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Abstract

This report presents results from the first year of a two-year study, investigating associations of five air pollutants (CO, NO_2, NO_X, formaldehyde and acetaldehyde) with the presence of natural gas appliances in California homes. From November 2011 to March 2012, pollutant concentration and occupant activity data were collected in 155 homes for 6-day periods. The sample population included both single-family (68%) and multi-family (32%) dwellings, with 87% having at least one gas appliance and 77% having an unvented gas cooking appliance. The geometric mean (GM) NO_2 levels measured in the kitchen, bedroom and outside of homes were similar at values of 15, 12 and 11 ppb, respectively. In contrast, the GM NO_X levels measured in the kitchen and bedroom of homes were much higher than levels measured outdoors, at levels of 42 and 41 ppb, compared to 19 ppb, respectively. Roughly 10% of sampled homes had 6-day average NO_2 levels that exceeded the outdoor annual average limit set by the California Ambient Air Quality Standards (CAAQS) (30 ppb). The GMs of the highest 1-h and 8-h CO level measured in homes were 2.5 and 1.1 ppm, respectively. Four homes had a 1-h or 8-h concentration that exceeded the outdoor limits set by the CAAQS. The GM formaldehyde and acetaldehyde concentrations measured in homes were 15 and 7 ppb, respectively. Roughly 95% of homes had average formaldehyde levels indoors that exceeded the Chronic Reference Exposure Level set by the California EPA (7 ppb). Concentrations of NO_2 and NO_X, and to a lesser extent CO were associated with use of gas appliances, particularly unvented gas cooking appliances. Based on first principles, it is expected that effective venting of cooking pollutant emissions at the source will lead to a reduction of pollutant concentrations. However, no statistical association was detected between kitchen exhaust fan use and pollutant concentrations in homes in this study where gas cooking occurred frequently. The lack of statistical association between kitchen venting and pollutant concentrations may have been due to mischaracterization of whether or not range hoods were exhausting to the outdoors or were functioning properly, or due to a low capture efficiency of the range hood resulting from the predominant use of front cooktop burners by participants in this study.

Contents

1. Introduction

Combustion exhaust from gas appliances in residences can under some conditions produce hazardous levels of indoor air pollutants in the living space. Typical gas appliances in homes include cooking ranges, furnaces and water heaters. The most common gas appliance fuel in California is natural gas, followed by a small percentage of appliances powered by propane (CEC, 2009). Pollutants generated by gas appliances include carbon monoxide (CO), nitrogen oxides (NO_X) and aldehydes. Short-term exposures to high concentrations of CO can be potentially fatal. CO alarms, which are mandatory in California, are intended to protect residents from acute and potentially fatal CO exposures; however, CO alarms do not detect low-level exposures. Long-term exposures to low levels of CO have been linked to flu-like symptoms (Penney, 2000; Hampson, 2000; Comstock, 1999), and may be misdiagnosed as chronic fatigue syndrome (Knobeloch and Jackson, 1999). Long-term residential exposures of children to elevated levels of NO_2 have been linked to respiratory symptoms, such as persistent cough, wheeze and shortness of breath (Neas et al., 1991; van Strien et al., 2004). An increase in respiratory symptoms among asthmatics has been found to be associated with long-term exposures to both formaldehyde (Garrett et al. 1999; Norback et al., 1995; Krzyzanowski et al.,1990; Delfino et al., 2003) and acetaldehyde (Delfino et al., 2003). Both formaldehyde and acetaldehyde have been classified by the US Environmental Protection Agency as possible carcinogens (USEPA 1999a, 1999b). Past studies have established that pollutants generated by residential gas appliances can reach levels in homes that exceed outdoor standards (Franklin et al., 2006; Ng et al., 2001; Hansel et al., 2008; Miller et al., 2009), yet there is a dearth of data that would allow an assessment of the current frequency of such occurrences among California residents. There is also a need to understand the relative importance today of factors found or thought in the past to impact indoor concentrations of combustion-generated pollutants.

For residential combustion appliances to adversely impact indoor air quality, two processes are required: (1) pollutant formation, and (2) entry of pollutants into the air in the occupied part of the home. Most combustion appliances exhaust directly to outdoors. However, pollutants produced during combustion can enter the indoor air space in several ways: from appliances that do not exhaust directly outdoors by design, such as most cooking burners and some decorative or portable heating devices; from leaks associated with broken vents, cracked heat exchangers, or cracked or disconnected flue connections; or from home depressurization interfering with atmospheric venting systems.

Impacts of natural gas appliances (or any other source) on indoor air quality can be assessed with fundamental-physical or empirical–statistical approaches. The fundamental approach considers the physical factors that are known or expected to influence pollutant concentrations indoors. The relationship between these physical factors is described by the mass-balance equation shown below (equation 1.1), which assumes that the air within the space is well-mixed.

$$\frac{dC_I}{dt} = \frac{E_i n_i}{V} + C_O\lambda - C_I(\lambda + k) \tag{1.1}$$

The factors affecting the indoor concentration (C_I) include the following: pollutant emission rate of appliance i (E_i), total duration of use of appliance i (n_i), and the mass emission rates during events ($E_i n_i/V$); the outdoor concentration (C_O) which contributes to indoor levels via air-exchange (λ) into the house; transformation and loss mechanisms indoors, which may include deposition to surfaces (k) and removal by air exchange to the outdoors (λ); and the volume of the space (V). This equation does not include emissions from other possible indoor sources, and treats deposition as a first order removal process (i.e., it does not account for an adsorption-desorption process). In addition, the equation does not include removal or generation of pollutants by chemical reactions. Reactions with ozone (O_3) may be an important sink for nitrogen oxide (NO) and an important source of NO_2. However, according to centrally monitored data provided by the California Air Resources Board (www.arb.ca.gov/adam), the average from November 2011 to March 2012 of the highest daily average O_3 concentration measured at any site in Alameda County was 21 ppb. Using this conservatively high outdoor O_3 concentration and assuming an air-exchange rate of 1 h^{-1} and an indoor O_3 deposition rate of 3.8 h^{-1} (Weschler et al.,1989), the steady state indoor O_3 concentration in a well-mixed home would be roughly 4.4 ppb. Since the mean NO_X level measured in homes was 10 times this value, and stoichiometry dictates that O_3 and NO react at a one-to-one ratio, indoor O_3 levels during our study are likely to have had a modest affect on the indoor concentrations of NO and NO_2.

The empirical–statistical approach to understanding impacts of residential appliances on indoor air quality involves measuring pollutant concentrations and characterizing physical factors in a large sample of homes, from which statistical correlations can be identified and used to extrapolate to the larger population. These two approaches are complementary, as results from an empirical assessment help to validate predictions from fundamental assessments or to identify physical processes not being accounted for, and knowledge based on physical parameters helps to guide the design of empirical–statistical assessments.

The broad goal of the study presented herein was to assess the relative influence of several factors on occupants' exposures to unvented combustion gases in homes in California, using both statistical and physical approaches. This was accomplished by measuring the concentrations of CO, NO_X, NO_2, formaldehyde and acetaldehyde over 6-day periods in 155 California homes, by either mailing air quality sampling materials to participants or having a researcher visit and deploy samplers. Information regarding physical characteristics of the home and household activities relevant to indoor air quality was collected via two participant surveys administered before and after the sampling period, and a home characterization protocol administered by researchers at homes that were visited.

Homes were selected for this study based on resident responses to a screening survey. Homes with characteristics expected to result in elevated pollutant concentrations based on physical considerations were disproportionately selected for participation, in order to characterize the extent to which pollutant concentrations reach levels of concern in homes that are anticipated to be the most affected. Associations between suspected risk factors and elevated pollutant concentrations were investigated using statistical methods. The measurements were also intended to enable estimation of gas appliance related pollutant exposures across the California population.

This is a 2-year study. This report presents summary statistics and tests of statistical hypotheses from data collected in the first year of the study. Results from the second year of data collection will be reported at a later date. In total, these results will assist with assessment of potential health hazards associated with gas appliance emissions by providing data from a broad spectrum of California homes.

2. Methods

2.1 Recruitment, Selection and Course of Interactions with Participants

Recruitment

Information about the study was distributed through a website, flyers, postings to organizational list-serves, contacts in groups or organizations that shared information about the study with members or associates, and word-of-mouth referrals to the project website. Phone calls were also made to 5 churches in 3 cities. Outreach to high-performance homeowners was accomplished by working through the networks of building contractors and residential energy research groups. E-mails were sent to 28 neighborhood associations in 7 cities, 13 student associations at 6 universities, 5 religious groups in 3 cities, 4 professors at 3 community colleges, and 5 local and regional non-profit organizations. Both physical and electronic announcements included a link to the project website that provided an overview of the study and information about how to become a participant. When individuals were contacted for outreach purposes, they were asked to refer others to the website or distribute flyers; no individual was contacted for the purpose of direct recruitment. We did not track the forwarding of information and no compensation was offered or awarded to anyone for sharing information about the study. Since participants were selected on a rolling basis, individuals who participated early in the sampling period were encouraged to refer friends and family to the informational website. Although members of the Indoor Environment and Residential Building Systems research groups were not eligible to participate, they were encouraged to publicize the informational website among potentially interested contacts and associates.

Selection

Individuals interested in participating were directed to complete a screening survey by either going to the project website or calling the research study director. Ultimately, 248 screening surveys were completed—243 through the website and 5 over the phone. The methodology used to select homes was designed such that homes with characteristics expected to cause higher pollutant concentrations would be oversampled. The screening survey was used to identify factors that increase the likelihood and magnitude of pollutants entering the home from gas appliance use. Responses to the screening survey were used to give homes a "risk score" based on a rating system designed by researchers to provide a rough comparison of the risk of elevated combustion pollutant concentrations in homes (Table 2.1). Points were assigned to a home based on the presence and use of any unvented gas heaters, presence and use of gas cooking appliances (which were assumed to release some fraction of their exhaust into the home), and the location and use of gas heaters or water heaters within the home (indicating the possibility of backdrafting and spillage). The point sum was increased by a multiplicative factor for those homes that were smaller, newer, or had been recently weatherized, since homes with these characteristics are expected to have higher indoor concentrations for any given rate of indoor emissions. The multiplicative factor was increased for lower income households, on the premise that they are more likely to have lower quality appliances and to continue to use appliances even after performance degrades.

Table 2.1. Algorithm for determining a “risk score” used to evaluate the likelihood of elevated pollutant concentrations resulting from gas appliance use.

Points for gas cooking appliances based on amount of use				
	<1x / week	1-3x / week	4-7x / week	>7x / week
Cooktop	1	1.5	2	3
Oven	1	1.5	2	3
Points for primary gas heater (evaluate per appliance).				
Unvented heater [a] in living space	2			
Unvented heater in adjacent space [b]	0.5			
Vented gas heater in living space	1			
Vented gas heater in adjacent space [b]	0.5			
Points for supplementary gas heater based on amount of use (evaluate per appliance).				
	<few x / wk	few x / wk	few x / day	
Unvented heater in living space	1	2	3	
Unvented heater in adjacent space [b]	-	1	2	
Vented gas heater in living space	-	1	1.5	
Vented gas heater in adjacent space [b]	-	0.5	1	
Points for gas storage water heater per number of residents (evaluate per appliance)				
	1-2 people	3-4 people	5+ people	
Vented water heater in living space	0.5	1	1.5	
Vented water heater in adjacent space [b]	-	0.5	1	
Multiplier for other household characteristics (*Sum points for categories below, add 1, then multiply by sum of points from above*)				
Year home was built	< 1995 -	1995-2005 0.1	> 2005 0.2	
Size of home (square feet)	< 500 0.3	500-1000 0.2	1000-1500 0.1	>1500 -
Household gross income ($1000/year)	< 30 0.3	30-60 0.1	>60 -	
Weatherization renovations	No -	Yes 0.2		

[a] Included use of gas oven for space heating.
[b] Adjacent space” includes attic, basement or attached garage.

Interactions with participants

Screening survey respondents whose homes were selected for sampling were contacted by telephone approximately two weeks prior to the planned week of sampling. At this time, we confirmed availability for participation during the planned week of sampling, obtained informed consent, and settled on the method of sampler deployment at the home. Samplers were deployed in homes using one of two methods. The first method was to mail the sampling packages to the home and provide instructions for the participant to set them up. The second method was to have a researcher visit the home to set up the samplers. For the first year of sampling, researcher visits were focused on “high-performance green” homes that had been built or extensively renovated with the goal of substantially increasing energy efficiency and improving indoor air quality.

In the case of the homes to which samplers were mailed, the participants were called one week prior to the sampling period to complete a 30-minute phone interview and to discuss the best method for mailing the package. The samplers were mailed in a 9.5 inch by 12.5 -13 inch padded envelope, enclosed in an outer 12.5 inch by 15 inch Tyvek® envelope. The participants were instructed to discard the outer envelope, and use the inner padded envelope to mail the materials back at the end of the sampling period. Participants were given the option of having the samplers delivered and returned via the US Postal Service or FedEx, depending on which option was most convenient for them. Participants were asked to set up the samplers within one day of their arrival using detailed instructions that were provided to them (Appendix A). Individuals who had trouble setting up the samplers were instructed to call one of the researchers to have the set-up process described over the phone. Participants recorded the set-up and repackaging time on the provided instruction sheet, which they included in the return mailer. Following set-up, they were asked to take two photos of the samplers at each location—one showing the samplers up close and another showing the sampler placement in the room—and transmit the photos electronically (i.e. via email or text message) to the research study director so that correct placement could be confirmed. Once set up, the samplers remained in place for 6 days, during which time no action was required of the participants. Near the end of the 6-days, an email was sent to the participants to remind them to repackage the samplers using the provided instructions and to schedule a time for a final 10-minute phone interview. The completion of the final phone interview marked the end of an individual's participation. One to three months following completion, participants were sent $75 and a report of results from their home. A template of the report sent to participants is provided in Appendix B.

For homes that researchers visited, the 30-minute interview was administered either over the phone or in-person during the first visit. The first visit lasted 1.5 to 2 hours, and included both the set-up of sampling materials and the administering of a home characterization protocol, which is described in more detail in the following section. The second visit lasted 1 to 1.5 hours; it included repackaging of sampling materials, and in some cases also included the final interview. In other cases, the final interview was administered over the phone 1-3 days following the end of the sampling period. Participants of homes that were visited received the same incentive payment and final report as those who received samplers via mail.

Data Collection

Sampling commenced in late November 2011 and ended in mid-April 2012. During that time, 6 to 11 homes were sampled every week, with the exclusion of three weeks during the winter holidays. Data collection included the following: time-resolved measurement of pollutants, environmental parameters and appliance use; time-integrated measurement of pollutants; participant survey about the home, appliances and occupant activities; and for homes that were visited, researcher inspection of the home and appliances. Pollutant concentrations and environmental parameters were measured in a bedroom and kitchen at every home, and outdoors at a subset of homes. A summary of the measured parameters is provided in Table 2.2

Table 2.2 Summary of pollutant and environmental monitoring instruments used in study

Parameter	Manufacturer, model	Data resolution	Location of deployment
Measured at ALL homes			
Aldehydes [a]	Waters, Sep-Pak XPoSure	Time integrated	Bedroom, kitchen, outdoors
NO_X, NO_2 [a]	Ogawa NO_X/NO_2 sampler	Time integrated	Bedroom, kitchen, outdoors
CO (ambient)	Lascar, USB-EL-CO300	1-minute	Kitchen
T, RH (indoors)	HOBO, U10	1-minute	Bedroom, kitchen,
Furnace operation (indicated by T)	HOBO, U10	1-minute	Furnace supply register
Water heater operation (T)	HOBO, U12-014	1-minute	Water heater exhaust flue
Water heater spillage (T)	HOBO, U12-014	1-minute	Top of water heater, adjacent to draft hood
T, RH (outdoors) [a]	HOBO, U23 Pro v.2	1-minute	Outdoors
Measured ONLY at visited homes			
Particle number	Dylos, DC1700	1-minute	Kitchen
CO_2	Extech, CO_2 SD800	1-minute	Bedroom
Particle number [b]	TSI P-Track	1-minute	Kitchen
Burner exhaust CO, air-free [b]	Testo, 327	1-second	Water heater and furnace flue

[a] Outdoor sampling occurred at a subset of homes.
[b] Air-free CO and particle number measurements with the P-Track were made as part of the house characterization protocol at the visited homes, and were not conducted for the duration of sampling at those homes.

