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Subject: Comments on the Public Workshop: 2022 Scoping Plan Update – Building Decarbonization Workshop

Dear Deputy Executive Officer Sahota:

Southern California Gas Company (SoCalGas) appreciates the opportunity to provide public comments on the California Air Resources Board (CARB) 2022 Scoping Plan Update – Building Decarbonization Workshop held December 13, 2021. We thank you for also extending the deadline to submit public comments. California is seeking to achieve carbon neutrality goals by 2045; however, there is currently no blueprint or consensus on the path to get there. Collaborative and fact-based engagement among all stakeholders is essential to achieve these goals. Effective building decarbonization solutions that serve and advance the public interest must also be carefully designed and based on empirical scientific data to avoid the imposition of inequitable affordability effects.

The societal need to decarbonize is critical to combat climate change and avert its impacts. Changes in the climate can also worsen the quality of the air outdoors, which infiltrates into indoor environments. "Rising carbon dioxide (CO_2) levels and warmer temperatures can increase outdoor airborne allergens which can infiltrate indoor spaces. Warmer temperatures and shifting weather patterns can lead to more frequent and severe wildfires. Smoke and other particle pollution generated outdoors, including from wildfire events and dust storms, can infiltrate into indoor environments and contribute to levels of indoor particulate matter."[1] Mitigation of these public health impacts should not be overlooked as drivers of policy. These health impacts should be

[1] "Indoor Air Quality and Climate Change," U.S. Environmental Protection Agency, December 16, 2021. Available at https://www.epa.gov/indoor-air-quality-iaq/indoor-air-quality-and-climate-change.

considered in any risk-benefit or cost-benefit analysis of building electrification and strategies for energy decarbonization in buildings. As such, our comments focus on:

1. Diesel Combustion Increase with Increased Electricity Demand.
2. Risks of Appliance Electrification.
3. Ventilation Improves Air Quality from All Indoor Sources that Potentially Impact Health.
4. Similarity of Particulate Matter (PM) for Cooking Appliances Regardless of the Energy Source.
5. Decrease of Nitrogen dioxide (NO_2) from Appliances Over the Years.
6. Evidence Regarding Exceedances of NO_2 Standards is Overstated.
7. State Nitrous Oxides (NOx) Emissions are Misrepresented.

1. Diesel Combustion Increase with Increased Electricity Demand

Increasing load on the electric grid at the scale currently proposed will have significant impacts on energy system reliability, resiliency, and affordability. "Power outages may occur with more frequent extreme weather, making it more difficult to maintain comfortable indoor temperatures and healthy indoor air quality, and leading to more frequent use of portable generators."[2] Thus, adverse public health effects from the use of diesel backup generators (BUGs) could be exacerbated by this policy approach.

Diesel-fired generation is growing at a rapid pace in California with enough capacity to power 15 percent of the electric grid.[3] Per CARB, "[the] demand for reliable back-up power has health impacts of its own. Of particular concern are health effects related to emissions from diesel BUGs. In 1998, California identified diesel [particulate matter (PM)] as a toxic air contaminant based on its potential to cause cancer.[4] The majority of diesel PM is small enough to be inhaled deep into the lungs and make them more susceptible to injury."[5] According to the Mount Sinai Selikoff Center for Occupational Health, long-term exposure to diesel exhaust can cause the worsening of existing lung conditions, such as asthma.[6] The increase in diesel BUGs statewide is troublesome, as the generators tend to be located near public spaces, such as schools and workplaces.[7]

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[2] "Indoor Air Quality and Climate Change," U.S. Environmental Protection Agency, December 16, 2021. Available at https://www.epa.gov/indoor-air-quality-iaq/indoor-air-quality-and-climate-change.
[3] "The Diesel-Fired California Dream," California Energy Markets, October 8, 2021, No. 1662. Available at https://www.newsdata.com/california_energy_markets/bottom_lines/the-diesel-fired-california-dream/article_f65b1070-2876-11ec-b3f1-f3ef2c8a4076.html.
[4] "Summary: Diesel Particulate Matter Health Impacts," California Air Resources Board, 2022. Available at https://ww2.arb.ca.gov/resources/summary-diesel-particulate-matter-health-impacts.
[5] "Use of Back-up Engines for Electricity Generation During Public Safety Power Shutoff Events," California Air Resources Board, 2022. Available at https://ww2.arb.ca.gov/resources/documents/use-back-engines-electricity-generation-during-public-safety-power-shutoff.
[6] "Diesel Exhaust Exposure," Mount Sinai Selikoff Centers for Occupational Health, May 2016. Available at https://www.mountsinai.org/files/MSHealth/Assets/HS/Patient%20Care/Service-Areas/Occupational%20Medicine/Diesel%20Exhaust%20Exposure.pdf.
[7] "Diesel Back-Up Generator Population Grows Rapidly in the Bay Area and Southern California," M. Cubed. Available at https://www.bloomenergy.com/wp-content/uploads/diesel-back-up-generator-population-grows-rapidly.pdf.

Even more concerning is that many of the diesel BUGs are located within disadvantaged communities and can potentially burden these residents with high levels of carcinogenic pollutants.[8] For example, nearly one million people were affected by a Public Safety Power Shut-off (PSPS) event in October 2019 and utilized 125,000 diesel BUGs for electrical power.[9] CARB estimated that diesel BUGs used during this time emitted 9 tons of diesel soot, which is the equivalent of about 29,000 heavy-duty diesel trucks driving on California's roadways for one month.

According to an analysis conducted by Bloom Energy and PowerOutage.us, from 2017 to 2019, there were 50,000 significant blackout events in California that affected 51 million customers.[10] Utility initiated "de-energization" events (*i.e.*, PSPS), while on the rise, were only a small fraction of outages recorded during this time period.[11] Blackouts have traditionally been interpreted as a rural problem, however, data by Bloom Energy indicates that larger cities (urban) in California could face a higher risk of blackout events and more customers impacted.[12] Bloom Energy notes that: "[a]mong California's 25 largest cities, San Bernardino—which had 1,208 blackout events affecting the equivalent of 1.4 million utility customers—experienced the most blackouts on a per capita basis. Using customers impacted divided by population as a rough approximation of how many times a typical resident experienced a blackout, the average person in San Bernardino experienced more than 6 outages…Los Angeles alone accounted for 5,787 blackout events affecting the equivalent of 6.4 million utility customers."[13] Aging electric grid infrastructure is cited as a main cause of these blackouts and it has been estimated that a single blackout event in October 2019 incurred over $2 billion in costs to small commercial and industrial businesses.[14] Thus, consideration must be given to increasing loads on the electric grid.

2. Consideration Must be Given to the Risks of Appliance Electrification

We agree with CARB's Air Pollution Specialist Dana Papke Waters who stated "*[h]ow best to facilitate decarbonization is a central question before the state…importantly, how do we advance decarbonization equitably…*"[15] Martha Dina Argüello, Executive Director of Physicians for Social Responsibility-Los Angeles (PSR-LA), echoed this sentiment as she expressed concern of rushing electrification policies because the costs can undermine keeping the lights on and preserving Californians' homes.[16] Pierre Delforge of the Natural Resources Defense Council stated that if the State decarbonizes and electrifies without considering the risks, it could lead to costs higher than

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[8] *Ibid.*
[9] "Emission Impact: Additional Generator Usage Associated with Power Outage," California Air Resources Board, January 30, 2020. Available at https://ww2.arb.ca.gov/sites/default/files/2020-01/Emissions_Inventory_Generator_Demand%20Usage_During_Power_Outage_01_30_20.pdf.
[10] "California Power Outage Map," Bloomenergy, 2022. Available at https://www.bloomenergy.com/bloom-energy-outage-map/.
[11] *Ibid.*
[12] *Ibid.*
[13] *Ibid.*
[14] *Ibid.*
[15] *See* CARB Public Workshop: 2022 Scoping Plan Update – Building Decarbonization Recording, December 13, 2021, at 00:05:28. Available at https://www.youtube.com/watch?v=0YGLHOgw6xc.
[16] *See* CARB Public Workshop: 2022 Scoping Plan Update – Building Decarbonization Recording, December 13, 2021, at 02:04:25.

replacing gas appliances.[17] He continued to state that, in many cases, equipment costs can be passed down to tenants in the form of higher rents, which could lead to displacement and less affordable housing, and operating costs could increase as buildings often have minimal efficiency equipment and poor installation.[18] However, the opportunities of decarbonization and electrification could lead to improved affordability of housing when building and equipment efficiency are coupled with demand flexibility.[19] As such, the decision for complete electrification of buildings is complex and the risks must be thoroughly understood. We offer the following analyses for CARB's consideration in selecting building decarbonization and electrification scenarios for the 2022 Scoping Plan.

