without ventilation. Separately, Kile et al. (2014) reported that asthma was statistically significantly decreased by 44% for children who lived in households where gas stoves were used for cooking only when compared to children who lived in households where gas stoves were used for cooking and heating. We have not identified any comparable studies for electric stoves, but ventilation would still decrease exposures to pollutants from cooking, etc.

The key point is that improved ventilation will potentially result in large health benefits, whether appliance energy sources are natural gas or electricity. Such ventilation will address not only pollutants associated with emissions from natural gas or electric stoves, but also other pollutants associated with cooking, and other indoor air pollutants.

**Appendix: References discussed in footnotes 6-7 and 32-50**

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