Indoor sampling

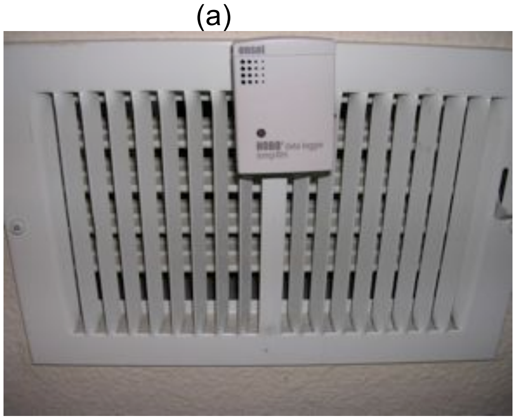
Sampling packages were deployed in the kitchen and bedroom of every home measuring the following parameters: nitrogen dioxide (NO_2), nitrogen oxides (NO_X), formaldehyde (HCHO), acetaldehyde (CH_3CHO), temperature (T) and relative humidity (RH). Carbon monoxide (CO) was measured only in the kitchen of every home. The kitchen samplers were placed in a location that would not inconvenience the residents, and that was ideally at least 3 feet from the cooktop and oven, 6 feet from exterior doors and windows that are frequently opened and 2 feet from the floor and ceiling. However, in some cases, particularly in smaller kitchens, not all of the criteria were achieved. In households with children under the age of 18, participants were asked to place the second set of samplers in the bedroom of one of their children, ideally the youngest. They were given the option of locating samplers in another bedroom but in all cases participants chose to locate the samplers in the child's bedroom. In homes without children, samplers were placed in the bedroom of the head of household. The requested siting for bedroom samplers was on a surface that had not been recently lacquered, painted or refinished, that was convenient to the residents, and that was at least 6 feet from exterior doors and windows that were frequently opened and 2 feet from the floor and ceiling.

Furnace and water heater operation were monitored to assist with determining whether use of these appliances corresponded with changes in the CO concentration. Furnace operation was monitored by deploying a thermistor (HOBO U10) on one of the supply registers. Water heater operation was monitored using a data logger that included an internal thermistor (HOBO U12) and attached thermocouple (Omega Engineering KMQXL-125E-6). The device was mounted on the top of the water heater so that the tip of the thermocouple was placed in the center of the exhaust flue, with the intention that the thermistor be far enough from the draft hood to avoid large temperature increases when the appliance was venting properly. The thermocouple monitored operation of the water heater's main burner, and the thermistor placed outside the perimeter of the draft hood was intended to identify instances of spillage of hot exhaust gases. Spillage was identified by visually inspecting temperature traces to identify any instances when spikes in the exhaust temperature (measured by thermocouple) were followed by spikes in the temperature outside of the perimeter of the draft hood (measured by thermistor). Pictures of samplers set-up in the kitchen, bedroom, furnace and water heater of one home are shown in Figure 2.1.

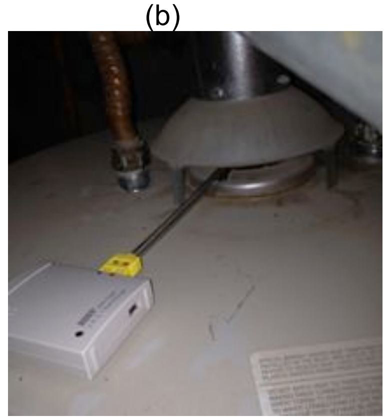
Information regarding characteristics of the samplers and loggers deployed in each home is summarized in Table 2.2.

(a)

(b)



(c)



(d)

Figure 2.1. Example placement of (a) bedroom samplers (Note: temperature sensor is on the back of the tin), (b) kitchen samplers mounted on the refrigerator, (c) furnace sensor, (d) water heater sensor. Samplers/sensors were deployed and photographed by participants.

Outdoor sampling

The following parameters were measured outdoors: nitrogen dioxide (NO_2), nitrogen oxides (NO_X), formaldehyde (HCHO), acetaldehyde (CH_3CHO), temperature (T) and relative humidity (RH). Outdoor sampling occurred at a minimum of one home that was considered representative of the cluster of homes sampled each week. This resulted in 1 to 4 outdoor samples being collected each week. Effort was made to select homes in as few clusters as possible to minimize the number of outdoor samples needed each week. The main criteria for outdoor sampler placement were (1) a location that could easily and safely be accessed by the participant and (2) a location at which the samplers would not be at significant risk of disturbance (vandalism or exploration). As a result, outdoor sampling generally occurred at single-family homes with back yards or apartments with private balconies. Pictures of sampling packages set-up outdoors at two homes are shown in Figure 2.2. Outdoor samplers were deployed in closed tins with vent holes to provide protection from outdoor elements; thus, the samplers themselves are not visible from the pictures.

Figure 2.2. Pictures of outdoor sampler placement at two homes.

Additional data collected at visited homes
At homes visited by researchers, the following additional sampling was conducted. A home characterization protocol was administered that included assessment of the following: home size and layout; appliance technology, age, level of maintenance, and location within the home; presence and location of other possible pollutant sources in the home (e.g. candles, incense); and presence and type of exhaust, ventilation and/or filtration systems. The home characterization protocol included two methods for characterizing pollutant emissions from gas appliances. The first method involved measuring air-free CO in the flue of vented appliances using a combustion gas analyzer (Testo 327, Testo USA, Inc.). The second involved a test of pollutant concentrations generated by the gas-cooking appliance. The test was conducted by using two cooktop burners at 75% power to heat pots filled with water for 5 minutes, then alternating to the other two burners for 5 minutes, followed by 5 minute use of the oven and then broiler burner, with concurrent time-resolved measurement of particle number (PN), CO and CO_2 in the kitchen. Finally, the home characterization protocol included the measurement of sound levels produced by the kitchen exhaust fan at each fan setting, when a fan was present. Carbon dioxide (CO_2) concentrations were measured in the bedroom of all visited homes for the duration of sampling at that home. At the majority of visited homes, particle number concentrations were measured in the kitchen, and two VOC absorption tubes were placed indoors and one was placed outdoors of the home, and small devices were installed to emit small amounts of a harmless chemical (hexafluorobenzene) to allow for the determination of air exchange rate. A summary of all the pollutant and environmental monitoring instruments used in this study is provided in Table 2.2.

Participant interviews
The pre-measurement interview was designed to collect information regarding the following: home age, size and degree of air-tightness; gas appliance technology, age, location, condition and frequency of use; presence of electric cooktop, oven, water heater and/or space heating

equipment (in place of gas); presence of other pollutant sources inside and outside of the home; and household demographics. In the case of homes where samplers were mailed, the interview provided key information about the home and appliances that would not otherwise be obtained. In the case of the visited homes, information collected by the researcher during the visit could be compared to that collected from the participant during the interview to check the accuracy of participant responses. The post-measurement interview was designed to characterize the activities of the home during the sampling period, including the following: frequency of use of the appliances, occupancy patterns, and use of other potential pollutant sources inside and outside of the home. Questions that might affect resident behavior were saved for the final interview. These included questions about frequency of kitchen exhaust fan use, reasons why the kitchen exhaust fan was not used (if applicable), and condition of the stovetop and oven (flame quality, operational problems etc.). The screening, initial and final interview questions are provided in Appendix C.

2.2 Sample Handling and Quality Assurance (QA) Procedures

Sample handling

A regular schedule for sampler preparation, deployment and processing was maintained throughout the sampling period. Prior to deployment, aldehyde cartridges were stored in a refrigerator until the morning of shipment. The NO_X/NO_2 samplers were generally built on the preceding Friday, and stored at room temperature in airtight bags. Packages were mailed to participants on Monday morning, and were usually received by Tuesday and rarely later than Wednesday. Participants were asked to set up the samplers as soon as possible, ideally within 24 hours, and to then repackage them six days later. Thus, participants who set up the samplers on Tuesday evening, which was most often the case, were asked to repackage them on the following Monday evening and mail them back Tuesday morning. The majority of returned packages were received at the lab on Wednesday or Thursday, though it was not uncommon to receive one or two packages on Friday. Within 24 hours of their arrival, packages were opened and their contents inventoried. Besides ensuring that all the sampling materials had been returned, the inventory also included checking that all of the airtight bags were well sealed and that the correct sensor IDs had been recorded for each home.

Following the inventory, aldehyde cartridges were stored in a freezer at -20 ºC and NO_X/NO_2 samplers in a laboratory at room temperature to await analysis. Data loggers were downloaded within a few days of their arrival, and were launched for deployment at the next set of sites. NO_X/NO_2 and aldehyde samplers were extracted within 1 week of their arrival, and were chromatographically analyzed within 1 week of extraction. According to information published by the manufacturers, exposed NO_X/NO_2 samples can be stored for 2-3 weeks and extracted samples can be stored for 90 days.[1] Exposed aldehyde samplers can be stored for 2 weeks and extracted samples are stable for up to 1 month.[2] Aldehyde sample extracts were analyzed in a high-performance liquid chromatography (HPLC) system and NO_X/NO_2 extracts were analyzed in an ion chromatography (IC) system, per procedures provided by Waters Inc. and Ogawa & Co. Inc., respectively. Formaldehyde and acetaldehyde mass values output by the HPLC were converted to concentrations using the duration of deployment and the passive sampling rates determined in validation experiments described later in this report. NO_2 and NO mass values output by the IC were converted to concentrations based on the algorithm described by Ogawa & Co. Inc., using the measured T and RH and the noted sampling duration. The Ogawa NO_X

[1] www.ogawausa.com/pdfs/prono-noxno2so206.pdfz
[2] www.waters.com/webassets/cms/support/docs/wat047204.pdf

samplers have been validated by Singer et al. (2004). At homes where T and RH data were not available for the kitchen or bedroom (<10%), a value was approximated based on the measurement made in the other location at that home. In cases where there was no outdoor T and RH data, a value was acquired using centrally monitored weather data.

Quality assurance

The following procedures were used to calculate the Minimum Detection Limits (MDL) and Limits of Quantification (LOQ) for formaldehyde, acetaldehyde, NO_2 and $NO_{x,}$ based on analytical methods. The MDL was calculated by taking the standard deviation of 7 samples of the same certified standard, and multiplying it by the students' t-value corresponding to a 99% confidence level and a standard deviation estimate with n-1 degrees of freedom, according to US EPA procedure (Title 40 Code of Federal Regulations Part 136, Appendix B, revision 1.11). The LOQ was calculated as 10 times the standard deviation of the 7 analyzed standard samples. Certified standards of 100 μg/L nitrite and nitrate, and of 8.79×10^{-3} μg/L formaldehyde and acetaldehyde were use for the analysis. This analysis was performed mid-way through the data collection period. Excluding field blanks, one formaldehyde sample (outdoor) and one NO_2 sample (bedroom) were below the LOQ. The results for these samples were replaced with a value of 0.5 LOQ.

The following procedures were used to minimize and assess the frequency of contamination of the time-integrated samples. Prior to deployment, all parts of the Ogawa NO_X samplers were cleaned with deionized water and air-dried in a laboratory free of combustion sources; they were assembled and placed into sealable envelopes on the Friday before shipping out to participants. The aldehyde samplers required no assembly. They were transported to the participating homes in the individual airtight bags in which they were sent by the manufacturer. The seal on each airtight bag was checked upon receiving the returned samplers from the participants. The end caps on the aldehyde samplers provided a second level of protection from contamination in both directions. Contamination in the field was assessed by deploying duplicate and blank NO_X/NO_2 and aldehyde samplers at 1 to 3 homes every week, for a total of 30 duplicates and 35 blanks for each type of sampler. Homes that received duplicate or blank samplers received one for each type of pollutant (i.e. NO_X/NO_2 and formaldehyde/acetaldehyde); however, no home received a set of both blank and duplicate samplers. Residents were instructed to deploy duplicate samplers in the bedroom and to keep field blanks in their airtight bags for the duration of the sampling period. Prior to mailing back the sampling package, they were instructed to open the bags of the field blanks, and remove the sampler for 10 seconds before replacing and resealing. This last step was intended to asses how commonly substantial contamination occurred in transit, due to an improperly sealed bag. The average concentration measured by the blank NO_X and NO_2 samplers was 11% greater than the LOQ. The averages measured by the blank formaldehyde and acetaldehyde samplers were 18% and 64% greater, respectively, than the corresponding LOQ. The average relative deviations for all pairs of NO_X, NO_2, formaldehyde and acetaldehyde duplicate samples were 4%, 6%, 5% and 6%, respectively.

The following procedures were used to assure quality in the analysis of time-integrated samples. Analytical blanks were included with every batch of samples run through the ion chromatography (IC) or high-performance liquid chromatography (HPLC) systems. For the IC analysis, a blank was included after every 5 samples to ensure that there was no carry-over contamination. Certified standards were purchased for each instrument. Target analytes were identified and measured by comparison to these standards. For the IC, a full calibration series was included with each set of samples analyzed. For the HPLC, one continuing calibration standard was included with each set of samples analyzed. A multipoint calibration series was run every 6 months on the HPLC system. Sample extracts were saved and rerun on occasion, either to confirm unusual results or to test the error introduced by a delay in the analysis of extracts.

The following procedures were used to assure quality of data from continuous monitors. During the data collection phase, CO sensors were calibrated roughly every 2 weeks, and the CO_2 sensors were calibrated roughly every month. The CO calibration involved exposing 6 to 10 sensors to concentrations of roughly 0, 25 and 50 ppm in a 3.8 L chamber. The CO_2 calibration involved exposing 6 to 7 sensors to concentrations of roughly 500, 1250, and 2500 ppm in an 18.9 L chamber. The calibration spans were achieved by titrating CO and CO_2 concentrations of 0.1% and 10%, respectively, with ultra zero air using a Dynacalibrator (Valco Instruments Co. Inc., Model 760). The precise span level was calculated by measuring the flow rate of each gas at the beginning and end of the exposure period. For the CO loggers, an intercept adjustment was calculated based on the loggers response at zero and a slope was calculated from a best-fit linear regression of the logger's response to the 3 tested spans. For the CO_2 loggers, both the slope and intercept were calculated from a best-fit linear regression. In November 2011, prior to the start of data collection, the CO data loggers exhibited a mean $\pm$ one standard deviation slope and intercept (calculated across loggers) of 1.09 ± 0.02 and -0.02 ± 0.05 ppm, respectively, and the CO_2 loggers exhibited a mean slope and intercept (calculated across loggers) of 1.34 ± 0.01 and -99 ± 12 ppm, respectively. In April 2012, at the completion of data collection, the CO data loggers exhibited a mean slope and intercept of 1.12 ± 0.05 and -0.19 ± 0.39 ppm, respectively, and the CO_2 loggers exhibited a mean slope and intercept of 1.24 ± 0.03 and -148 ± 59 ppm, respectively. Data collected at each home were adjusted using an average of the slope and intercept calculated from the calibration experiment that took place immediately before and after the sampling period at that home. For the one home where CO readings were high but highly irregular, the participant was offered and accepted the opportunity to do a second week of CO monitoring. Results from the second CO logger indicated that the first logger had been malfunctioning.

The following procedure was used to confirm that samples and monitors from different locations within the homes were accurately tracked. NO_X/NO_2 holders were labeled, and upon return, were checked to ensure that residents had put samples into the bag correctly labeled for its location of deployment. The same was not done for the aldehyde samplers, due to the sampler configuration. However, the NO_X/NO_2 holders were found switched at only 1 of the 127 homes to which samplers were mailed; therefore, the switching of samplers between the bedroom and kitchen is not suspected to have been a significant source of error. The ID numbers of data loggers intended for deployment at each location in homes were recorded prior to departing the lab. At homes to which samplers were mailed, returned packages were inventoried and the records were checked to confirm that the correct ID numbers had been recorded. At homes that were visited, the ID numbers on loggers deployed at each location were recoded during the first visit, after deployment, and confirmed during the second visit, prior to packaging.

We intended to test the accuracy of participant responses to interview questions by comparing information provided by participants in the initial interview with observations made by researchers at the homes that were visited. The data collected in the first year of the study were not suitable for this validation check for two reasons. First, the majority of visited homes in the first year were "high performance" homes. Study participants living in these homes generally were more interested and knowledgeable than the typical homeowner about appliances and building mechanical systems in their home than was characteristic of the residents of conventional homes. Consequently, a test of the accuracy of participant responses from this group could not be accurately extended to the rest of the sample. Second, in practice, differences between initial interview responses and observations made in the home were not systematically documented. Thus, a comparison of participant responses with researcher observation was not possible from the year one data set, nor would it have been very helpful. We did, however, conduct a comparison of responses to questions included in both the screening survey and initial survey. This comparison indicated that roughly a third of respondents could not accurately respond to detailed questions about their appliances and building mechanical systems without the help of a researcher over the phone, reinforcing the decision to conduct the initial and final interviews only over the phone, rather than making the questions available for completion online.

The following procedure was used to characterize potential bias of NO_X and NO_2 measurements made within the outdoor enclosure tin. Tests were performed on four occasions throughout the sampling period, by collocating multiple samplers outside a home in two different enclosure configurations for 6-day periods. One configuration was a relatively open dome-shaped enclosure that had been validated in past experiments (Singer et al., 2004). The second was a more closed box-shaped enclosure with ~1 cm diameter holes drilled on several sides of the box and fitted with grommets. A picture of both types of outdoor enclosures is shown in Figure 2.3. In this study, the open dome enclosure was used at the homes that were visited, while the closed box-shaped enclosure was used at the homes to which samplers were mailed, due primarily to its lighter weight and smaller size.