Based on analyses of natural gas consumption for a large number (N =17,072) of households located within a low-income portion of Southern California, researchers found that diurnal patterns of hourly natural gas use largely coincide with the timing of daily peak electricity loads.[20] This suggests that electrification of cooking appliances may substantially add to electricity demands during the same periods where peak electricity load already occur, and likely result in only limited GHG emissions benefits in the absence of a fully decarbonized electrical grid. Fournier et al.[21] recommended that electrification initiatives initially target natural gas end-use appliances which have the highest expected efficiency gains (like hybrid heat-pump based electric water heaters) and whose anticipated time-of-use is less likely to coincide with periods of peak-electricity demand. Additionally, in 2019 California's residential price per million BTU for electricity was four and a half times the price of natural gas according to the U.S. Energy Information Administration (EIA).[22] Specifically, *the U.S. EIA states that California's residential price for electricity for a million BTUs was $56.14 while the same equivalent of energy for natural gas was $12.61.*[23] Therefore, switching to electric-only appliances could have a greater financial impact on residents—a cost that low-income households can ill afford.

The South Coast Air Quality Management District (SCAQMD) is considering including appliance electrification as a stationary source control measure in its 2022 Air Quality Management Plan (AQMP). The SCAQMD recently developed the Net Emissions Analysis Tool (NEAT) to calculate the changes in NOx emissions and costs associated with switching residential appliances to lower-emitting technologies. Overall, the most cost-effective scenario for water heater electrification from NEAT anticipates average costs of nearly $850,000 per ton of NOx reduced. In some scenarios, NEAT predicts that the average electrification costs can approach $3,500,000 per ton of NOx reduced. These values are 28 to 117 times greater than the upper limit of the cost-effectiveness values anticipated in the 2016 AQMP for control measure CMB-02-Emission Reductions from Replacement with Zero or Near-Zero appliances in Commercial and Residential

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[17] *See* CARB Public Workshop: 2022 Scoping Plan Update – Building Decarbonization Recording, December 13, 2021, at 02:03:45.

[18] *Ibid.*

[19] *Ibid.*

[20] Fournier ED, Cudd R, Federico F, Pincetl S. 2020. Implications of the timing of residential natural gas use for appliance electrification efforts. Environmental Research Letters, 15(12), p.124008.

[21] *Ibid.*

[22] "California State Profile and Energy Estimates: Residential Sector Energy Price and Expenditure Estimates, 1970-2019, California," U.S. Energy Information Administration. Available at https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_prices/res/pr_res_CA.html&sid=CA.

[23] *Ibid.*

Applications (~$30,000 per ton) and the 2016 AQMP cost-effectiveness threshold of $50,000 per ton of NOx reduced. This analysis shows that appliance electrification is not substantially cost-effective compared to the use of more fuel-efficient or controlled equipment. (See Appendix F).

3. Ventilation Improves Air Quality from All Indoor Sources that Potentially Impact Health

Some stakeholders often state that electrification of appliances will improve indoor air quality. However, a 2021 Lawrence Berkeley National Laboratories (LBNL) report concluded that routine use of kitchen ventilation allows cooking, whether from electric or gas energy sources, to occur safely with respect to both acute and chronic exposures.[24] Ventilation is a useful tool to improve indoor air quality, not only for fine particulate matter (with aerodynamic diameter less than 2.5 microns, $PM_{2.5}$) and NO_2, but also for other indoor pollutants. Improved ventilation is most likely to result in large health benefits across all populations and address numerous sources that contribute to indoor air quality. During the workshop, Martha Dina Argüello, PSR-LA, discussed the Strategic Actions for a Just Economy (SAJE) Report which includes prioritizing ventilation in homes.[25] In fact, LBNL researchers recommended capture efficiencies for various sized residences with the aim of keeping exposures at a health-protective level. Researchers discussed that pollutants are generated from cooking with any energy source and concluded that excluding gas cooking appliances does not eliminate the need for effective kitchen ventilation.[26] As such, during the California Energy Commission (CEC) Title 24 proceeding for the 2022 Energy Code,[27] SoCalGas asked for more stringent mechanical ventilation and capture efficiencies for all stove tops and buildings as there are multiple health benefits that have been scientifically proven.[28,29] This is consistent with CARB's stated goal to develop efficient and effective solutions that will reduce levels of all sources of indoor air pollution and enhance public health across all sectors.

Additionally, the influence of outdoor air on indoor air quality has decreased over the years, as outdoor air concentrations of PM (including $PM_{2.5}$) and other criteria pollutants have decreased,

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[24] Singer BC, Chan WR, Delp WW, Walker IS; Zhao H. 2021. Effective Kitchen Ventilation for Healthy Zero Net Energy Homes with Natural Gas. California Energy Commission. Publication Number: CEC-500-2021-005.
[25] *See* CARB Public Workshop: 2022 Scoping Plan Update – Building Decarbonization Recording, December 13, 2021, at 02:33:50.
[26] Singer BC, Chan WR, Delp WW, Walker IS; Zhao H. 2021. Effective Kitchen Ventilation for Healthy Zero Net Energy Homes with Natural Gas. California Energy Commission. Publication Number: CEC-500-2021-005.
[27] "2022 Building Energy Efficiency Standards", California Energy Commission. Available at https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency.
[28] *See* SoCalGas Comments on the Proposed Changes to the 2022 Energy Code Update Rulemaking, June 21, 2021, at 6. Available at https://efiling.energy.ca.gov/GetDocument.aspx?tn=238386&DocumentContentId=71682.
[29] The CEC adopted the 2022 Energy Code in 2021 which increased minim kitchen ventilation requirements. The vent hood capture efficiencies for electric stoves range from 50 percent to 65 percent and for natural gas stoves from 70 percent to 85 percent, depending on the size of the dwelling unit. *See* "2022 Building Energy Efficiency Standards", California Energy Commission. Available at https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency.

due in part to regulations of ambient air quality.[30,31] Improvements in energy efficiency have also led to a tighter building envelope.[32] As a result, outdoor air pollution does not infiltrate into newer buildings as readily. The converse of this, is that emissions from indoor sources are more likely to remain indoors. Air quality and public health specialists recognize there are numerous sources of indoor air pollutants associated with potential health impacts, in particular asthma.[33,34] These sources include mold, droppings from cockroaches and pests, pet dander, dust mites, smoke from woodburning stoves and cigarettes or marijuana, chemical irritants from household products, gas appliances, and activities such as cooking.[35] We agree with Earthjustice Senior Research and Policy Analyst Sasan Saadat's public comments during the workshop.[36] Building decarbonization and retrofits for existing buildings should not focus solely on electric technology, but should incorporate mold removal, asbestos treatment, and other measures that create healthier homes.[37]

Despite the benefits of ventilation, surveys show that many households do not use kitchen stove vent hoods because they simply forget to turn it on or because they find it to be noisy.[38] Therefore, vent hoods that turn on automatically when the stove is turned on improve conformance. This strategy has been used in Japan and is found to be effective.[39] Given this, SoCalGas asked for implementation of automatic vent-hoods and supported research to quiet fan motors during the CEC Title 24 proceeding.[40] The development of quieter fan motors could also encourage people to routinely use kitchen ventilation.

4. Particulate Matter (PM) is Similar for Cooking Appliances Regardless of the Energy Source

Although certain indoor air quality parameters will improve with electrification (in particular, NOx and NO_2 emissions), the health benefits associated with electrification of gas stoves are likely overstated. Regardless of fuel source, the process of cooking food itself is a well-recognized source

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[30] "Particulate Matter ($PM_{2.5}$) Trends," US EPA, May 26, 2021. Available at https://www.epa.gov/air-trends/particulate-matter-pm25-trends.
[31] "Nitrogen Dioxide Trends" US EPA, May 26, 2021. Available at https://www.epa.gov/air-trends/nitrogen-dioxide-trends.
[32] Institute of Medicine. 2011. Climate Change, the Indoor Environment, and Health. Washington, DC: The National Academies Press. Available at https://doi.org/10.17226/13115.
[33] "Asthma Triggers: Gain Control," US EPA, November 26, 2021. Available at https://www.epa.gov/asthma/asthma-triggers-gain-control.
[34] "Common Asthma Triggers," Center for Disease Control and Prevention, August 21, 2020. Available at https://www.cdc.gov/asthma/triggers.html.
[35] Seguel JM, Merrill R, Seguel D, Campagna AC. 2017. Indoor Air Quality. American Journal of Lifestyle Medicine, 11(4), p.284.
[36] *See* CARB Public Workshop: 2022 Scoping Plan Update – Building Decarbonization Recording, December 13, 2021, at 01:43:05.
[37] *Ibid.*
[38] *See* CEC Presentation on Commissioner Hearing on Indoor Cooking, Ventilation, and Indoor Air Quality held September 30, 2020, at 3. Available at https://efiling.energy.ca.gov/getdocument.aspx?tn=234999.
[39] *See* CEC Commissioner Hearing on Indoor Cooking, Ventilation, and Indoor Air Quality Recording, September 30, 2021, at 01:55:25. Available at https://energy.zoom.us/rec/share/WHFZ24svriDddPx48ZzWt6yviJkkasB10ChjHRsWoVSBz7ImDEUSc1KnnIPP0eY.c-PTAnLe3RaaMjoM?startTime=1601481928000.
[40] *See* SoCalGas Comments on the Proposed Changes to the 2022 Energy Code Update Rulemaking, June 21, 2021, at 6.

of $PM_{2.5}$ and ultrafine PM (particulate matter with aerodynamic diameter less than 0.1 microns). PM is primarily formed during cooking processes such as frying, sautéing, and toasting. As such, PM is similar whether the energy source is gas or electric. (See Appendix A). NO_2 can also be produced as a byproduct of cooking, albeit in lower concentrations than that emitted from gas stoves.

Electrification of cooking appliances will have minimal or no impact on asthma reduction as long as other indoor air pollutants which trigger asthma remain.[41] In fact, the CEC Draft 2021 Integrated Energy Policy Report (IEPR) Volume on Energy Efficiency and Building, Industrial, and Agricultural Decarbonization states *"[w]hile field and simulation modeling studies have looked at the impacts of household interventions, such as improved ventilation, outreach/education, air cleaners, and high-efficiency filtration on children with asthma, there are no known studies that directly investigate the impact of kitchen electrification on asthma outcomes* (emphasis added)."[42] As such, the CEC intends to research the relative effects of cooking and ventilation interventions on asthma, especially relative to other important indoor air pollutants factors that trigger asthma.[43] SoCalGas urges and supports CARB to coordinate with the CEC on such research solicitations as it is vital to public health.

5. Nitrogen dioxide (NO_2) from Appliances has Decreased Over the Years

Collectively, the evidence for an association between gas appliances and increased asthma incidence or prevalence is overstated. NO_2 concentrations in residences with gas stoves are much lower in newer residences partly due to changes in the ignition systems (See Appendices B and C). Recent studies demonstrate that residents' exposures to NO_2 in households with electric stoves are statistically similar to households with gas stoves with electric starters (only ~5 parts per billion higher).[44] Prohibiting gas appliances, when other numerous indoor sources of asthma triggers have not been eliminated or mitigated, is unlikely to result in a substantial reduction in asthma.[45] Because asthma is a multifactorial disease with both genetic and environmental components. We strongly believe mechanical ventilation and improvements to the building envelope (i.e., removal of asbestos) will improve indoor air quality, and thus, public health.

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[41] *See* Ramboll's Comments on CEC Workshop on Randomized Trial Study to Determine the Impact of Gas Stove Interventions on Children with Asthma, March 16, 2021, at 2-3. Available at https://efiling.energy.ca.gov/GetDocument.aspx?tn=237177&DocumentContentId=70359.

[42] "2021 Integrated Energy Policy Report: Draft Report, Volume I: Energy Efficiency and Building, Industrial, and Agricultural Decarbonization," California Energy Commission, January 12, 2022, at 19. Available at https://www.energy.ca.gov/publications/2021/2021-integrated-energy-policy-report.

[43] *See* CEC GFO-21-301-Randomized Trial Study to Investigate the Impact of Gas Stove Interventions on Children with Asthma, September 1, 2021. Available at https://www.energy.ca.gov/solicitations/2021-09/gfo-21-301-randomized-trial-study-investigate-impact-gas-stove-interventions.

[44] Spengler J, Schwab M, Ryan PB, Colome S, Wilson AL, Billick I, Becker E. 1994. Personal exposure to nitrogen dioxide in the Los Angeles Basin. J Air & Waste Management Assn, 44(1), pp.39-47. *Also see* Appendix B.

[45] *See* Ramboll's Comments on CEC Workshop on Randomized Trial Study to Determine the Impact of Gas Stove Interventions on Children with Asthma, March 16, 2021, at 2-3. Please note that Senior Managing Consultant Linda Dell agreed with comments made by Dr. Ann Harvey and Dr. John Balmes at the workshop regarding triggers of asthma.

We suggest for CARB staff to evaluate all studies before representing conclusions on gas stoves and asthma as it is misleading to the public. The Lin et al. (2013) meta-analysis[46] cited by presenters at the workshop failed to mention that the results are based on conclusions of 19 epidemiological studies and are inconsistent with results found by Lin et al. and Wong et al. (See Appendix E). The separate longitudinal analysis of a birth cohort by Lin et al. (2013) concluded there is "*…little evidence for an adverse effect of exposure to gas cooking on the development of asthma and allergies* (emphasis added)."[47] In fact, the study found that current and lifetime wheeze (which is a symptom of asthma) were not consistently associated with gas cooking. Further, the Wong et al. (2013)[48] study, published concurrently as the Lin et al. (2013) meta-analysis,[49] found no association between gas stoves and asthma. Wong et al. (2013) concluded that *"…we detected no evidence of an association between the use of gas as a cooking fuel and either asthma symptoms or asthma diagnosis* (emphasis added)."[50] This study is also cited in the Draft 2021 IEPR, which asserts "… a global study of asthma among children reported no association between gas cooking and symptoms of asthma."[51] Again, we respectfully request that CARB coordinate with the CEC on research solicitations related to gas stoves and asthma as it is vital to public health.

6. Evidence Regarding Exceedances of NO_2 Standards is Overstated

During the workshop, presenters used scientifically unsupported statements, such as "indoor concentrations of NO_2 would be illegal if they were outdoors," based on a UCLA study that modelled (not measured) indoor air quality. This model used unrealistic assumptions in buildings, such as no ventilation for appliances or water heaters. Additionally, the model did not identify any exceedances of NO_2 or NOx for stoves when the concentration was appropriately averaged over 1-hour.[52] The UCLA study also compared modelled peak (i.e., highest concentrations) to 1-hour indoor air quality standards and assumed that the "peak" exposure was a 1-hour elevation, instead of the peak exposure value over 1-hour of exposure. This assumption, although false, was necessary to conclude that the 1-hour standard was exceeded. This is important to note, as short-term outdoor standards and indoor air quality guidelines allow for "peak" exceedances if the time-averaged exposure (for example, 1-hour in the case of NO_2) is not exceeded. Exposure duration is

[46] 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.
[47] Lin W, Gehring U, Oldenwening M, de Jongste JC, Kerkhof M, Postma D, Smit HA, Wijga AH, Brunekreef B. 2013. Gas cooking, respiratory and allergic outcomes in the PIAMA birth cohort study. Occup Environ Med, 70: 187-94.
[48] 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.
[49] 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.
[50] 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.
[51] "2021 Integrated Energy Policy Report: Draft Report, Volume I: Energy Efficiency and Building, Industrial, and Agricultural Decarbonization," California Energy Commission, January 12, 2022, at 18.
[52] 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. Available at: https://ucla.app.box.com/s/xyzt8jc1ixnetiv0269qe704wu0ihif7.

critically important to understanding whether ambient air quality standards (whether for outdoor or indoor air) are in fact exceeded. In fact, the relative risk estimates associated with NO_2 concentrations in epidemiological studies are estimated using time-averaged exposures (whether over 1-hour, two weeks, or one month, or longer) and not on the basis of "peak" exposures. (See Appendix D). Given this, the health benefits of electric stoves in the UCLA study are substantially overestimated because the exposures are substantially overestimated.