Figure 2.3. Two enclosure configurations for NO_2 / NO_X sampling: Configuration on the left was used at homes that were visited and has been validated in past studies. Configuration on the right was used at homes to which samplers were mailed.

The first outdoor validation experiment took place on 22 November 2011, simultaneous with pollutant sampling in the first set of homes in this study. The first experiment involved collocating a pair of samplers, each in a different type of enclosure, at the front of a single family home, and deploying a third sampler in a dome enclosure at the back of the home. The results of this experiment indicated that the true NO_2 and NO_X concentrations were, respectively, 31% and 34% higher than the concentration measured by samplers in the closed box. Consequently, the number of holes in the box surface was increased from four to six, which was the largest number of holes deemed possible without overly exposing the samplers to outdoor elements. This slightly modified design was used at homes sampled from Week 3 through Week 19. The subsequent three outdoor validation experiments were initiated on 29 November 2011, 7 February 2012 and 11 April 2012, and involved collocating three pairs of samplers in each enclosure type for six day periods outside of a single home, now with the box enclosure having 2 additional holes. For the first two experiments, the three pairs were deployed in different locations along the exterior of the home, while in the third experiment the three pairs were located together. Results from all four experiments are show in Table 2.4.

Table 2.4. Results from outdoor validation experiments. Each row corresponds to collocated samplers.

Start Date	Box NO_2 (ppb)	Dome NO_2 (ppb)	Box NO_X (ppb)	Dome NO_X (ppb)	Box NO (ppb)	Dome NO (ppb)
11/22/11	12.3	16.0	30.7	42.6	18.3	26.6
11/22/11		16.1		39.9		23.8
Mean (RSD)	12.3	16.1 (0.4%)	30.7	41.3 (4.6%)	18.3	25.2 (7.9%)
11/29/11	13.3	15.8	28.8	31.2	15.4	15.4
11/29/11	14.8	17.3	31.5	33. 3	16.7	16.0
11/29/11	12.2	15.8	27.9	29.2	15.7	13.4
Mean (RSD)	13.4 (9.7%)	16.3 (5.3%)	29.4 (6.4%)	31.2 (6.6%)	15.9 (4.3%)	14.9 (9.1%)
2/7/12	13.9	18.7	29.6	33.4	15.7	14.7
2/7/12	18.2	18.8	29.5	31.8	11.3	13.0
2/7/12	15.1	21.7	34.1	38.4	18.9	16.7
Mean (RSD)	15.7 (14.1%)	19.7 (8.6%)	31.1 (8.5%)	34.5 (10.0%)	15.3 (24.9%)	14.8 (12.5%)
4/11/12	5.1	5.7	6.0	7.4	0.7	1.2
4/11/12	4.6	6.0	7.0	8.1	2.0	1.4
4/11/12	4.9	5.5	4.7	6.9	-0.2	1.7
Mean (RSD)	4.9 (5.2%)	5.7 (4.4%)	5.9 (19.5%)	7.5 (8.1%)	0.8 (132%)	1.4 (17.6%)

An attenuation factor for NO_2 measured in the box was calculated from results of the last three experiments by linearly regressing the average concentrations measured in the box against the average simultaneously measured in the domes, with the intercept of the regression forced through zero (Figure 2.4). The resulting slope of 1.23 was used to adjust the NO_2 data measured by samplers deployed in the box-enclosures at homes sampled in Weeks 3-19. NO_2 concentrations measured in the initial box configuration during the first two weeks (i.e. the box with less openings) were adjusted using the ratio of concentrations measured in the box and dome enclosures in the first experiment (22 November 2011). Since surface deposition is not expected to be a significant sink for NO concentrations, the NO_X concentration was adjusted by taking the sum of the measured NO concentration and the adjusted NO_2 concentration.

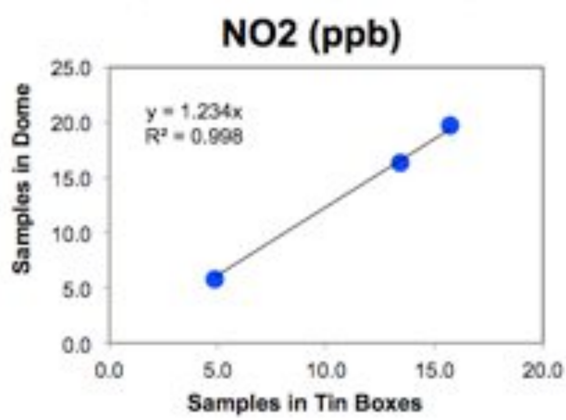


Figure 2.4. Linear regression of NO_2 concentrations measured by samplers in two outdoor enclosure types. Each data point represents the average of three pairs of samplers deployed for a six day period.

The following procedure was used to confirm the sampling rate of the Waters Inc. aldehyde samplers. These samplers are intended by the manufacturer to be used actively, not passively, as used in this study. However, a study conducted by Shinohara et al. (2004) reported that these aldehyde samplers could be used passively, and reported passive sampling rates of 1.48 and 1.23 mL/min for formaldehyde and acetaldehyde, respectively. In 2010, a laboratory experiment was conducted at LBNL to confirm these sampling rates. The experiment involved suspending 9 unmodified Waters aldehyde samplers in a 70 L chamber for 98 hours, during which an aqueous mixture of formaldehyde and acetaldehyde was injected into the chamber using a syringe pump and a GERSTEL Tube Spiking Apparatus. A Waters sampler connected to a peristaltic pump was used to collect a 40 to 50 L active sample at seven points during the experiment, in order to determine the syringe delivery rate of the aldehyde solution, and to monitor the aldehyde concentration in the chamber during passive sampling. The passive sampling rates calculated from the results of this experiment were 1.25 and 0.97 mL/min for formaldehyde and acetaldehyde, respectively.

Between April and July 2012, six further validation experiments were conducted by Lawrence Berkeley National Lab to ascertain the passive sampling rate of the Waters DNPH cartridges in residential settings. All six experiments were conducted in homes, one over a 10-day period and five over 6-day periods. The 10-day experiment was conducted as follows: On day one, 14 aldehyde samplers were deployed with two connected to pumps for active sampling and 12 deployed for passive sampling. Every two days, the two active samplers were removed and sealed in airtight bags and replaced with two new samplers. This step was repeated every two days of the 10-day sampling period, until 10 active samplers had been used, each deployed for two days. On day four, three of the passive aldehyde samplers were removed and packaged in airtight bags, but were *not* replaced. Every two days following day four, six, and eight, three more of the passive samplers were removed, until the final triplicate was removed on day 10. A sample schedule of the 10-day experiment is shown in Table 2.5. Results from this 10-day experiment were used to calculate a passive sampling rate and to investigate whether the sampling rate was stable over a 10-day period. The six-day field experiments involved deploying five aldehyde samplers, two connected to pumps to sample actively and three sampling passively. At the end of the six days, all five samplers were packaged and subsequently analyzed. Thus, one data point for comparison was acquired from the six-day field experiments, while four points were acquired from the 10-day field experiment. Results from the experiments are presented in Table 2.6. Using only the Day 6 results from Site 1 where a 10-day experiment occurred, the average ± standard deviation of sampling rates for formaldehyde and acetaldehyde for six days of sampling were 1.10 ± 0.09 and 0.86 ± 0.13 mL/min, respectively. These sampling rates were used to calculate formaldehyde and acetaldehyde concentrations measured in homes. Results from the 10-day experiment at Site 1 suggest that the sampling rate for aldehyde species may increase with time, but additional experiments would be required to determine whether the jump in calculated sampling rate between Day 6 and Day 8 of the experiment is repeatable or just variability between deployments.

Table 2.5. Sample schedule for 10-day aldehyde passive sampling rate validation experiment.

	Sample Name [a]	Day 1	2	3	4	5	6	7	8	9	10
Active Samples	ACT12-x										
	ACT34-x										
	ACT56-x										
	ACT78-x										
	ACT910-x										
Passive Samples	PASS4-x										
	PASS6-x										
	PASS8-x										
	PASS10-x										

[a] The "x" at the end of sample names is intended to identify duplicates (active samples) and triplicates (passive samplers). Results of the experiment are shown in Table 2.6.

Table 2.6. Results from aldehyde passive sampling rate validation experiments.

Experiment ID	Sampling duration (days)	Pump flow rate (mL/min)	Formaldehyde concentration (ppb) [b]	Acetaldehyde concentration (ppb) [b]	Formaldehyde sampling rate (mL/min, RSD)	Acetaldehyde sampling rate (mL/min, RSD)
Site 1-4d[a]	4.1	10.4	11	5	1.01 (10%)	0.65 (16%)
Site 1-6d	6.0	10.2	10	5	0.99 (4%)	0.68 (6%)
Site 1-8d	8.0	10.2	10	5	1.02 (3%)	0.89 (11%)
Site 1-10d	10.0	10.2	10	5	1.08 (7%)	0.86 (10%)
Site 2	6.1	10.3	12	6	1.03 (8%)	1.04 (1%)
Site 3	5.9	12.8	41	10	1.16 (6%)	0.96 (7%)
Site 4	6.0	11.2	30	11	1.09 (11%)	0.90 (8%)
Site 5	5.6	10.6	123	7	1.09 (6%)	0.79 (8%)
Site 6	5.9	13.6	12	5	1.23 (16%)	0.81 (16%)

[a] A 10-day experiment occurred at Site 1. At the remaining sites, a six-day experiment occurred.
[b] Concentrations determined from active sampling.

2.3 Data Analysis

The first step in data analysis was to calculate summary statistics from the time-series data. CO and CO_2 data were reviewed visually to identify instances of elevated concentrations. The following statistics were calculated from CO data: highest 1 h and 8 h average concentrations, the number of 1 h and 8 h running averages that exceeded the California Ambient Air Quality Standards of 20 or 9 ppm, respectively, and the fraction of 1-min readings that exceeded 5 ppm. The CO time-series data of homes that exceeded either of the outdoor standards were subsequently compared against temperature sensors deployed on the furnace and water heater, as well as questionnaire data regarding cooking habits and potential outdoor sources, in order to determine possible causes of the high levels.

The following statistics were calculated from CO_2 data: highest 15 min and 1 h concentrations, the number of 15 min and 1 h running averages that exceeded 2500 and 1000 ppm, respectively, and the fraction of 1-min readings that exceeded 1000 ppm. The CO_2 data may also be used to estimate air-exchange rates from periods of concentration decay following departure of all the occupants.

The following statistics were calculated from indoor and outdoor ambient temperature and relative humidity data: mean over entire period, mean overnight (24:00-5:00), mean daytime (9:00-15:00), and mean evening (19:00-21:00). This data was subsequently analyzed to investigate diurnal trends in the indoor to outdoor temperature difference, which is expected to have an affect on air-exchange, and to calculate NO_X and NO_2 sampling rates.

Temperature data from sensors deployed on the water heater and furnace were used to determine the frequency of operation, by identifying occurrence of the temperature exceeding a specific threshold. In the case of water heaters, a visual review of profiles indicated exhaust flues exceeded 100 °C when the water heater was in use, and remained below 100 °C below when not in use; thus, this temperature was selected as the threshold. An example water heater temperature profile is provided in Figure 2.5.

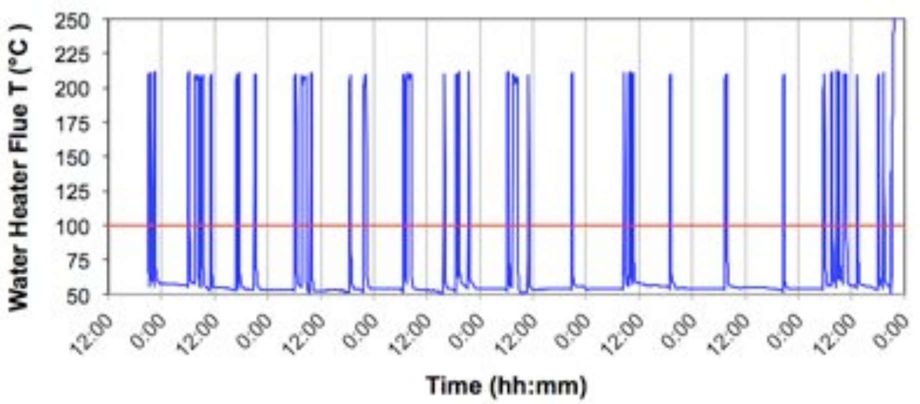
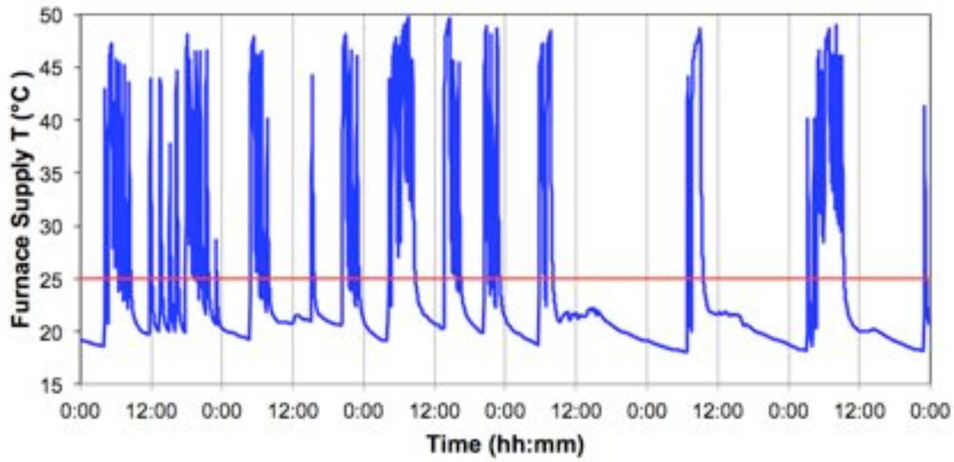
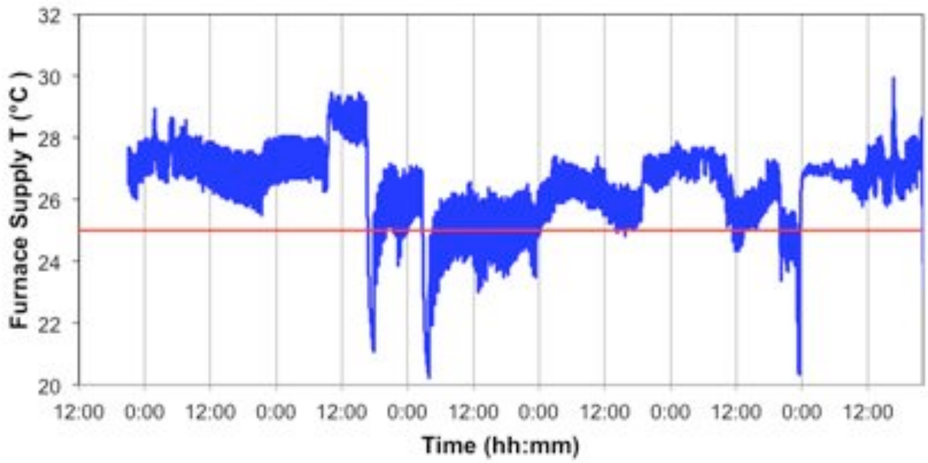


Figure 2.5. Temperature profile measured by thermocouple at top of water heater flue at site 1405. A horizontal red line is drawn through the temperature threshold used to indicate when water heater burner was firing.

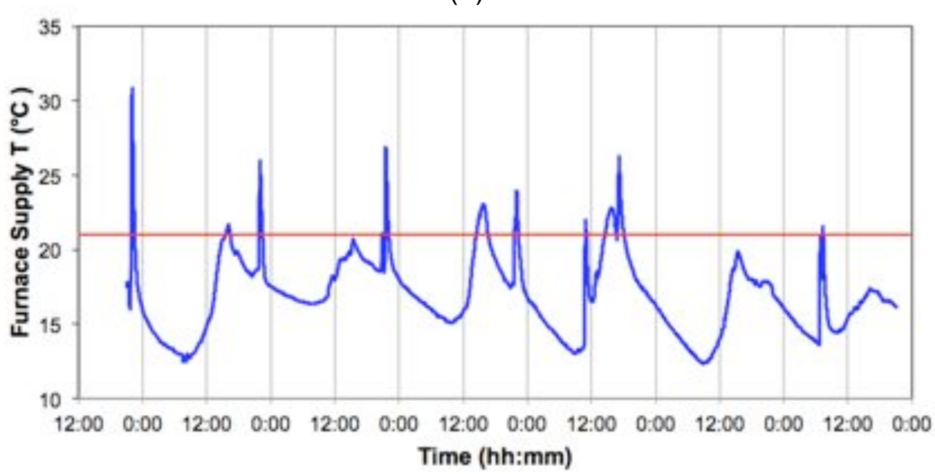
The determination of a temperature threshold for furnace use was not as straightforward, since the temperature sensors were not in the exhaust flue, but in various positions near a furnace supply register. Temperatures at heating supply registers can vary widely and the temperature sensors were not always optimally placed. The temperature profile measured by the furnace sensor at sites 0106, 1503, and 0804, all of which had central furnaces, are shown in Figure 2.6. In some homes, the temperature rose significantly above the baseline, clearly indicating heater use, as was the case at site 0106. In other homes, there were relatively rapid but small increases in temperature – on the order of a few degrees C – that likely indicate heater use, as was the case at site 1503. In this category, a threshold was selected such that all periods in which the heater was generally in use would be captured, even if not capturing all on/off cycles of the burner. In other homes, the temperature increase occurred more slowly, and was sometimes on the same scale as peaks associated with changes to home air temperature, as was the case at site 0804. This latter category was attributed to heater use when it occurred at night or early AM, but not during mid-day when temperatures rise with daily solar patterns.



(a)



(b)



(c)

Figure 2.6. Temperature profiles from furnace sensors at (a) 0106, (b) 1503 and (c) 0804. The red horizontal line represents the threshold above which the furnace is assumed to have been in use.

Each home for which no outdoor sampling occurred was assigned the outdoor NO_2, NO_X, formaldehyde and acetaldehyde levels measured outside the home designated to be representative of the cluster during the same week of sampling. For the 74 homes for which no onsite outdoor sampling occurred, the location of the assigned outdoor data ranged from <10 meters (e.g. the house next door) to 37 km from the home, with a mean distance of 4.6 km. The two furthest distances between the home and the nearest outdoor sampler (26 and 37 km) occurred during weeks when a participant who had been assigned an outdoor sampling package, deployed it a week late; thus, the measurements from that home could not be used to characterize outdoor levels at other nearby homes as planned. The third and fourth furthest distances (21 and 23 km) occurred during a week when the sampled homes were in exurban areas of similar landscape and similar distances from the Pacific Ocean and San Francisco Bay, but were spread further apart than usual. Since CO was not monitored outdoors at any of the homes, centrally-monitored outdoor CO concentrations were queried from an online database maintained by the California Air Resources Board (CARB). Centrally monitored NO_2 and NO_X concentrations were also queried from the CARB database and compared with results from the subset of homes where sampling occurred outdoors to investigate comparability between local and regional measurements. Most homes were assigned the concentration measured by the nearest central monitoring station, but 3 sites were assigned concentrations from the next closest station because it was evaluated as having outdoor source characteristics that were more similar to that of the home. Specifically, two homes in Pacifica and one in San Mateo were assigned concentrations from San Rafael and Cupertino, respectively, verses San Francisco Mission Bay, which was the nearest site to all three. The location of the nearest central monitoring station assigned to each home ranged from 0.8 to 99 km (furthest distance was for two homes in Sonora sampled during a week when data from the local central monitoring station was not available), with a mean distance of 11 km. Figure 2.7 shows regressions of the NO_2 and NO_X concentrations measured outside of homes against the concentration assigned to those same homes from a central monitoring station. Figure 2.8 shows the same data for only those sites where the nearest central monitoring station was within 5 km from the home. The onsite measurements have been adjusted to account for bias in readings resulting from the enclosure.

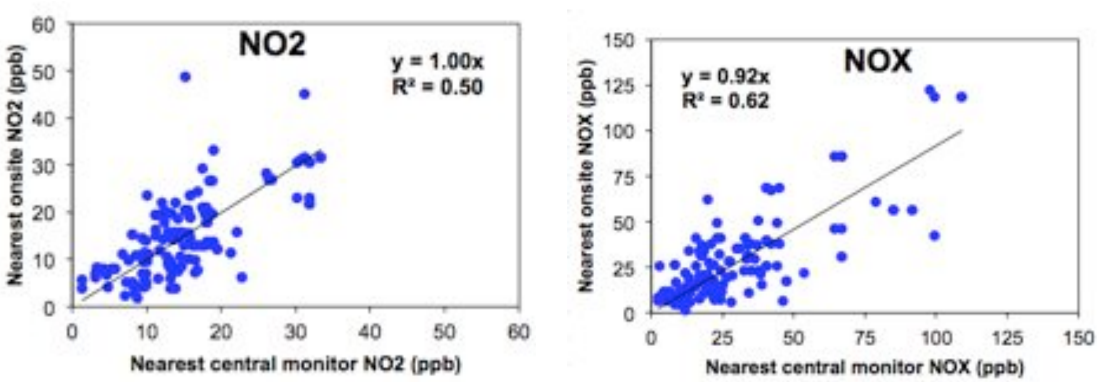


Figure 2.7. Regression of NO_2 and NO_X concentrations measured outside of homes (adjusted for losses in outdoor enclosure) against concentrations assigned from central monitoring station (n=83).

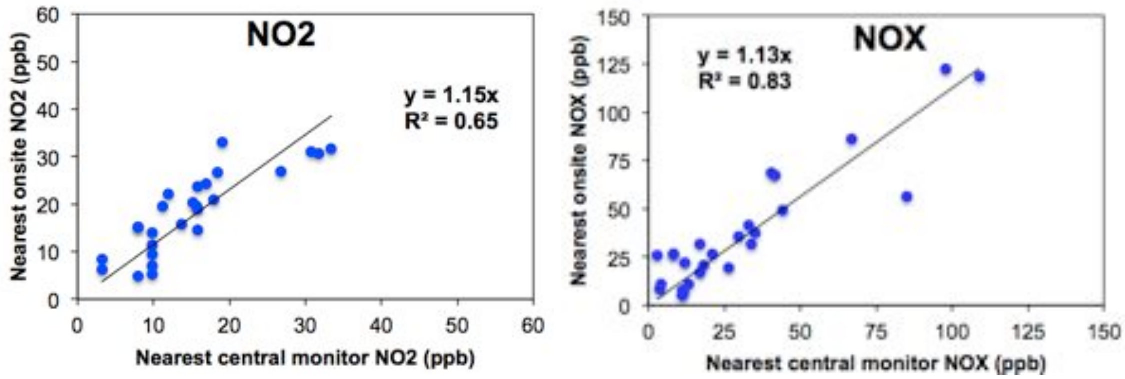


Figure 2.8. Regression of NO_2 and NO_X concentrations measured outside of homes (adjusted for losses in outdoor enclosure) against concentrations assigned from central monitoring station, for only those homes that had a central monitoring station within a 5 km distance (n=26).

Pollutant data measured indoors and outdoors at each home were imported into R Statistical Software, along with responses to the initial and final questionnaires, for statistical analysis. Summary statistics, including the 5th and 95th percentile, 1st and 3rd quartile, median, mean and standard deviation were calculated for each pollutant. In cases where measurements were below the LOQ, values were replaced with 0.5 LOQ for analysis purposes. Homes were divided into categories based on characteristics of the appliances, kitchen exhaust system, and resident activities, and the median pollutant levels for these groupings were tested for significant differences using the Kruskal-Wallis test.

NO_2 and NO_X concentrations were statistically analyzed using the directly measured indoor quantities and also the estimated amounts attributable to indoor sources. For NO_2, the indoor-attributed concentrations were calculated by subtracting one-fourth of the outdoor concentration from the concentrations measured in the kitchen and bedroom of each residence. This factor for outdoor NO_2 persisting indoors was calculated using equation (2.1), by assuming an air exchange rate (λ) of 0.35 h^{-1} based on previous results for Northern California homes in winter (Wilson et. al., 1993), an NO_2 indoor loss rate (k) of 1 h^{-1} (Yang et. al., 2004), and a penetration efficiency (P) of 1.

$$\frac{Steady\ \ State\ \ Indoor\ \ NO_2}{Steady\ \ State\ \ Outdoor\ \ NO_2} = \frac{\lambda P}{\lambda + k} \qquad (2.1)$$

For NO, the indoor loss rate was assumed negligible and the indoor levels attributed to outdoor air entry were assumed equal to the outdoor NO concentration. The indoor-attributed NO was therefore calculated as the indoor concentrations minus the outdoor concentration. The indoor-attributed NO_X concentration was calculated as the sum of the indoor-attributed NO and indoor-attributed NO_2 concentrations.

A summary of the different groupings for which differences in pollutant concentrations were analyzed is provided in Table 2.7.

Table 2.7. Groupings of homes for which differences in pollutant medians were tested

Grouping Description	Variable Type	Group 1	Group 2	Group 3	Group 4
Gas appliances present in the living space	Categorical	No gas appliance present in living space	*Only* vented gas appliances present in living space	O*nly* unvented gas cooking range present in living space	Both unvented and vented gas appliances present in living space
Amount of cooking with gas cooktops and/or oven	Ordinal	Gas cooktop and/or oven used ≤ 7 times during sampling	Gas cooktop and/or oven used >7 to <14 times during sampling	Gas cooktop and/or oven used ≥14 times during sampling	
Kitchen exhaust fan use (homes with frequent gas cooking)	Ordinal	Kitchen exhaust fan used rarely or never	Kitchen exhaust fan used “about half of the time” when cooking	Kitchen exhaust fan used “most of the time” when cooking	

3. Results

3.1 Sample Characteristics

A total of 155 homes were sampled during the first year of the study. Of those homes, 132 homes were selected as having substantial risk of pollutants from gas appliances; these homes had a mean risk score of 4.3 based on the scoring system shown in Table 2.1. The remaining 23 homes were selected to serve as controls, and had risk scores of less than 1. These homes had either no gas appliances, or had one or two vented gas appliances outside of the main living space. A frequency distribution of the risk scores is shown in Figure 3.1.

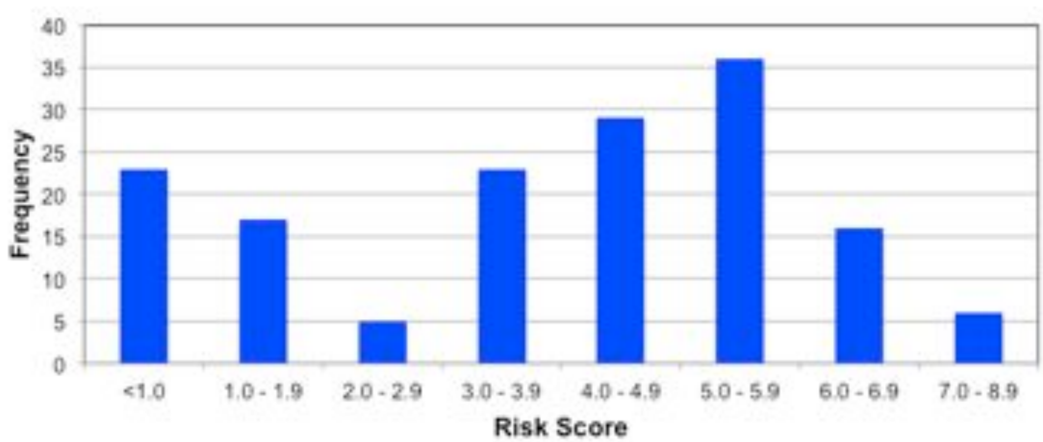


Figure 3.1. Frequency distribution of risk scores calculated for the 155 homes in the study.

All but one of the homes were located in Northern California. Among those homes, 128 were located in 8 of the 9 counties defined by the California government as the San Francisco Bay Area: Alameda, Contra Costa, San Francisco, San Mateo, Santa Clara, Marin, Sonoma and Solano (census.abag.ca.gov). The remaining 27 homes were located in the following 9 counties: Humboldt, Yolo, Sacramento, San Joaquin, Tuolumne, Santa Cruz, Monterey, Merced and Los Angeles. The sample population included both single-family (68%) and multi-family (32%) dwellings. The distribution of homes among 12 of these 14 counties (excluding Merced and Los Angeles) is shown in Figure 3.2.

Figure 3.2. Number of homes sampled in each county. Homes sampled in Humboldt (n=1) and Los Angeles (n=1) counties are not shown.

The sample population successfully overrepresented homes with gas appliance types and use patterns that were hypothesized to put them at risk of high pollutant concentrations. Specifically, there was at least one gas appliance in 87% of homes, and an unvented gas cooking appliance in 77%. The gas cooktop was reportedly used at least 7 times during the week of sampling in 51% of homes, and was used more than 17 times in 12%. Participants reported that they either did not have a kitchen exhaust fan or that they rarely or never used it in 63% of homes. A summary of the gas appliance and kitchen exhaust use characteristics of the sample population is presented in Table 3.1.

Table 3.1. Gas appliance use and kitchen exhaust characteristics of sample population

	Number	Percentage [a]
Types of appliances present		
No gas appliances	19	12%
Vented gas appliances only (i.e. furnace and/or water heater)	17	11%
Unvented gas appliances only (i.e. cooking appliances)	46	30%
Vented and unvented gas appliances	73	47%
Gas cooktop usage during sampling period		
7 times or less	39	26%
More than 7 times, less than 14 times	42	27%
More than or equal to 14 times	34	22%
No gas cooktop	37	23%
Did not answer	3	2%
Gas oven usage during sampling period		
Zero times	29	19%
1-5 times	65	42%
More than 5 times	4	3%
No gas oven	57	37%
Kitchen Exhaust fan usage when present		
Used most of the time	37	24%
Used about half the time	20	13%
Used rarely or never	43	28%
Did not answer	7	5%
No functional exhaust fan present	48	31%

[a] Represents percentage of the total sample population.

Some of the demographic factors expected to put a home at risk of elevated pollutant concentrations from gas appliances were under-represented in the first-year study sample. Specifically, 43% of the participating households had a combined annual gross income of $100,000 or greater, 63% had at least one resident with a graduate degree, and 50% had only 1 or 2 occupants. However, the majority of participants' homes had a floor area below the average size of new homes in the Western region of the US in 2005 (National Association of Home Builders), with 26% of the homes having a floor area of less than 1000 sq. ft. and 76% having a floor area of less than 2000 sq. ft. The high performance homes tended to be larger with fewer residents than the conventional homes, but the education and income levels of the two groups were similar. The racial distribution of the sample was similar to that of the California population, which, according to the 2010 Census, is made up of 74% White, 7% Black, 2% American Indian or Alaskan Native, 14% Asian, and 38% Hispanic persons. (Note that the US Census does not consider "Hispanic" as a race, thus individuals that report a Hispanic ethnicity are also counted within one of the race categories). Thus, the primary difference between the ethnic distribution of the study sample and the California population is an overrepresentation of the Asian/Pacific Islander population and underrepresentation of the Hispanic/Latino population. A summary of the demographic data is presented in Table 3.2. A distribution of responses to every question in the initial and exit questionnaire is provided in Appendix D.

Table 3.2. Demographics of first-year study sample. Number of homes reported separately for high performance and traditional homes; percentage reported for total.

	Traditional	High-Perform.	Total
Types of appliances present	**Number**	**Number**	**Percentage**
Home rented	47	3	32%
Home owned	84	21	68%
Floor Area of home (sq. ft.)			
<1000	41	0	26%
1000-2000	65	12	50%
>2000	19	11	19%
Did not answer	6	1	5%
Number of residents			
1 – 2	65	12	50%
3 – 4	52	9	39%
5 or more	14	3	11%
Presence of minors and seniors			
At least one resident <18 years old	41	10	33%
At least one resident >64 years old	20	7	17%
All residents between 18-64 years old	70	7	50%
Highest education level of residents			
Less than Bachelors degree	9	0	6%
Bachelors degree	38	10	31%
Graduate degree	84	14	63%
Ethnicities represented by residents [a]			
Native American	1	1	1%
Black, African-American	5	2	5%
Hispanic/ Latino	20	1	14%
Asian or Pacific Islander	45	2	30%
White, Caucasian	97	21	76%
Combined Gross Income			
<$25k	10	0	6%
$25-49k	17	3	13%
$50-74k	23	1	15%
$75-99k	19	2	14%
$100-150k	33	5	25%
>$150k	21	7	18%
Did not answer	3	6	6%

[a] Residents were allowed to report more than one ethnicity; therefore, the sum of percentages is greater than 100.

Sampling materials were mailed to 126 homes. All but one of the packages that were mailed or delivered to the homes were returned to the lab. One package was stolen from a doorstep before the participant returned home to retrieve it. NO_2, NO_x and aldehyde samples from 2 homes were deemed contaminated because the residents sent the samplers back unsealed (and uncapped in the case of the aldehyde samplers). CO data were not obtained in 21 homes: 18 due to battery failure and 3 due to instrument failure.

The research team visited 28 homes to deploy the sampling materials. CO_2 loggers were deployed in all of these homes, and air-exchange rate and particle measurements were made in 23 homes. The home characterization protocol was conducted at all 28 of the visited homes. In 8 of the homes, CO_2 data were not obtained due to battery failure. Also in 8 homes, tracer gas air-exchange rate measurement data were discarded due to apparent cross contamination between the PFT emitter and the VOC collection tubes. Table 3.3 summarizes the number of homes for which each pollutant was measured successfully.

Table 3.3. Number of homes each data parameter was collected.