Additionally, presenters at the workshop stated that 12 million Californians are routinely exposed to NO_2 concentrations above 100-parts per billion (ppb) as if it were a factual statement based on measured data without qualifying that it is a prediction based on a major extrapolation from a small modelling study by Logue et al. (2014).[53] The researchers' modelling claimed that indoor NO_2 concentrations might exceed 100-ppb as a 1-hour average (which is the federal outdoor 1-hour National Ambient Air Quality Standard). The study also only examined range hoods at 55 percent capture efficiency, which was described as the average capture efficiency of range hoods based on an earlier study.[54] Referencing findings from a study that is not consistent with current recommendations for capture efficiencies[55] and/or the building code is misleading.

7. State NOx Emissions are Misrepresented

Transparent, fact-based policymaking also requires honest presentation and assessment of data – for which CARB workshops are an important stakeholder forum. This includes recognizing when panelist presentations may fall short of applicable standards of candor. During the workshop, a panelist stated that buildings are now one of largest contributors to both indoor and outdoor pollution as compared to transportation (passenger vehicles) and electricity generation. The slide by the presenter purported to illustrate that building emissions are a majority source of smog-forming NOx emissions.[56] Such misinformation creates obstacles rather than facilitates sound policymaking.

Figure 1 (below) utilizes CARB's 2020 sectoral NOx emissions projections for each of the three sectors that were presented in the slide: transportation (in total), buildings, and electric generation (including cogeneration).[57] As is evident, the transportation sector is responsible for greater than ten times the NOx emissions as all 12 million buildings in California and almost 30 times more than electricity generation (cogeneration is included as these are industrial sized power plants that produce steam and electricity).

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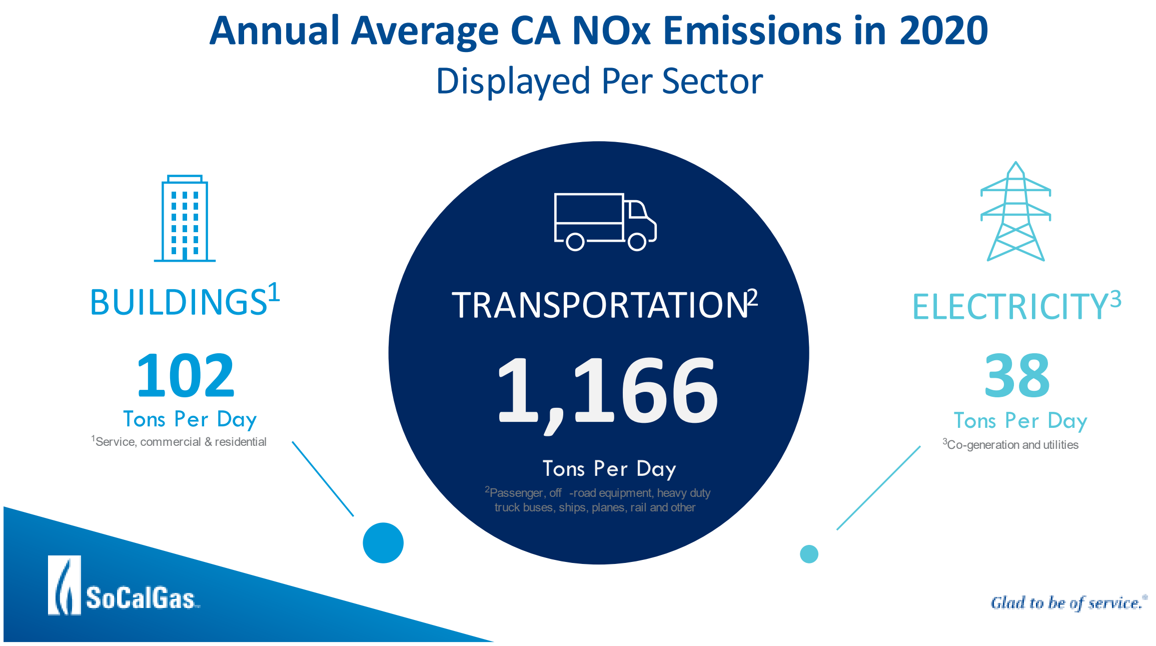
[53] Logue JM, Klepeis NE, Lobscheid AB, Singer BC. 2014. Pollutant exposures from natural gas cooking burners: a simulation-based assessment for Southern California. Environmental Health Perspectives, 122(1): 43-50.
[54] Singer BC, Delp WW, Apte MG, Price PN. 2012. Performance of installed cooking exhaust devices. Indoor Air, pp.1600-0668.
[55] *Ibid.*
[56] *See* RMI Presentation: Decarbonizing California's Buildings, December 13, 2021, at Slide 3. Available at https://ww2.arb.ca.gov/sites/default/files/2021-12/RMI-sp22-buildings-ws-12-13-21.pdf.
[57] "2016 SIP Emission Projection Data, 2020 Estimated Annual Average Emissions (Statewide)," CARB, 2019. Available at https://www.arb.ca.gov/app/emsinv/2017/emssumcat_query.php?F_YR=2020&F_DIV=0&F_SEASON=A&SP=SIP105ADJ&F_AREA=CA#0.

Figure 1. 2020 Annual Average California NOx Emissions (circles are to scale)[58,59]



Conclusion

The thermal needs of buildings, as the primary impetus for emissions reductions, are largely clear and straightforward, but reducing building emissions is complicated. As a common carrier, SoCalGas' primary business is to provide non-discriminatory fuel transportation services to those who request it. Larger customers, which in some instances can include core customers, are free to procure their own fuel and have it delivered by the States' gas utilities. This foundational market design element has significant regulatory jurisdictional implications to building decarbonization strategies. As one starting point, we recommend that CARB, in conjunction with the CEC and California Public Utilities Commission, establish statewide energy efficiency targets with regulatory and incentive structures that are cost-effective, feasible in practice, will not adversely impact public health and safety,[60] and which can and should advance building electrification.

SoCalGas outlined its goals to achieve net-zero emissions, including Scope 3 emissions, in ASPIRE 2045.[61] Scope 3 emissions result from the energy use decisions made by SoCalGas customers and over which, in most instances, we have limited means to influence. SoCalGas is thus aligned with facilitating, advancing, and actuating State policies for reducing our customers' emissions, including building electrification. We respectfully assert that establishing meaningful and aggressive energy efficiency targets for buildings is a beneficial starting point that, if done

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[58] *Ibid.*
[59] *Ibid.*
[60] *See* Warren-Alquist Act, 2021 Edition, Section 25310 (c)(1). Available at https://www.energy.ca.gov/sites/default/files/2021-05/CEC-140-2021-001.pdf
[61] "ASPIRE 2045: Sustainability and Climate Commitment to Net Zero," SoCalGas Company, March 2021. Available at https://www.socalgas.com/sites/default/files/2021-03/SoCalGas_Climate_Commitment.pdf.

thoughtfully and carefully, will advance building electrification while minimizing affordability burdens. SoCalGas will act to implement energy efficiency programs and decarbonized fuel strategies, as a comprehensive and supportive framework to meet our shared decarbonization objective.

Respectfully,

/s/ Kevin Barker

Kevin Barker
Senior Manager
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RAMBOLL

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BUILDING DECARBONIZATION AND INDOOR AIR QUALITY

January 21, 2022

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Dear Mr. Barker:

SoCalGas Company requested Ramboll to evaluate the building decarbonization and indoor air quality discussion at the California Air Resources Board (CARB) 2022 Scoping Plan – Building Decarbonization Workshop held December 13, 2021. We highlight some of the issues that were misrepresented or not fully or fairly discussed in the presentations in the corresponding Appendices. We also reviewed relevant scientific articles to provide a more comprehensive discussion of these issues. The appendices are as follows:

- Appendix A: Cooking Process Produces PM
- Appendix B: Gas Appliances Have Improved
- Appendix C: Support from Recent CEC Studies
- Appendix D: The Recent UCLA Report Models (Rather than Measures) Indoor Air Quality, Without Any Duration, Leading to Unsupported Conclusions About Exceedances of Ambient Air Quality Standards and Resulting Health Impacts
- Appendix E: The Epidemiological Literature on the Association of Gas Stoves and Asthma is Inconsistent and Must Be Fully Evaluated
- Appendix F: Appliance Electrification is not Cost-Effective

If you have any questions, please do not hesitate to contact Ramboll.