Data Parameter Collected	Number of homes	Source of data loss
NO_2, NO_X	153	Returned unsealed
Aldehyde	153	Returned unsealed
CO	134	Battery failure, instrument failure
CO_2 (visits only)	19	Battery failure
Particle number (visits only)	23	Not available for all homes
Air-exchange rate (visits only)	15	Contamination
Home characterization (visits only)	28	NA

3.2 Univariate Statistics

NO_2 and NO_X

Cumulative distributions of directly measured indoor and indoor-attributed NO_2 and NO_X in homes are shown in Figures 3.3 and 3.4, respectively. These plots also present the calculated arithmetic mean (AM) and the geometric mean (GM) and geometric standard deviation (GSD) of a log-normal distribution fitted to the data. The data were plotted on a log scale, illustrating the lognormal characteristics of the distribution. The GM of directly measured NO_2 in the kitchen, bedroom and outdoors of homes were similar at values of 15, 12 and 11 ppb, respectively. In contrast, the GM NO_X levels measured in kitchen and bedrooms were 42 ppb and 41 ppb, respectively, while the GM measured outdoors was 19 ppb. For NO_2, the outdoor levels were higher than the indoor-attributed levels in roughly half of the samples collected in kitchens and roughly 75% of the samples collected in bedrooms. For NO_X, the indoor-attributed levels were almost always higher than the outdoor levels.

Figure 3.5 shows a linear regression of the bedroom and kitchen NO_2 concentrations against the outdoor concentration associated with that site, and of the bedroom concentration against the kitchen concentration. As expected, these regressions indicate that the outdoor NO_2 level influenced the levels in the bedroom and kitchen, but that this influence was sometimes overshadowed by the contribution of indoor sources. Conversely, the kitchen and bedroom NO_2 levels were strongly correlated (R^2= 0.81), with the kitchen level tending to be slightly higher.

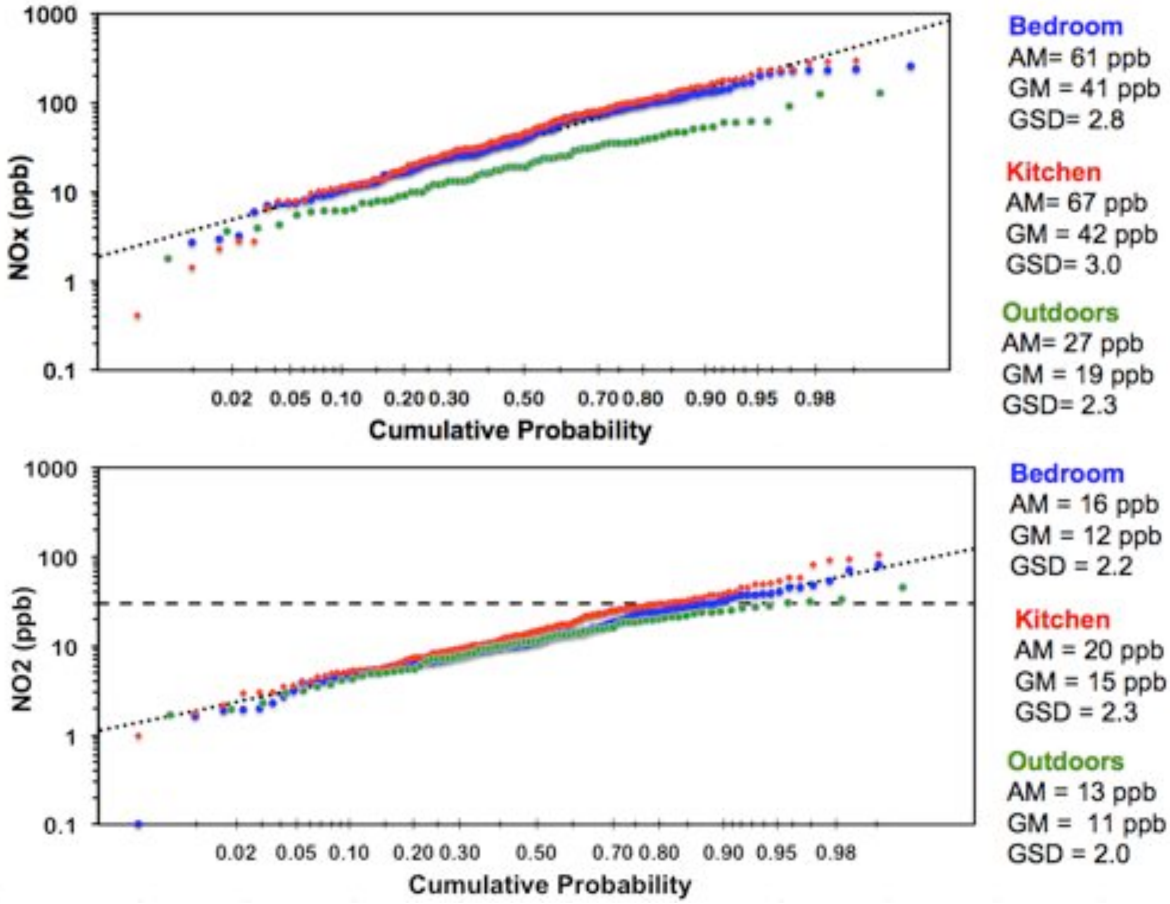


Figure 3.3 Cumulative distribution of measured NO_X and NO_2 concentrations. The dashed line on the NO_2 plot represents the California EPA outdoor annual standard. The dotted line represents a lognormal distribution with the same statistical properties as the bedroom data. Summary statistics are presented to the right of the plot (AM= arithmetic mean, GM= geometric mean, GSD= geometric standard deviation).

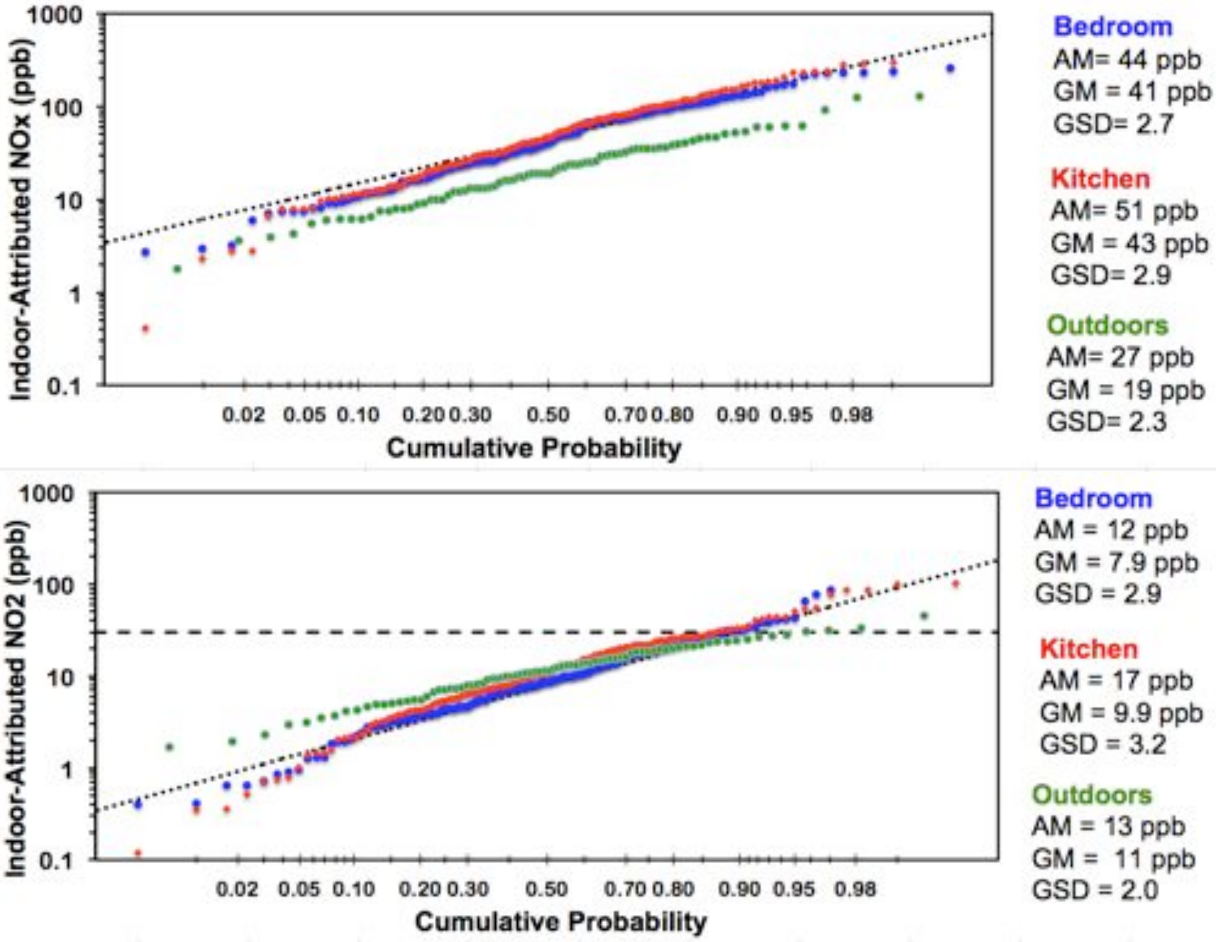
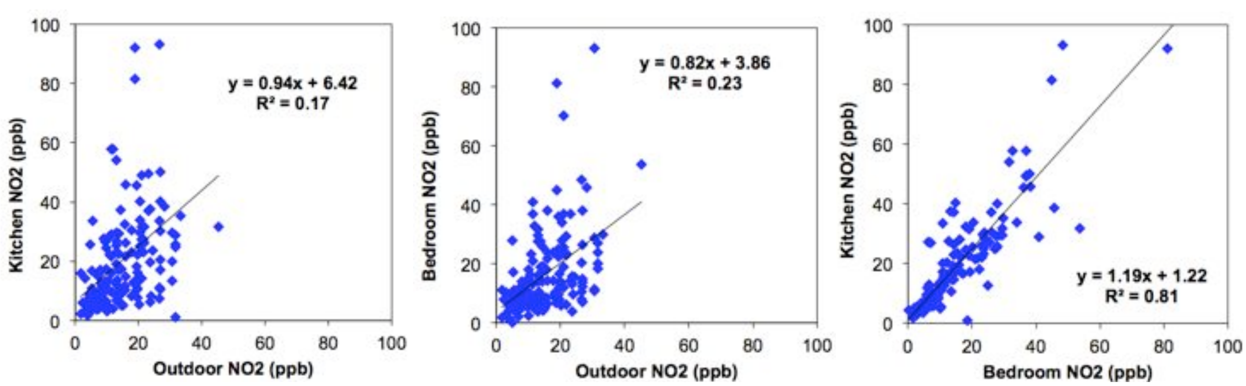


Figure 3.4 Cumulative distribution of estimated NO_X and NO_2 concentrations attributed to indoor sources, calculated as the measured indoor concentration minus the estimated concentration indoors from outdoor pollutants. The dashed line on the NO_2 plot represents the California EPA outdoor annual standard. The dotted line represents a lognormal distribution with the same statistical properties as the bedroom data. Summary statistics are presented to the right of the plot (AM= arithmetic mean, GM= geometric mean, GSD= geometric standard deviation).



(a) (b) (c)

Figure 3.5 Linear regression of (a) kitchen NO_2 vs. outdoor NO_2, (b) bedroom NO_2 vs. outdoor NO_2, and (c) kitchen NO_2 vs. bedroom NO_2.

Roughly 10% of sampled homes were found to have an average NO_2 level during the sampling period that exceeded the outdoor standard for annual average of 30 ppb set by the California Air Resources Board. The highest NO_2 and NO_X concentrations of 108 and 295 ppb, respectively, were measured in the kitchen of site 1004, which was a 2-bedroom townhouse with a pilot-ignited gas cooking appliance that was more than 15 years old, and that was used daily to cook breakfast and dinner. The participant also reported that the kitchen was a separate room connected to the rest of the home by only a doorway, and that there was no kitchen exhaust system. The NO_2 and NO_X levels measured in the kitchen at site 1004 were 55% and 22% higher, respectively, than the levels measured in the bedroom. The formaldehyde and acetaldehyde levels measured in the kitchen at this site were in the top 5% and 30% of the sample population, respectively, and the 8-h and 1-h peak CO levels were in the top 20%.

Formaldehyde and acetaldehyde

Cumulative distributions of the formaldehyde and acetaldehyde concentrations measured in the kitchen, bedroom and outdoors of all homes are shown in Figure 3.6, which illustrates that these pollutants also conformed well to a lognormal distribution. A GM formaldehyde concentration of 15 ppb was measured in both the bedroom and kitchen of homes. The GM level measured outdoors was significantly lower at a value of 2 ppb. Roughly 95% of homes had average formaldehyde levels indoors that exceeded the Chronic Reference Exposure Level set by the California EPA (7 ppb). However, these results are lower than those of Weisel et al. (2005), who measured median indoor and outdoor formaldehyde concentrations of 20.1 and 6.5 ppb, respectively, in 398 homes in Elizabeth, NJ, Houston, TX, and Los Angeles, CA. They are also lower than those of Offermann (2009), who measured a median indoor formaldehyde concentration of 29 ppb (converted from units of $\mu g/m^3$ assuming P = 1 atm and T = 293 K) among 108 single-family California homes that were 2-6 years old at the time of sampling in the mid-2000s. Thus, although formaldehyde levels measured in the homes sampled in the present study were high relative to the CA standard, the central tendency is below what has been measured by studies of other homes in the United States.

A GM acetaldehyde level of 9 ppb was measured in both the bedroom and kitchen of homes, which significantly exceeded the GM level measured outdoors of 0.9 ppb. These results for acetaldehyde are also lower than those of Weisel et al. (2005) and Offermann (2009). Weisel et al. (2005) measured median indoor and outdoor acetaldehyde concentrations of 18.9 and 5.4 ppb, respectively, among the 398 homes. Offermann (2009) measured a median indoor concentration of 11.1 ppb (units converted assuming P = 1 atm and T = 293 K), among the 108 homes.

The highest measured formaldehyde concentration in the present sample was 83 ppb, and was measured at site 0205, which was a 1-bedroom apartment that had been renovated within the previous 5 years. The apartment contained new gas cooking appliances that were rarely used; thus, the elevated formaldehyde concentrations are expected to have resulted from emissions by building materials, furniture or other household products. It should be noted that the highest formaldehyde concentrations measured throughout the entire first year was in a home sampled as part of the aldehyde passive sampling rate validation. The 6-day average of 123 ppb was measured in the newly renovated kitchen of this home (see Table 2.6). The highest acetaldehyde level of 115 ppb was measured in the kitchen of site 1010, which was a 1-bedroom duplex unit with gas cooking appliances. The gas storage water heater was outside of the living space, and the residents used an electric space heater to heat their home. Site 1010 was one of only a few homes that had an average acetaldehyde exceeding the formaldehyde concentration, and it was the only home for which the acetaldehyde concentration exceeded the formaldehyde by an order of magnitude.

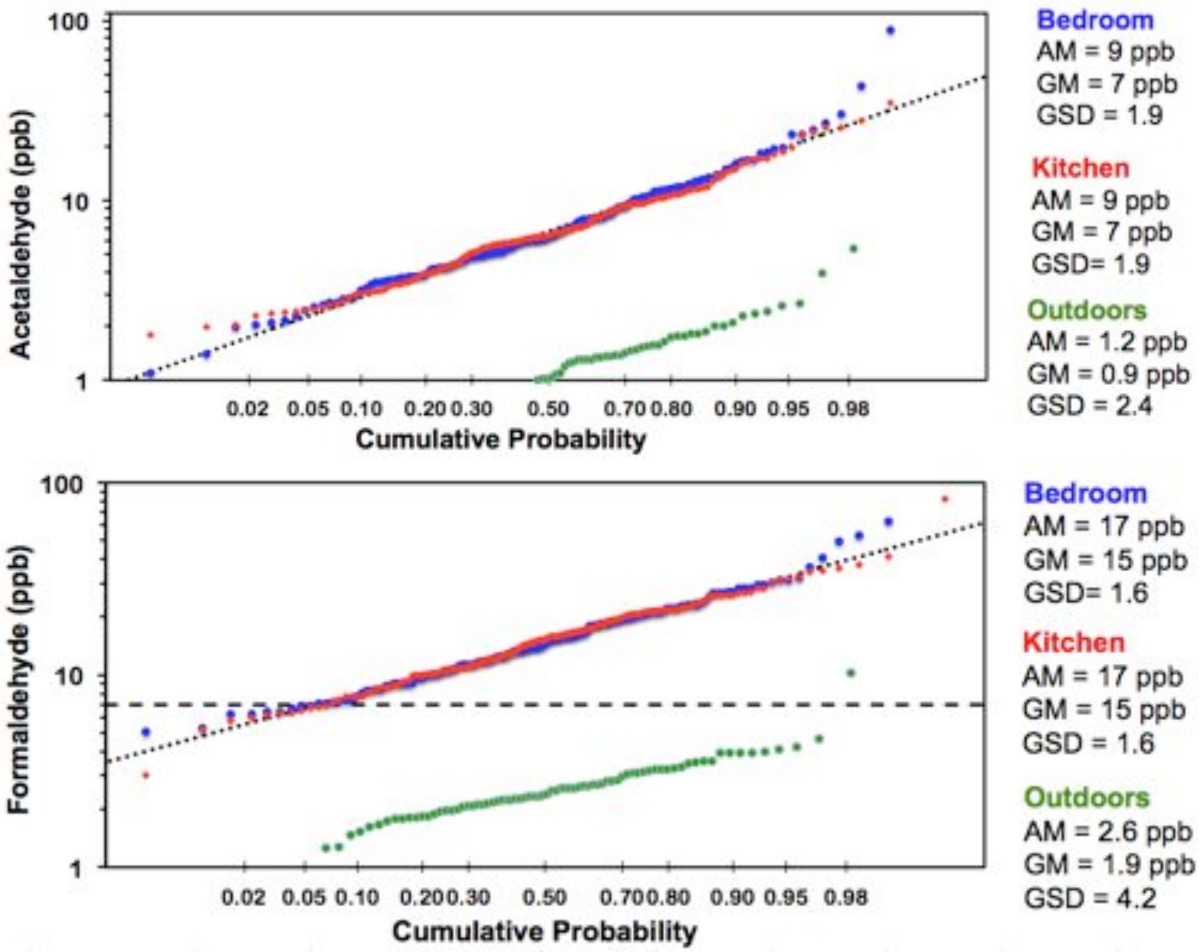


Figure 3.6. Cumulative distribution of formaldehyde and acetaldehyde concentrations. The dashed line on the formaldehyde plot represents the California EPA Chronic Reference Exposure Level. The dotted line represents a lognormal distribution with the same statistical properties as the pollutant data measured in the kitchen. Summary statistics are provided to the right of the plot (AM= arithmetic mean, GM= geometric mean, GSD= geometric standard deviation).

Carbon monoxide

Cumulative distributions of the highest 1 h and 8 h CO concentrations measured in the kitchen of homes are shown in Figure 3.7. Data points are plotted on a log scale; however, only data above 1 ppm were fitted to the lognormal distributions. Below 1 ppm – which is 10% of the lowest calibrated value – the biases related to calibration drift are large relative to the measurement. Most importantly, any measurement at these low concentrations indicates a home without substantial indoor sources. The GMs of the highest 1-h and 8-h CO levels were 2.5 ppm and 1.1 ppm, respectively. Of the 134 homes at which CO levels were measured, 4 had a 1-h or 8-h concentration that exceeded the CA outdoor standard. Time series plots for these 4 sites are presented in Figure 3.8. The first site (0307) was a studio apartment located in an urban area. The only gas appliance in the living space was a cooking range, which was reported to be used daily to cook breakfast and dinner. The cause of the elevated levels at this home is unclear, but the cooking appliances could potentially have been the cause. The second site (0606) was a 2-bedroom single family home with a gas cooktop, oven, water heater and central furnace. The cooktop and oven were the only gas appliances in the living space. The participant reported using one or the other burner each day, sometimes more than once. The elevated CO levels at this home resulted from events that lasted several hours with a peak of 30 ppm. The cause of this peak is unclear. The third site (1010) was mentioned in the previous section as the home having the highest measured acetaldehyde concentration. The participant reported that the gas cooktop was used multiple times each day. As mentioned earlier, the water heater was located in an outdoor closet adjacent to the home and heat was provided by an electric appliance. It is possible that the CO peaks at this home were caused by the cooktop. The final home was a 1-bedroom in-law unit (1405) with a gas fireplace, water heater and cooking range in the living space. The participant reported that in this home, they generally used their cooking burners and fireplace multiple times per day. Sampling at this home occurred for 7 days. This home experienced multiple CO peaks on most days, generally occurring between the hours of 8:00 and 20:00. The magnitude of the peaks ranged from roughly 5 to 30 ppm. This home was subsequently visited by researchers to inspect the appliances. The inspection revealed that the air-free CO concentration in the fireplace exhaust was over 1000 ppm, whereas the cooking appliances and water heater had low CO emissions. This suggests that the gas fireplace was the culprit for the elevated CO levels at site 1405. A picture of the gas fireplace is shown in Figure 3.9. However, a plot of the CO concentration and fireplace operation time-series data (Figure 3.8) indicates that fireplace operation did not always cause increases in CO and there were some increases in CO that were not associated with fireplace use. Thus, it is possible that there was another source of CO inside or outside of the home.

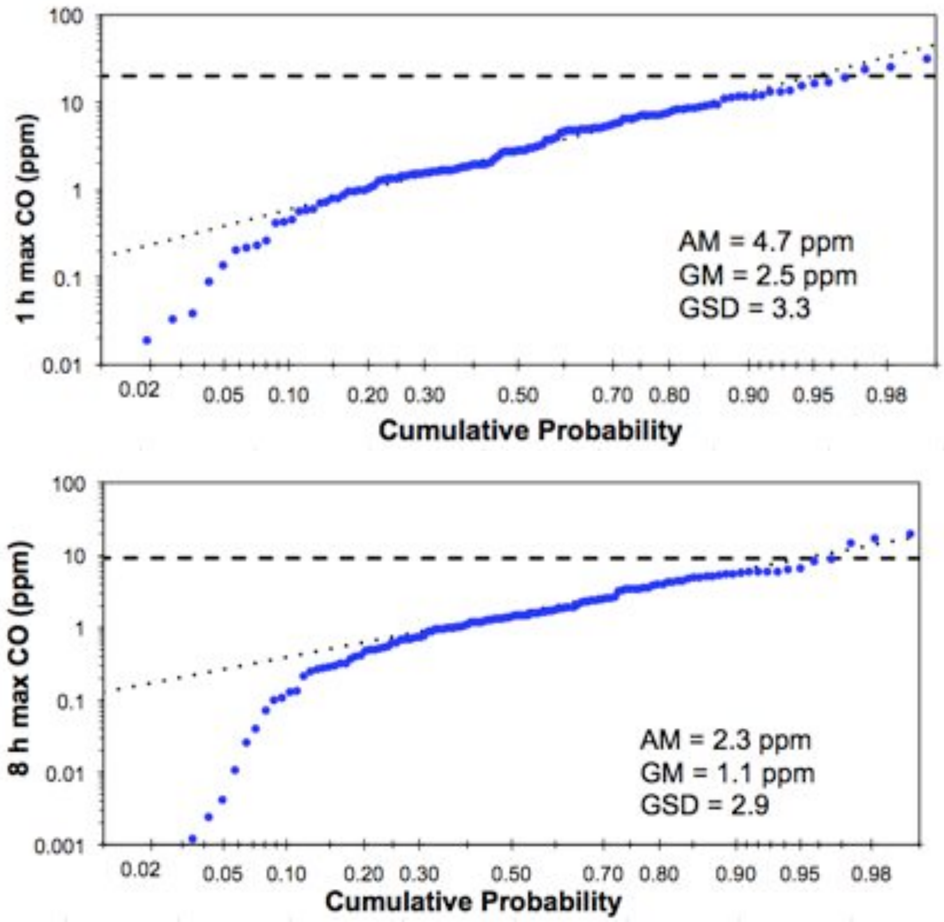


Figure 3.7. Cumulative distributions of highest 1-h and 8-h mean CO concentrations. The dashed lines represents the corresponding California EPA outdoor standard. The dotted line represents a lognormal distribution with the same statistical properties as the pollutant concentrations measured above 1ppm. The GSD is also calculated for values above 1 ppm.

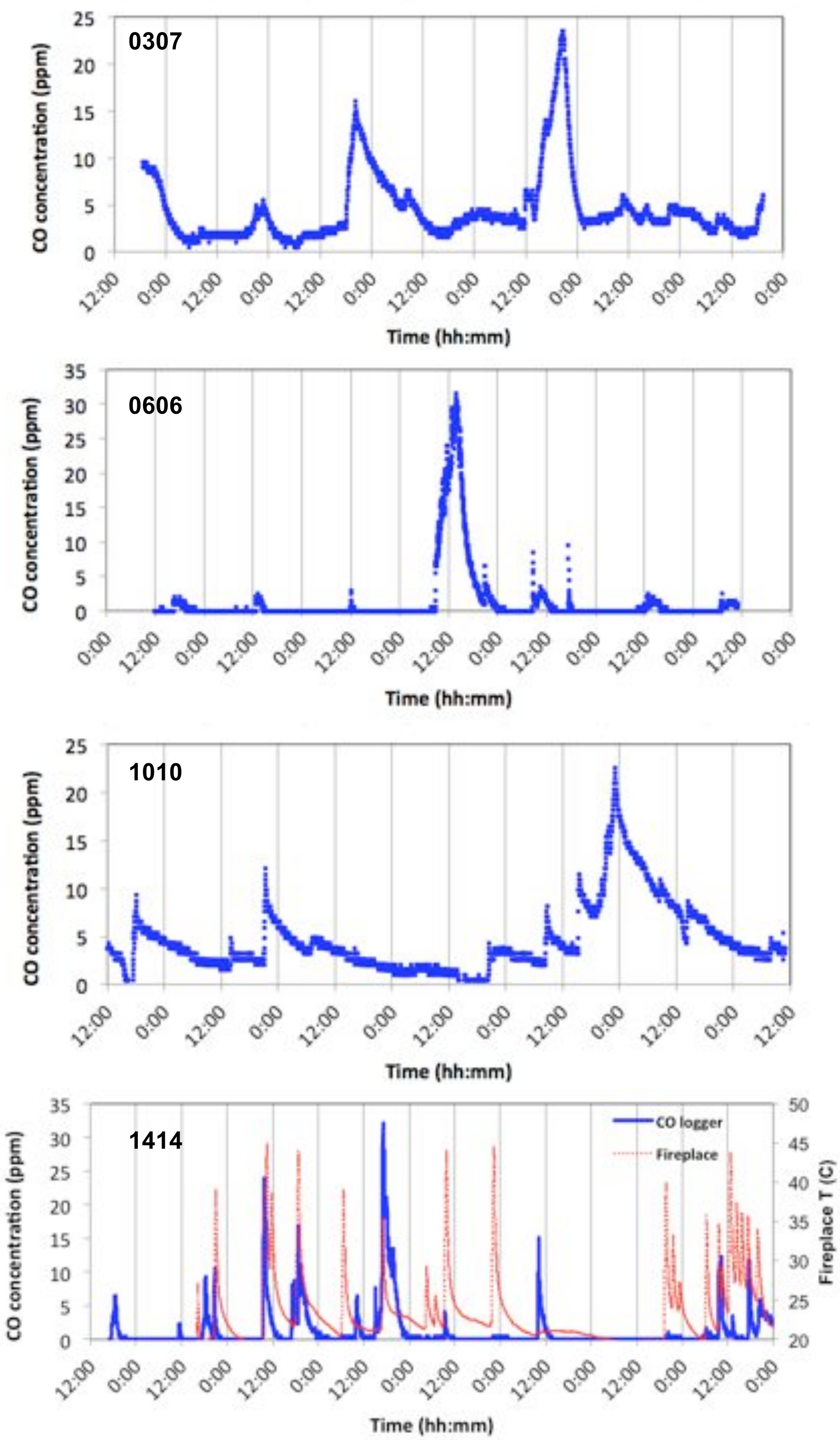


Figure 3.8. CO time-series plots for the 4 sites that exceeded either the 1-h or 8-h outdoor standard, or both. The corresponding home ID is provided on the top left corner of the plot.

Figure 3.9 A picture of the gas fireplace at Site 1405, which has been identified as the cause for the elevated CO levels measured at the home.

3.3 Bivariate Analysis

Bivariate analysis was used to investigate covariances between pairs of pollutants and between measurements made at different locations within a home. The result of this covariance analysis is presented in Table 3.4. The NO_2 and NO_X levels included in this analysis are the calculated indoor-attributed concentrations, whereas as-measured concentrations were analyzed for the remaining pollutants. As expected, NO_2 and NO_X measured at the same location are strongly correlated with each other (R^2>0.60). In addition, 1-h peak CO concentrations were strongly correlated with 8-h peak CO concentrations measured at homes (R^2=0.85). Formaldehyde and acetaldehyde measured in homes were not strongly correlated with one another (R^2>0.03). In the case of both the NO_X and aldehyde species, levels measured in the kitchen were strongly correlated with those measured in the bedroom (R^2>0.60).

Non-parametric statistical tests were conducted to investigate the difference between the distributions of pollutant levels measured for different groups of homes based on characteristics expected to influence pollutant concentrations. Only results for pollutants measured in the kitchen are presented, as these concentrations were highly correlated with the concentrations measured in bedrooms. Likewise, only results for the highest 1-h, and not 8-h, CO concentration are presented.

Table 3.4. Coefficient of determination (R^2) between pollutants measured at different locations in homes. Some pollutants have been adjusted to estimate the indoor concentrations resulting from indoor sources [a]. Letters “B” and “K” following pollutant abbreviations represent measurements made in bedrooms and kitchens, respectively. (FA = formaldehyde, AA = acetaldehyde, N2= NO_2, and NX= NO_X.)

	N2-B	NX-B	N2-K	NX-K	FA-B	AA-B	FA-K	AA-K	CO-1h	CO-8h
N2-B	1.00	0.62	0.79	0.56	0.00	0.00	0.00	0.00	0.25	0.28
NX-B		1.00	0.61	0.86	0.00	0.10	0.03	0.11	0.20	0.28
N2-K			1.00	0.76	0.00	0.01	0.00	0.00	0.16	0.18
NX-K				1.00	0.00	0.07	0.02	0.07	0.17	0.23
FA-B					1.00	0.03	0.69	0.01	0.01	0.00
AA-B						1.00	0.06	0.90	0.02	0.10
FA-K							1.00	0.04	0.00	0.00
AA-K								1.00	0.03	0.12
CO-1h									1.00	0.85
CO-8h										1.00

[a] NO_X concentrations adjusted by subtracting concentration measured simultaneously outdoors. NO_2 concentrations adjusted by subtracting ¼ of the simultaneous outdoor concentration.

Appliances in living space

To investigate the effect of different types of appliances in the living space of homes, the study sample was divided into the following four categories: (1) no gas appliances, (2) only vented gas appliances (e.g. furnace or water heater), (3) only unvented gas cooking appliances, (4) both vented gas appliances and unvented gas cooking appliances. Box plots comparing distributions of NO_2, NO_X and 1-h max CO levels for these 4 categories of homes are shown in Figure 3.10. Results are presented for indoor-attributed NO_2 and NO_X concentrations and directly measured CO concentrations. In all cases, the two categories of homes with unvented gas cooking appliances had a higher median pollutant level than the homes with either vented or no gas appliances in the living space. The Kruskal-Wallis test confirmed at least one of the six pair-wise differences between groups was statistically significant in the case of all 3 analyzed pollutants ($p<0.05$). In all cases, the primary factor affecting the difference appears to be the unvented gas cooktop. A follow up Mann-Whitney test investigating differences in the levels of these three pollutants (indoor-attributed kitchen NO_2, indoor-attributed kitchen NO_X and 1-h max CO levels) between two groups of homes—those with and those without unvented gas cooking—confirms that the difference is statistically significant in all three cases ($p<0.05$).

Figure 3.11 shows plots of formaldehyde and acetaldehyde levels for the same 4 categories of homes. This analysis indicates that the presence or absence of any type of gas appliance in the living space is not clearly associated with elevated formaldehyde or acetaldehyde levels.