Yours sincerely,

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Appendices

Appendix A: Cooking Process Produces PM

The process of broiling, baking, sautéing, toasting, and barbecuing contribute to the generation of such PM (Abt et al., 2000; Sun et al., 2018). A Canadian study of 132 households concluded that cooking contributed about 22% to the total daily $PM_{2.5}$ exposure in the participating homes (Sun & Wallace, 2020). In this study, 79% of the stoves were electric ranges and 21% were gas ranges. The average concentration of $PM_{2.5}$ in the living room during a cooking event was 12 µg/m^3 (geometric mean, with 95% confidence interval of 9.9-14 µg/m^3). In a study examining emissions and source strengths from the cooking of complete meals, mean emission rates and source strengths of $PM_{2.5}$ varied between 0.54-3.7 mg/min and 15-68 mg/min, respectively (O'Leary et al., 2019). 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.

Additional studies of cooking, stove types, and $PM_{2.5}$ and ultrafine PM emissions reached similar conclusions. For example, in a study designed to evaluate the influence of the food, cooking temperature, type of oil, and stove type on emissions of $PM_{2.5}$ and ultrafine PM, emission rates and aerosol characteristics were determined for a variety of cooking methods (Buonnano et al., 2009). Overall, more PM was emitted with increased cooking temperatures, and cooking fatty foods produced more PM than vegetables. Emissions also varied dependent on the type of oil used. Importantly, while gas stove used without food had slightly higher particle number-based emission factors (largely reflecting ultrafine PM) when compared to electric stoves used without food, these differences changed under certain cooking conditions. In fact, electric stoves generated higher mass concentrations (largely reflecting bigger PM such as $PM_{2.5}$) under some cooking conditions (Buonnano et al., 2009). The type of food used for grilling was also very important, with fatty foods producing the most particles. Additionally, cooking temperature was found to influence particle emissions for both gas and electric stoves.

A review of controlled exposure studies concluded that cooking using gas ranges produced more ultrafine PM and $PM_{2.5}$ compared to electric ranges (Torkmahalleh et al., 2017) with gas stoves producing up to 2.9-fold more $PM_{2.5}$ (based on mass concentration) compared to electric stoves, and between 1.25 to 7.57-fold more ultrafine PM (based on particle number concentration) compared to electric stoves. However, when no food was present (just the burners on), the difference in ultrafine PM was less than 2-fold. Cooking method (boiling, steaming, stewing, pan frying, deep frying, grilling, broiling, baking) influenced the particle emission rates. Oil-based methods (frying) and grilling produces greater particle concentrations compared to water-based methods (steaming and boiling). Such studies also report that the smoke temperature of the oil is correlated with PM emission rates and that the exposed surface area and oil temperature impact PM emissions. Given the well-established data on cooking emissions and other indoor air pollutants, attributing indoor air quality impacts only to natural gas appliances is not supported.

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Appendix B: Gas Appliances Have Improved

Gas appliances equipped with gas-fed pilot lights have not been manufactured since 2012 (US Department of Energy 2009, 10 CRF Part 430[1]), and thus all newer residences should have lower concentrations of NO_2, including residences using gas as a cooking energy source. NO_2 concentrations in new construction are therefore anticipated to be closer to those in households with electric stoves, and comparisons of data from older gas appliances to electric appliances from years ago are not providing accurate estimates of the (smaller) reduction in NO_2 concentrations that would occur today if one were to switch to electric stoves.

Studies which segregated their analysis of NO_2 concentrations from gas stoves into homes having gas stoves containing gas-fed pilot lights compared to gas stoves having electric ignition systems found that residences with gas stoves having electric ignition systems have markedly lowered NO_2 concentrations (Lee et al., 1998; Spengler et al., 1994). Comparisons of personal exposures of residents in Los Angeles, California households (as measured over 48 hours using personal monitors) having electric stoves with residents in households having gas stoves equipped with electric ignition systems showed only a 5-ppb difference in NO_2 exposure, while the difference was 15 ppb when residents having electric stoves were compared to residents having gas stoves equipped with gas-fed pilot lights (Spengler et al., 1994). Similarly, indoor NO_2 concentrations measured in Boston, Massachusetts households having gas stoves equipped with electric ignition systems (duration of sampling not indicated; same sampling device as Raw et al. 2004, below) were also approximately 10-ppb lower than those households with gas stoves equipped with gas-fed pilot lights (Lee et al., 1998).

While certain studies show higher NO_2 concentrations in residences with any type of gas stove (without segregating residences with stoves equipped with gas-fed pilot lights from residences with stoves equipped with electric starters) when compared NO_2 concentrations in residences with electric stoves (Raw et al., 2004; Garcia-Algar et al., 2003; Lee et al., 2000) these studies present a limited and outdated perspective of the use of gas appliances. However, even these earlier studies show NO_2 concentrations that are not considerably higher than those in residences with electric stoves. For example, in one study residences with gas stoves had a geometric mean concentration (2-week sample collection) of 22 ppb NO_2 compared to 12 ppb in residences with electric stoves (Raw et al. 2004). Another study reported that residences with gas stoves had mean concentrations (sampling duration 7-14 days) of 24 ppb NO_2, compared to 15 ppb in residences with electric stoves (Garcia-Algar et al. 2003). A third study found residence with gas stoves had a mean NO_2 concentration (2-day sampling duration) of 14 ppb, while compared to the 9 ppb mean concentration in those with electric stoves (Lee et al. 2000). When gas stoves were segregated into those equipped with gas-fed pilots and those equipped with electric starters, these differences become smaller, with residences having appliances with electric starters having measured NO_2 concentrations which are much closer to measured NO_2 concentrations in residences having electric appliances. Therefore, outdated studies from 20 or more years ago — when a greater percentage of the households had gas ranges with gas-fed pilot lights — are not the appropriate studies for predicting health risks in more contemporary residences. Unfortunately, many of the recent statements discussing gas stoves do not appear to have considered the decreases in NO_2 concentrations over time.

[1] Department of Energy. 10 CFR Part 430. Energy Conservation Program: Energy Conservation Standards for Certain Consumer Products (Dishwashers, Dehumidifiers, Microwave Ovens, and Electric and Gas Ranges and Ovens) and for Certain Commercial and Industrial Equipment (Commercial Clothes Washers) Federal Register April 8, 2009 Vol 74(6): 16040-16096.

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Appendix C: Support from Recent CEC Studies

CEC-commissioned a set of two studies that further demonstrate that ventilation of homes has improved indoor air quality, including lowering exposures to NO_2 to concentrations more comparable to residences with electric stoves. In the first study (Offermann 2009), 108 new homes in California were examined, where the overwhelming majority (98%) had electric ranges. In the second study (Chan et al., 2020), 70 homes in California were evaluated to examine the impacts of mechanical ventilation standards that were required after the 2008 California Building Energy Efficiency Standards on indoor air quality were implemented. These standards required the presence of either a venting range hood or an exhaust fan in the kitchen in new homes. Table 1 outlines the characteristics of the homes in each of the two studies.

Table 1. Comparison of Home Characteristics in the Offermann (2009) and Chan et al. (2020) Studies

	California New Home Study (CNHS) **Offermann 2009**	**Healthy Efficient New Gas Homes (HENGH)** **Chan et al. 2020**
Number of homes included in study	108	70
Characteristics of homes	Single-family detached homes Owner-occupied, primary Occupied at least 1 year Built after January 2020 No smoking in homes (3% smoke outside home)	Single-family detached homes Owner-occupied Built in or after 2011 Non-smoking participants
Electric versus gas?	Cooktops: 98% electric/ 2% gas; 85% vented to outdoors	Cooktops: 0% electric/ 100% gas cooktops
	Ovens: 73% electric/ 27% gas; 2% vented to outdoors	Ovens: 57% electric/ 43% gas (venting status not reported)
	Clothing dryers: 24% electric/ 76% gas; 98% vented to outdoors but 11% had exhaust leaks	Clothing dryer: 40% electric/ 60% gas
	Forced air units (heating/cooling): 100% gas-fired heaters	Heating systems: 99% gas / 1 % electric
	Water Heater: 2% electric/ 98% gas	Water heater: 100% gas
	Gas log fireplaces: 61% decorative (vented outdoors) / 31% sealed (vented outdoors) [remainder presumably had no fireplace]	Gas fireplace: 46% (all vented to outdoors)
Area of homes	Median area of residences: 2,703 ft^2	Median area of residences: 2,767 ft^2