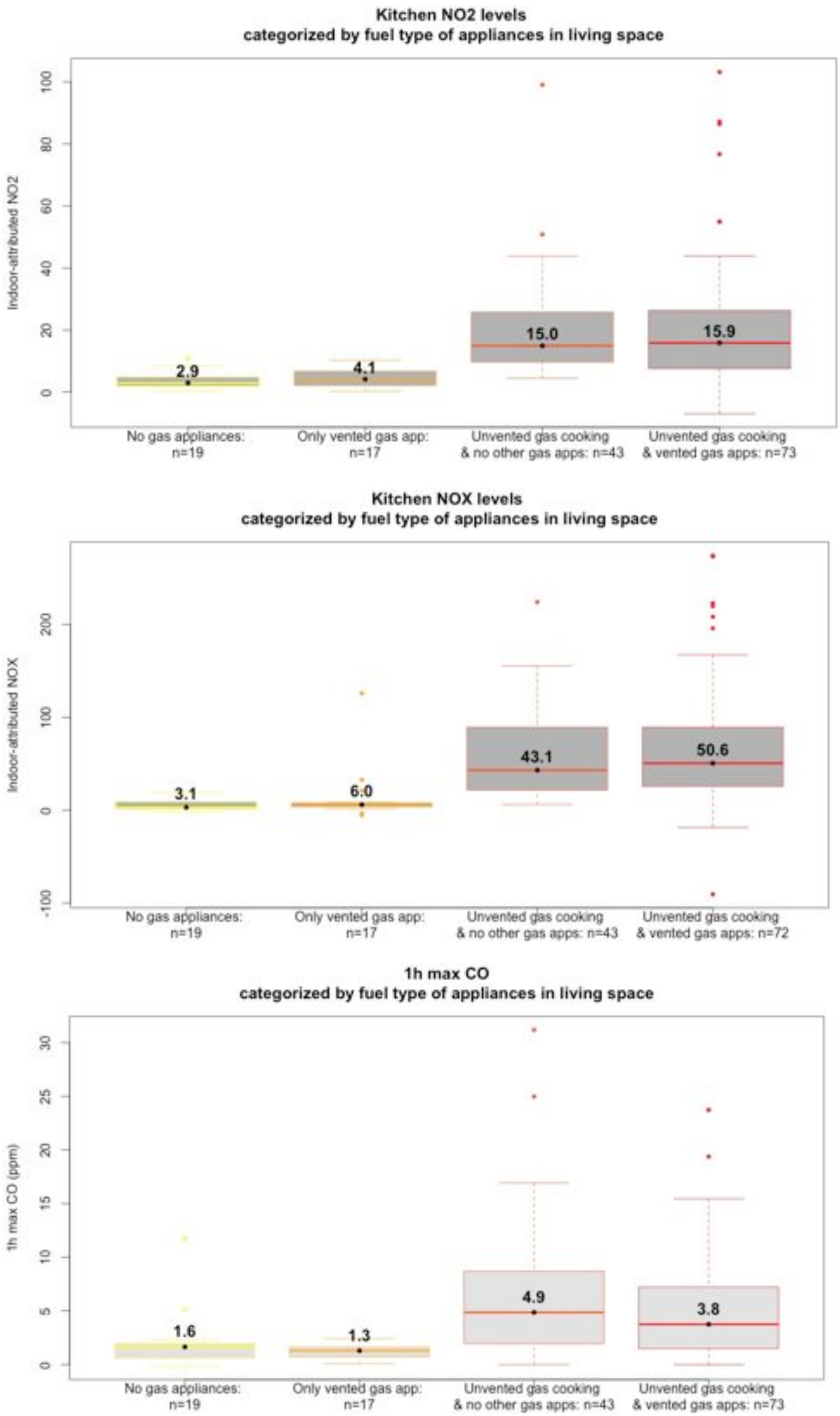
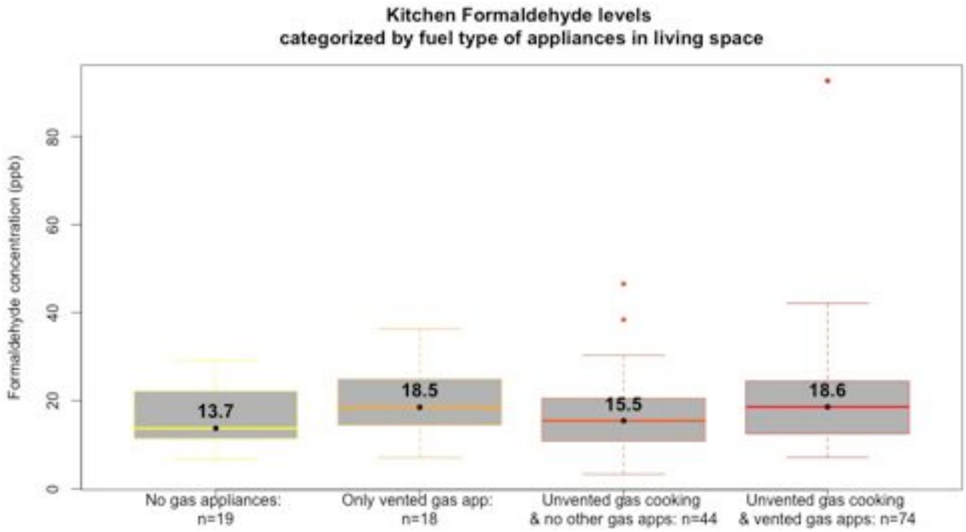


Figure 3.10. Impact of appliance types in living space on indoor-attributed kitchen NO_2 and NO_X and directly measured indoor 1-h max CO. Boxes show inter-quartile range (IQR). Whiskers span to the highest and lowest values within 1.5 IQR. Statistical difference was detected between groups without and those with unvented gas cooking appliances for all 3 pollutants.



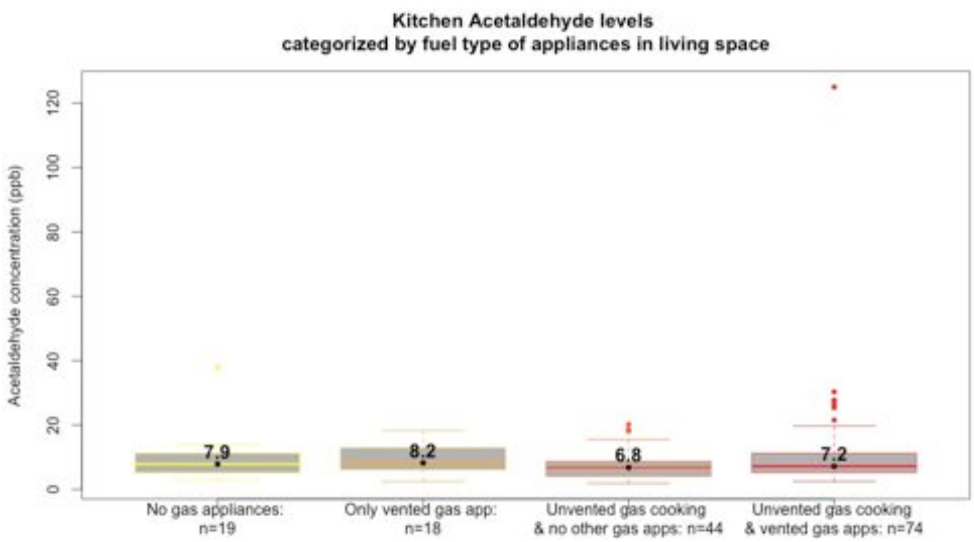


Figure 3.11. Impact of appliance types in living space on kitchen formaldehyde and acetaldehyde. Boxes show inter-quartile range (IQR). Whiskers span to the highest and lowest values within 1.5 IQR. No statistical difference between groups was detected for either pollutant.

Weekly cooktop usage

The impact of cooking fuel and frequency of cooktop usage on pollutant level was investigated by dividing the sample into six categories defined by (a) whether the cooktop was electric or gas, and (b) whether the residents cooked roughly once, twice, or more than twice per day. Box plots showing the results of this analysis for indoor-attributed NO_X and NO_2, and the highest 1-h CO concentrations measured in the kitchen are presented in Figure 3.12. A visual review of the plots suggests little difference or variation in pollutant levels resulting from different cooktop use frequencies at homes with electric appliances, which is expected since an electric appliance is assumed not to generate combustion pollutants. Conversely, pollutant levels do appear affected by the frequency of cooktop use in homes with gas cooktops. Analysis of these 6 groups with the Kruskal-Wallis test indicated a statistical difference between at least 2 of the groups for every pollutant ($p<0.05$). Two follow-up Mann-Whitney tests were conducted to further investigate differences by fuel and by amount of cooking for gas cooktops. The first test investigated the difference between homes that used an electric cooktop ≥14 times per week (i.e. high electric cooking) and those that used a gas cooktop for ≤7 times per week (i.e. low gas cooking). The test indicated that there was a significant difference ($p<0.05$) between the medians of the 2 groups for both bedroom and kitchen NO_X and NO_2, but not for CO. The second follow-up test investigated the difference between homes that used a gas cooktop ≤7 times per week (i.e. low gas cooking) and those that used a gas cooktop ≥14 times per week (i.e. high gas cooking). This test also indicated a statistical significant difference ($p<0.05$) in medians for NO_X and NO_2 but not the median 1-h max CO. Figure 3.13 shows the difference in kitchen formaldehyde and acetaldehyde concentrations among homes based on cooktop fuel type and cooking frequency. Both visual observation and the Kruskal-Wallis test confirm that there is no discernable difference in formaldehyde and acetaldehyde concentrations among these groups.

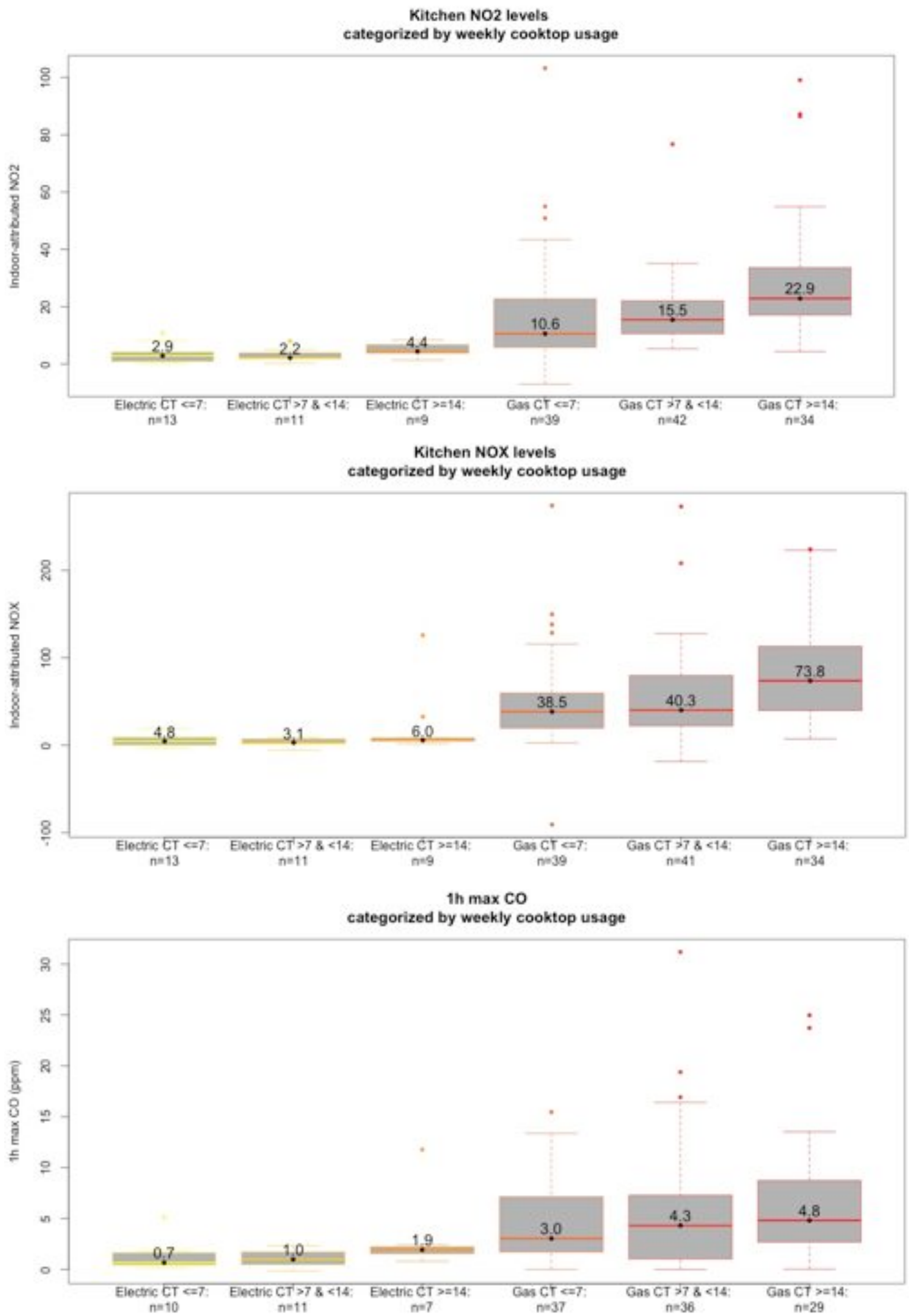


Figure 3.12. Impact of cooktop fuel and frequency of use on indoor-attributed NO_2 and NO_X, and highest 1-h CO concentrations. Boxes show inter-quartile range (IQR). Whiskers span to the highest and lowest values within 1.5 IQR. Statistical difference detected between at least two groups for all pollutants.

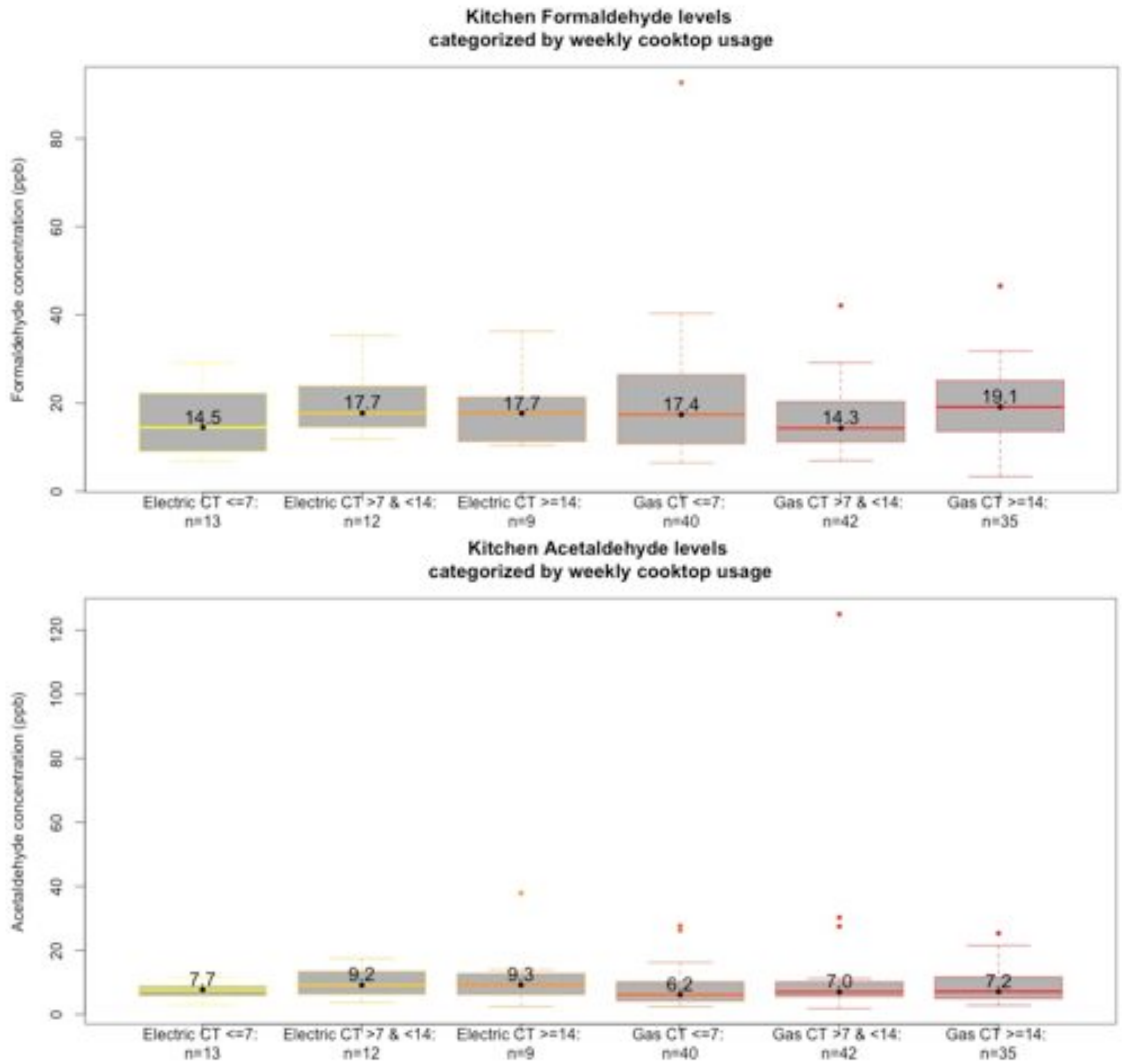


Figure 3.13. Impact of cooktop fuel and frequency of use on formaldehyde and acetaldehyde concentrations. Boxes show inter-quartile range (IQR). Whiskers span to the highest and lowest values within 1.5 IQR. No statistical difference between groups was detected for either pollutant.

A review of the cooking frequency box plots of the homes with gas cooktops indicates that there is a more substantial difference, for NO_2 and NO_X, and to a lesser extent CO, between the concentrations of the medium (>7x & >14x per week) and high cooking groups, versus between the concentrations of the low and medium cooking groups. The mass-balance box-model equation presented in the previous section (equation 1.1) provides some possible explanations for this result. According to this equation, the average pollutant concentration for a given group of homes is expected to increase with an increase in the total duration of cooking (n_i) or in the average pollutant emission rate of appliances (E_i), or with a decrease in the average home volume or air-exchange. In the case of this cooking frequency analysis, homes were categorized based on the total number of cooking events. However, the amount of time required to cook dinner is expected to be longer than the time required to cook breakfast or lunch (Klug et al., 2011). Thus, an increase in the number of dinners cooked between the two groups is expected to result in a greater concentration increase than would result from increases in cooking other types of meals. We conducted an analysis to see if the ratio of dinners cooked by the high and medium cooking group was higher than the ratio of dinners between the medium and low cooking groups. Figure 3.14 shows the average number of each type of meal cooked by each group included in the analysis. The medium cooking group for the gas cooking homes was characterized by 70% more dinners per week than the low cooking homes, but had roughly 2x more lunches and 3x more breakfast and “other” meals. Conversely, the average number of dinners was only slightly higher (5.7 vs. 5.1) for the high vs. medium cooking groups. Most of the difference between these groups is attributed to more breakfasts, lunches and other (non-meal) cooking events, i.e. to events of shorter duration. Thus, these results indicate that the proportional increase in the mean total cooking duration between the medium and high cooking is not likely to be higher than the proportional increase from the low to medium cooking groups.