	California New Home Study (CNHS) Offermann 2009	Healthy Efficient New Gas Homes (HENGH) Chan et al. 2020
Ventilation	Recruitment required at least 20 residences with mechanical ventilation. Overall, combination of: • opening windows and doors • mechanical exhaust air systems • mechanical outdoor air systems • mechanical nighttime cooling systems • occupant use of forced air unit systems • 85% cooking ranges had exhaust fans that vent to outdoors	100% had mechanical ventilation.
Sampling season	Evenly split summer/winter	23% winter; 19% spring; 39% summer; 20% fall

A comparison of results from these two studies demonstrates the improved air quality in newer residences with mandated mechanical ventilation. Median concentrations (1-week sampling duration) of formaldehyde decreased from 29 ppb to 18.2 ppb when comparing the earlier Offermann (2009) study to the later Chan et al. (2020) study. Median concentrations of $PM_{2.5}$ decreased from 10.4 ug/m^3 (24-hour sampling duration) to 5 ug/m^3 (1-week sampling duration), respectively. While the median concentration of NO_2 was slightly higher in the latter Chan et al. (2020) study (4.5 ppb [1-week sampling duration] compared to 3.2 ppb [24-hour sampling duration] in the earlier Offerman 2009 study), 100% of the homes in the 2020 study had gas ranges while only 2% of the homes in the 2009 study had gas ranges. 27% of the homes in the Offermann study had gas ovens (only 2% vented to outdoor air) compared to 43% of the homes in the Chen et al. (2020) study. The percentage of other gas appliances (heaters, water heaters, clothing dryers) was similar. Although the absolute concentration of NO_2 increased slightly in the 2020 study, the fact that the 2009 study had very few gas-fueled cooktops while the 2020 study was dominated by gas-fueled cooktops supports a conclusion that air quality for all measured pollutants improved for residences built after 2010.

Other studies support the trend of decreased NO_2 concentrations in homes in more recent years, which may be partially attributed to gas stoves switching from being equipped with gas-fed pilot lights to electronic starters, as well as other safety and efficiency improvements. For example, Belanger et al. (2006) reported an average NO_2 concentration (10-14 day sampling duration) of 25.8 ppb (48.5 µg/m^3) in homes with gas stoves that were sampled between 1997 and 1999. A later study conducted between 2006 and 2009 by the same investigators reported average NO_2 concentrations of 15.6 ppb (29.3 µg/m^3), a 60% reduction in NO_2 concentrations, in residences with gas stoves (1-month sampling duration) (Belanger et al., 2013). Note, the Belanger et al. (2006, 2013) studies were both conducted before the mandated elimination of gas-fed pilot lights which as noted above resulted in a significant decrease in NO_2 associated with gas cooking.

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Appendix D: The Recent UCLA Report Models (Rather than Measures) Indoor Air Quality, Without Any Duration, Leading to Unsupported Conclusions About Exceedances of Ambient Air Quality Standards and Resulting Health Impacts

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" (the UCLA Report; Zhu et al., 2020). This report was the basis of the conclusions cited on Slide 15 of the CARB presentation. The report sought to better understand health concerns of natural gas appliance use and attempted to analyze the health benefits of phasing out residential gas appliances in California. However, there are a number of overly simplistic (and extreme) assumptions made in the report, and the results have been improperly amplified by others citing the report. Among the more serious over-simplifications was the use of unreasonably conservative assumptions used in the modeling (i.e., ranges vented directly into the kitchen, drafting of gases from other sources into the indoor environment, use of ovens to heat the residences for 4-hour periods) to estimate unrealistic peak concentrations of NO_2. The modeled peaks were without a duration component, but nevertheless were directly compared to the US EPA 1-hour National Ambient Air Quality Standard of 100 ppb (i.e., they assumed the peaks persisted for 1-hour in duration). However, the assumption of these peaks persisting for such periods is unrealistic,[2] especially as authors cite that the entire cooking time over the course of a day is likely 1-hour *cumulative*. There is no scientific basis to compare peak concentrations, which are transient, to Ambient Air Quality Standards (which are based on 1-hour average concentrations). Accordingly, CARB's reliance on the UCLA report and its comparison of modeled peak NO_2 concentrations to the US EPA 1-hour National Ambient Air Quality Standard is unsupported and leads to misleading conclusions about health impacts.

Another use of unreasonably conservative assumptions in the UCLA report involves the stated health benefits associated with replacement of gas stoves with electric stoves. The UCLA authors estimate 354 fewer deaths, 304 fewer cases of chronic bronchitis, and 596 fewer cases of acute bronchitis if residential gas stoves were replaced by electric stoves. These estimates are based on modeling of health impacts using concentration-response functions derived from regression coefficients in epidemiological studies for PM. These concentration-response functions were not clearly identified by the UCLA authors; however, pollution concentrations measured or estimated in the studies were likely from the 1990s and earlier. None of the concentration-response functions were derived from epidemiology studies that evaluated indoor air concentrations or exposure to pollutants generated during cooking. In fact, there is substantial uncertainty around these estimates of avoided mortality and bronchitis. The UCLA authors further assume that all NO_2 generated indoors (which they overestimate, based on peak exposures) will exhaust to outdoor air, and generate PM from oxides of nitrogen (NOx).

Furthermore, the PM-related health benefits assume 100% use of renewable electricity now, which is not a reasonable assumption. In fact, in-state electricity generation from non-renewable sources will continue for the foreseeable future, and NOx, oxides of sulfur (SOx), and PM emissions from the generation of non-renewable electricity should therefore be included in any analysis of potential health benefits. CARB appears to recognize this, as they cited a report by Mahone et al. (2020) which evaluated three scenarios: High carbon dioxide removal (CDR), zero carbon energy, and balanced. Under these three scenarios, only zero carbon energy assumed 100% sales of electric appliances by 2030 and early retirement of all gas appliances by 2045. The other two scenarios did not assume early retirement of gas appliances. These

[2] "…under the assumption that exceedances of the threshold for the estimated peak concentrations only apply under a scenario where cooking occurs for an extended period of time and the air quality levels in the kitchen remain elevated for an entire hour…" (Zhu et al., 2020).

scenarios support the need to evaluate estimates of PM-associated deaths and cases of bronchitis resulting from realistic scenarios of electricity generation.

Ramboll recommends that Southern California Gas ask CARB to critically evaluate the full body of epidemiological and toxicological literature that informs indoor air quality guidelines, as well as use the same conservatism when evaluating the impacts of electric stove use compared to gas stove use, taking into account pollution originating from the generation of electricity.

References

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Appendix E: The Epidemiological Literature on the Association of Gas Stoves and Asthma is Inconsistent and Must Be Fully Evaluated

CARB, and others advocating for building electrification have relied upon the results of a meta-analysis[3] (Lin et al., 2013) that concluded that gas cooking increases the risk of childhood asthma. This meta-analysis was based on the results from 19 epidemiological studies. Other results reported by Lin et al. (2013), however, were inconsistent with this conclusion. Lin et al. (2013) did not find NO_2 to be associated with asthma (assuming that gas cooking is a surrogate for NO_2). Current and lifetime wheeze were not consistently associated with gas cooking (wheeze is a symptom of asthma) based on the results from 22 epidemiological studies. These latter results have been overlooked by people citing the Lin et al. (2013) meta-analysis.

Furthermore, the Lin meta-analysis does not include results from the International Study of Asthma and Allergies in Childhood (*ISAAC)*, a large, multinational collaborative study (Wong et al., 2013) published contemporaneously with the Lin et al. (2013) meta-analysis. In contrast to the Lin et al. (2013) meta-analysis, Wong et al. (2013) reported that asthma diagnosis, asthma symptoms, and wheeze symptoms in children were not associated with gas cooking. Given the size and global geographic distribution of participants in this study, this is an important study that contradicts the overall findings of the meta-analysis. To date, CARB has only depended upon the Lin et al. (2013) meta-analysis and has not considered the contemporaneous Wong et al. (2013) study. Both studies should be considered, as well as any additional studies published in more recent years.

Table 2 compares the characteristics and findings from each of these publications. Lin et al. (2013) reported a summary odds ratio (OR) for asthma of 1.32 (95% Confidence Interval [CI] 1.18–1.48). Wong et al. (2013) reported that there was no increased risk of asthma in 97,726 children, age 6-7 years old (OR 0.94, 95% CI 0.88–1.02). Similarly, there was no increased risk of asthma in 154,287 children age 13-14 years old (OR 0·99, 95% CI 0·93–1·05).[4]

Table 2. Comparison of Lin et al. 2013 Meta-analysis with Wong et al. 2013 Study

	Meta-Analysis (Lin et al. 2013)	**Multicenter (ISAAC) Collaborative Study (Wong et al. 2013)**
Subjects	66,380 children in 19 studies of gas cooking	512,707 children (adjusted analysis) 252,013 children (adjusted multivariate analysis)

3 A meta-analysis is a statistical procedure that combines estimates of effect from different studies.

4 An odds ratio is a measure of association between exposure and disease in two groups. An OR>1.0 means that exposure is associated with increased disease, while an OR<1.0 means exposure is associated with reduced disease. The 95% confidence interval describes a range of values for the OR that is consistent with the true association for the population, which cannot be observed but is estimated from epidemiological studies that sample from the population. The confidence interval is also used to describe the role of "chance" or random error. In the case of a 95% confidence interval that excludes 1.0, the result is considered "statistically significant." In other words, the measured association is unlikely to have occurred because of random error at a probability of 5%. When the confidence interval includes 1, this suggests that there is no real difference in risks between the exposed and comparison group. The confidence interval, however, does not address the potential role of confounding or systematic bias in epidemiological studies. Confounders are factors that travel along with the exposure and are themselves associated with disease risk. As an example, if an epidemiological study reported that gas stoves were commonly found in houses in which parents smoked cigarettes, while electric stoves were commonly found in houses in which parents did not smoke, the association between childhood asthma and gas stoves would be confounded by exposure to environmental tobacco smoke.

Table 2. Comparison of Lin et al. 2013 Meta-analysis with Wong et al. 2013 Study

	Meta-Analysis (Lin et al. 2013)	**Multicenter (ISAAC) Collaborative Study (Wong et al. 2013)**
Location	Australia (4 studies), England and Scotland (2 studies), Canada (3 studies), Germany (3 studies), The Netherlands (2 studies), Russia, Arizona, Maryland, Southern California, Washington	44 centers in 21 countries (6-7 yrs) 65 centers in 31 countries (13-14 yrs)
Study period	1972-2009 (14 studies before 2000)	1999-2004
Results	Asthma: Summary OR 1.32 (95% CI 1.18–1.48) Current wheeze: Summary OR 1.07 (95% CI 0.99–1.15)	Asthma, 6–7 yrs old: OR 0.94 (95% CI 0.88–1.02) Asthma, 13–14 yrs old: OR 0.99 (95% CI 0.93–1.05) Current wheeze, 6-7 yrs old: OR 0.96 (95% CI0.89–1.03) Current wheeze, 13-14 yrs old: OR 0.99 (95% CI 0.92–1.07)
Adjusted for	Varied by study: 4/19 (21%) did not adjust for other variables (unadjusted results) 5/19 (26%) adjusted for mold and/or dampness 4/19 (21%) adjusted for pets 10/19 (53%) adjusted for ETS	sex, region of the world, language, and gross national income, maternal education, maternal and paternal smoking, television watching, exercise, siblings (older and younger), consumption of fast food, frequency of truck traffic, and paracetamol use.

Lin et al. (2013) stated that "*residual confounding by (unmeasured) factors that are associated with gas cooking might be another explanation for our finding of an association between asthma and gas cooking, but not with indoor NO_2. However, this is not very likely as we used effect estimates from the included studies which were almost always adjusted for known determinants of childhood asthma*." However, a closer look at the 19 studies included in the Lin et al. (2013) meta-analysis finds that 4 studies (21%) did not adjust for any confounding factors, while only 53% (10/19) of the studies adjusted for environmental tobacco smoke. Therefore, residual confounding may in fact explain the potential discrepancy in the results reported by Lin et al. (2013) and Wong et al. (2013).

Only one of the studies included in the Lin et al. (2013) meta-analysis was conducted in California. McConnell et al. (2002) followed 3,535 children with no history of asthma from 1993 to 1998 in Southern California. After five years, the risk of diagnosed asthma was not significantly increased among children who lived in homes with gas stoves. In addition, the risks of asthma did not differ between children who had wheeze symptoms (relative risk 1.2, 95% CI 0.7–2.0) at entry into the cohort in 1993 and children who had no history of wheeze (relative risk 1.3, 95% CI 0.8–2.0) at entry into the cohort. In contrast, the authors reported increased risks of asthma among children in homes where humidifiers were used and in homes with furry pets. It is also important to note that the McConnell et al. (2002) cohort study evaluated the presence of gas stoves in homes based on questionnaires administered at entry into the cohort in 1993 or in 1996, when gas stoves having gas-fed pilot lights were more common.

Lin et al. (2013) also included studies from earlier years (14 of the 19 studies on gas cooking and asthma were conducted before the year 2000) where a greater proportion of residences likely had gas stoves with gas-fed pilot lights, not electric starters. Furthermore, only one of the studies included in the Lin et al. (2013) meta-analysis explicitly discussed the importance of ventilation as an unmeasured factor potentially leading to exposure misclassification (Willers et al., 2006). This exposure misclassification may have potentially biased the association between exposure to gas stoves and health in some studies; however, there was no statistically significant association between asthma and gas cooking in Willers et al. (2006), where kitchen ventilation was generally considered insufficient in houses with gas stoves. Lin et al. (2013) acknowledged the importance of ventilation when they stated *"Indoors, gas cookers can be replaced by electric cookers, and gas cooking fumes can be removed by using ventilation hoods."* The presence of other indoor pollutants, which were not taken into account in many of these studies, may also have been responsible for the asthma attributed to gas stove use.

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Appendix F: Appliance Electrification Is Not Cost-Effective

The California Air Resources Board (CARB) is proposing appliance electrification as a feasible strategy for building decarbonization in their 2022 Scoping Plan. The South Coast Air Quality Management District (SCAQMD) has considered including appliance electrification as a stationary source control measure in recent Air Quality Management Plans (AQMPs) but consistently determined that appliance electrification is not cost-effective. Therefore, it is not recommended that CARB propose appliance electrification as the sole control in its 2022 Scoping Plan building decarbonization methodology.

In preparation for release of their 2022 AQMP, SCAQMD developed the Net Emissions Analysis Tool (NEAT), which calculates the changes in NO_X emissions and costs associated with switching residential appliances to more efficient technologies (SCAQMD 2019). These more efficient technologies include both high-efficiency natural gas appliances and electric alternatives. NEAT relies on data reported in the 2009 Residential Appliance Saturation Survey (RASS) and is intended to model California's South Coast Air Basin in particular. However, the NEAT model does not account for several key costs associated with a transition to mass electrification, including costs for home electric panel upgrades and grid infrastructure upgrades. Additionally, while NEAT does contain estimates of greenhouse gas (GHG) emission changes and GHG cost-effectiveness, it does not contain the functionality to evaluate lower-carbon fuel options that can help decarbonize California. Finally, NEAT does not consider the need for backup diesel generation for residences with a high degree of appliance electrification that are located in areas prone to public safety power shutoff (PSPS) events. Operation of these generators could produce NO_x emissions that offset the benefits gained by switching to electric appliances.

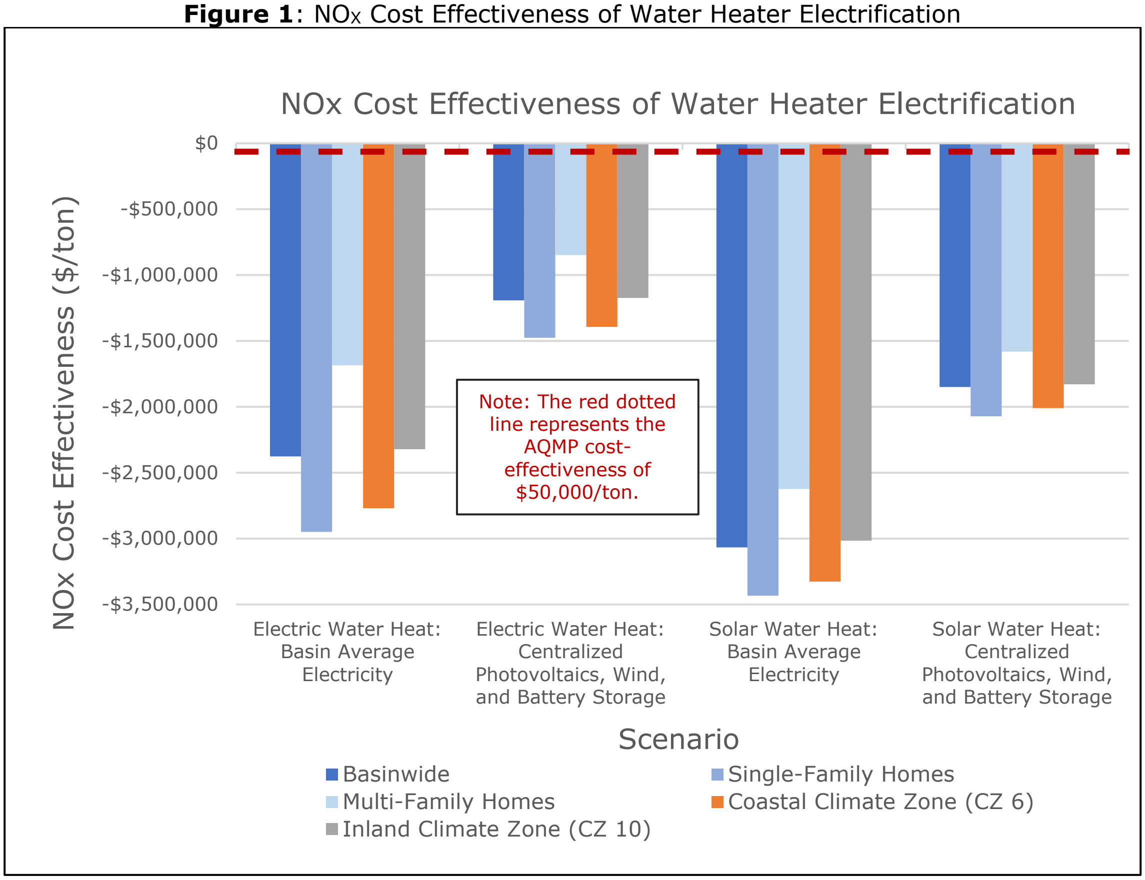
In the 2016 AQMP, SCAQMD proposed control measure CMB-02, "Emission Reductions from Replacement with Zero or Near-Zero Appliances in Commercial and Residential Applications," which looked at a variety of lower emission combustion technologies (SCAQMD 2017). This measure relies upon increased regulation for commercial furnaces used for space heating and additional regulations and incentives to replace commercial and residential natural gas appliances with new zero or near-zero technologies in order to reduce basin NO_X emissions. Electrification is incentivized, but not required as part of this measure. SCAQMD also suggests increased regulation of residential water and space heaters in order to meet the emissions reductions goals outlined in the AQMP. Overall, SCAQMD estimates that this control measure will cost \$15,000 to \$30,000 per ton of NO_X reduced.

We ran NEAT version 1.11 Beta[5] to evaluate the cost-effectiveness of switching residential water and space heating appliances from natural gas to electric equivalents. Ramboll's NEAT model runs demonstrate that appliance electrification for space and water heaters in the South Coast Air Basin would be significantly less cost-effective than the 2016 AQMP cost-effectiveness threshold of \$50,000 per ton NO_x reduced. For water heaters, the model was used to evaluate four scenarios which assumed that the conventional natural gas water heaters were replaced with electric water heaters or solar water heaters that utilize electricity as the backup power option. These scenarios were modeled using two different assumptions for electricity used to power the electric/solar water heaters: (1) basin-averaged electricity, and (2) renewable electricity from centralized photovoltaics, wind energy, and battery storage. Additionally, NEAT divided the model's cost-effectiveness results into five main categories. These included results for single-family homes and multi-family homes across the basin, as well as all homes in the Inland and Coastal climate zones within the basin. The cost-effectiveness for water heater electrification

5 Ramboll and SoCalGas have submitted comment letters to South Coast AQMD dated December 4, 2020 and January 7, 2021 noting bugs within the model, outdated model inputs, inaccurate cost data, and inconsistent emissions assumptions within the NEAT model. We note that SCAQMD has not released an updated version of the model at the time of this writing.

across all homes in the South Coast Air Basin (dark blue bars in **Figure 1**) ranged between $1,200,000 and $3,100,000 per ton of NO_x reduced. These values are twenty-four to sixty-two times less cost-effective than the AQMP cost-effectiveness of $50,000 per ton of NO_x. NEAT reports cost-effectiveness in terms of incremental cost divided by the change in emissions from appliance electrification. This approach is different from the conventional way that cost-effectiveness results are presented, which is incremental costs divided by a reduction in emissions. Thus, within the NEAT tool, a more positive (less negative) value implies greater cost-effectiveness.

Figure 1: NO_X Cost Effectiveness of Water Heater Electrification



Similarly, we ran NEAT to estimate the costs of switching natural gas space heaters to electric space heaters. As before, it was assumed that the electric space heaters were powered using basin-averaged electricity or using renewable electricity from centralized photovoltaics, wind energy, and battery storage. The model estimated that these upgrades could cost $360,000-$460,000 on average per ton of NO_x reduced, as shown in **Figure 2**, below. These values are seven to nine times less cost-effective than the SCAQMD cost-effectiveness of $50,000 per ton of NO_X.

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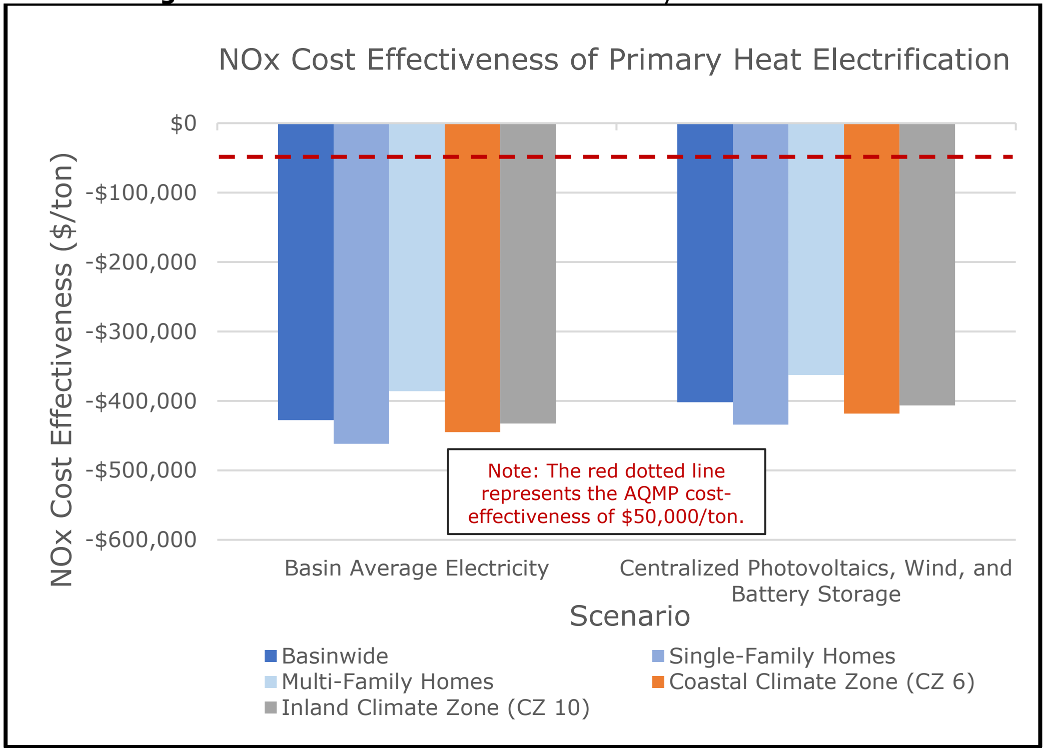
Figure 2: NO_X Cost Effectiveness of Primary Heat Electrification



Overall, the NEAT model results show that appliance electrification is not a cost-effective measure to achieve building decarbonization. Further as noted previously, the NEAT tool does not include several key cost components (panel and grid upgrades) and potential sources of emissions associated with appliance electrification (such as backup generators), which may make appliance electrification even less cost-effective. Additional feasibility concerns indicate that electrification may also be impractical for many residences in the South Coast Air Basin and throughout California. SCAQMD has refrained from mandating appliance electrification in their AQMPs due to concerns with cost-effectiveness.

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