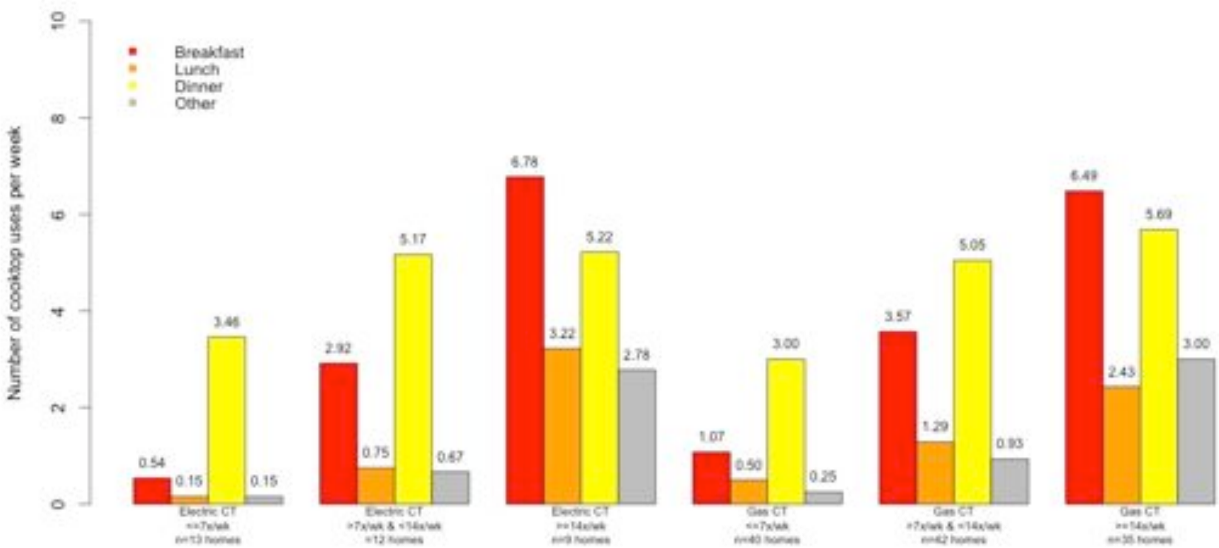


Figure 3.14. Average number of cook top uses per week for each type of meal, reported for 6 groups of home, categorized based on cooktop fuel and cooking frequency.

We decided to further explore the impact (or lack thereof) of cooking duration on the concentration of NO_2 and NO_X and CO in homes by estimating the total duration of cooking for each home using equation (3.1).

$$Total \quad cooking \quad time = N_B(t_B) + N_L(t_L) + N_D(t_D) + N_O(t_O) \qquad (3.1)$$

In this equation, N_B, N_L, N_D *and* N_O represent the number of times the participant reported using the cooktop to prepare breakfast, lunch, dinner and other meals during the week of sampling, respectively. Similarly, t_B, t_L, t_D and t_O represent the estimated duration of cooktop burner use when preparing breakfast, lunch, dinner and other meals, respectively. Duration of burner use for a given meal was estimated based on a cooking survey previously administered by Lawrence Berkeley National Lab, in which the majority of respondents reported using the cooktop for 6-10 minutes for breakfast or lunch, 16-30 minutes for dinner, and 1-5 minutes for “other” meals (Klug et al., 2011). Values of 8, 8, 23 and 3 minutes were selected for t_B, t_L, t_D and t_O, respectively. Subsequently, two regression analyses were performed with the estimated total cooking time as the independent variable, and with either pollutant concentration alone (indoor-attributed for NO_2 and NO_X and as measured for CO) or the concentration normalized by the floor area of the home as dependent variables. The results of this regression analysis (Table

3.5) further indicate that cooking duration is not one of the main factors influencing the concentrations of NO_2, NO_X and CO in the homes in this sample.

Table 3.5. Coefficient of determination (R^2) and slopes of regression of pollutant concentrations and normalized pollutant concentrations versus estimated total duration of cooking burner use.

	Bdrm. NO_2	Kit. NO_2	Bdrm. NO_X	Kit. NO_X	1-h max CO	8-h max CO
Raw concentration						
R^2	0.06	0.08	0.07	0.08	0.00	0.02
Slope	0.05	0.08	0.21	0.27	0.01	0.01
Concentration / (sq. ft. of floor area / 1000)						
R^2	0.03	0.04	0.04	0.04	0.00	0.00
Slope	0.06	0.09	0.21	0.25	0.00	0.00

Kitchen range hood use

Frequency of kitchen range hood use was the final characteristic for which differences in pollutant levels were analyzed. Based on first principles, if unvented gas cooking appliances are responsible for elevating pollutant levels in a home, removing pollutant emissions at the source via a kitchen range hood should result in a decrease in those levels. This effect was investigated by dividing homes that reported using a gas cooktop >7 per week into groups based on whether residents reported using their kitchen exhaust fan "most of the time," "about half of the time," or "rarely or never." Homes with recirculating kitchen exhaust fans were included in the "rarely or never" category. Box plots summarizing results of the comparison between these three groups for indoor-attributed kitchen NO_2, NO_X and highest measured 1-h CO concentration are shown in Figure 3.15. In the case of NO_2 and CO, median pollutant levels increased with decreasing kitchen exhaust fan use. However, in all cases, the difference between the groups was not statistically significant. As previously discussed, statistical analysis of homes with and without unvented gas cooktops indicated that homes with gas cooktops had higher levels of pollutants, particularly NO_X and NO_2. The lack of a significant influence of kitchen exhaust fan use at homes where gas cooking occurred often may result from one or more of the following factors: (1) a substantial fraction of kitchen exhaust fans were largely ineffective at removing exhaust gases under the conditions of operation (e.g. low speed operation, heavily soiled grease screens that impede airflow, poor design, etc.), (2) some fraction of kitchen exhaust fans thought by the participant to be venting were actually recirculating; or (3) the variability in pollutant emissions from gas cooktops across homes had a much larger effect than range hood use. Regarding factor (1), research has shown that operating a range hood fan on low while cooking on front burners may result in very low exhaust pollutant capture efficiency, particularly since most installed hoods have airflow rates below the manufacturer ratings (Delp and Singer, 2012; Singer et al., 2012). The majority of participants in this study reported using the front burners most often when cooking (68%); however, the fan speed reportedly used most often was fairly evenly distributed between low, medium and high settings (Appendix C, Tables C.35 and C.65). Follow-up work is needed to determine whether any of these factors were responsible for the lack of significant effect detected for kitchen exhaust fan use.

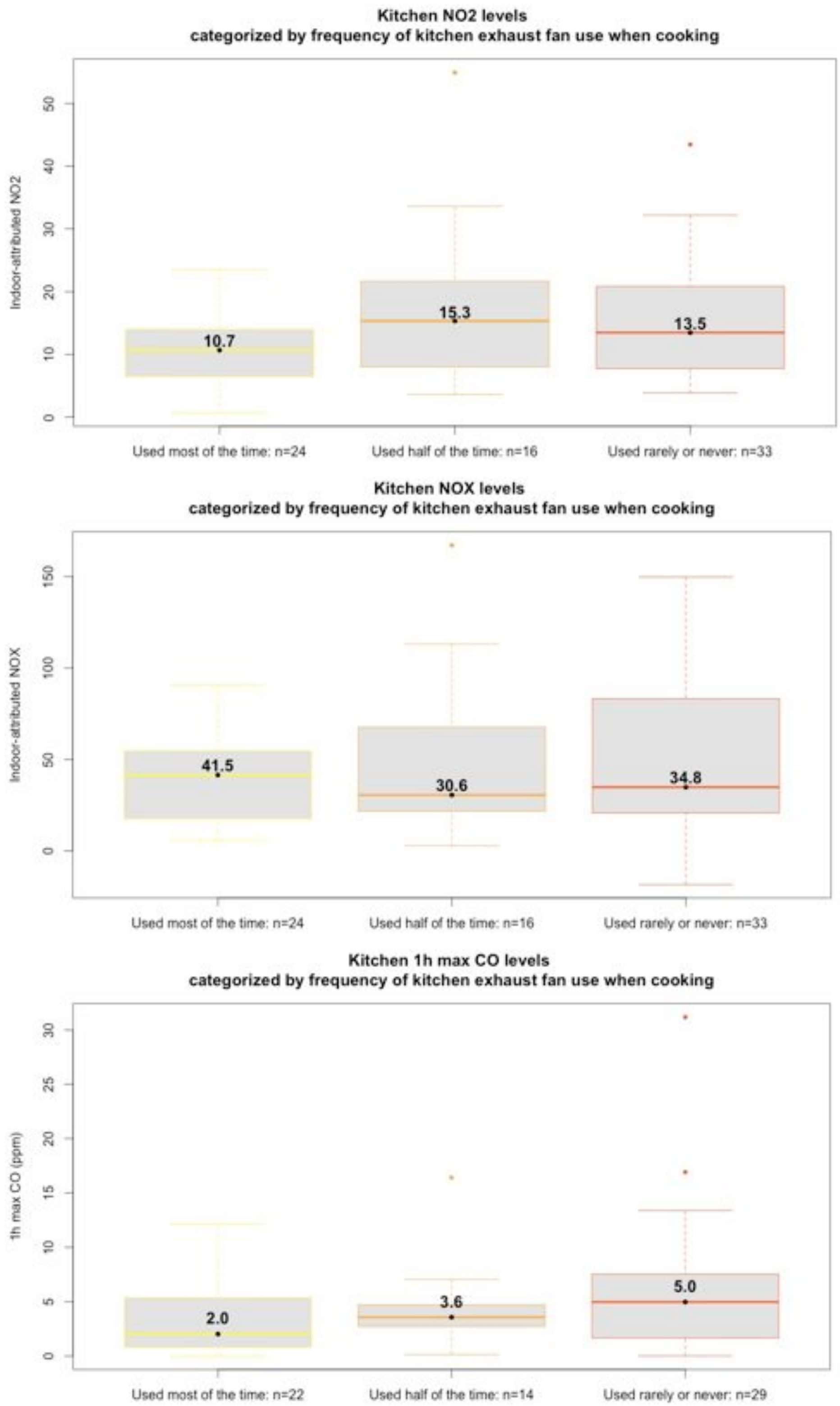


Figure 3.15. Impact of frequency of kitchen exhaust fan use among homes that used a gas cooktop often on kitchen NO_2, NO_X and highest 1 h CO concentration. Boxes show inter-quartile range (IQR). Whiskers span to the highest and lowest values within 1.5 IQR. No statistical difference between groups was detected for any pollutant.

4. Conclusions

Homes participating in this study were more likely to have indoor formaldehyde levels exceeding existing standards than to have any other measured pollutant exceed any existing indoor or outdoor standard. However, formaldehyde and acetaldehyde measured in homes in this study were lower than has been measured in past studies. Formaldehyde and acetaldehyde were not strongly influenced by gas appliance use, consistent with previous studies that have shown that other sources dominate indoor emissions of these pollutants. Conversely, NO_2 and NO_X, and to a lesser extent CO were correlated with use of gas appliances, particularly unvented gas cooktops. Of the 155 homes participating in the first year of this study, 3% had CO levels that exceeded an outdoor air quality standard and roughly 10% had NO_2 levels that exceeded the California Ambient Air Quality Standard for annual average concentration. Concentrations of formaldehyde, acetaldehyde, NO_2 and NO_X were similar in the bedroom and kitchen. CO was only measured in the kitchen. An obvious strategy for reducing pollutant emissions from cooking is to increase use and effectiveness of kitchen range hoods, since this technology already exists in many homes. Data from this study produced inconclusive results regarding the effectiveness of range hoods at reducing pollutant concentrations, possibly due to mischaracterization of whether or not range hoods were exhausting to the outdoors or were functioning properly, or due to a low capture efficiency of the range hood resulting from the predominant use of front cooktop burners by participants in this study. Consequently, more work is needed to determine if use of current kitchen range hoods is an effective strategy for reducing pollutants produced by gas cooking appliances, and whether their effectiveness can be improved by modifying residents' cooking habits.

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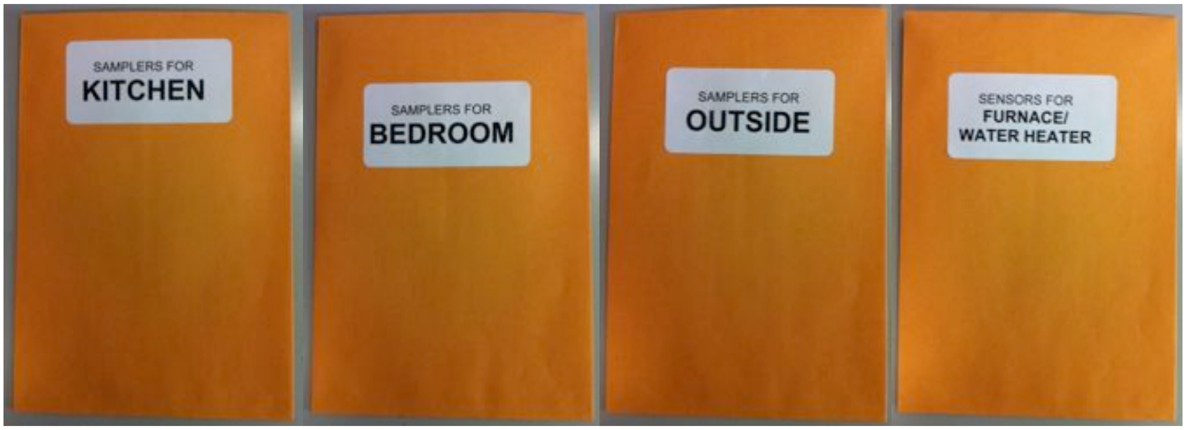
Appendices

A. Instructions mailed to residents

Instruction templates were created at the beginning of the study to be modified each week before sending to each home participating by mail. A different template was used for homes depending on whether they would receive packages via US Postal Service or Fed-Ex, and whether they would be deploying blanks or duplicate samples. An example set of instructions is included in this appendix. This set would be sent to a home receiving and resending the package of air samplers via FedEx, deploying blank but not duplicate samplers, and deploying sensors outside and on a water heater and furnace.

Hello **[Participants Name],**

This package contains the air samplers for your home. Inside this package, you will see **2** metal containers, **4** envelopes and **1** prepaid FedEx shipping label. If any of the envelopes or containers shown in the pictures below are missing, please call Nasim Mullen (510-517-2357) as soon as possible.



Air samplers for the *KITCHEN* | Air samplers for *BEDROOM* | Air samplers for *OUTDOORS* | Sensors for *FURNACE* and *WATER HEATER*

Containers for mounting air samplers in your home (Note: Lid of indoor container is for bedroom and base is for kitchen)

Padded manila envelope with prepaid FedEx shipping label

Instructions for setting up the samplers in each location are inside the envelopes. **Please open one envelope at a time and complete the setup before opening the next envelope.** This will help avoid mixing up samplers for different locations.

The instructions for each location ask you to take 2 pictures of the samplers: One picture close up, and one further away that shows where the samplers are in the room. If it is possible to take these pictures digitally, please send them to Nasim Mullen by email (Nmullen@lbl.gov) or text messaging (510-517-2357).

When you complete the setup at all locations, please put the envelopes, instructions and pre-paid return mailer in a safe place.

The samplers should require no maintenance during the week. Please conduct all of your normal activities.

After 6 days, follow the instructions in each envelope for repacking the samplers. Please put all of the envelopes in the return mailer(s) and send them back as soon as possible. A researcher will call you to see if you have any questions about preparing or mailing the package.

Please text Nasim Mullen at 510-517-2357 or email her at Nmullen@lbl.gov, when the package has been put in a FedEx drop box.

Here are FedEx drop off locations close to your home:

[Enter at least 3 addresses here]

After the samplers have been received in our laboratory and the exit survey has been completed over the phone, we will mail you $75 as a token of our appreciation.

Thank you for participating in the Healthy Homes Indoor Air Quality Study!

INSTRUCTIONS:
Setting up air quality samplers in your *KITCHEN*

Here is what is included in this package:

Formaldehyde sampler
inside airtight bag

SET-UP INSTRUCTIONS

1. Take the tin labeled “KITCHEN” on one side and “BEDROOM” on the other side. Separate the two pieces from each other. Put the lid (BEDROOM container) aside. Follow the instructions below to set up the KITCHEN container.

2. Find the bag labeled “Formaldehyde (Kitchen)” (blue dot), and cut top along dotted line. Take the formaldehyde sampler out from the bag, and remove the caps from both ends, as shown below. Put caps into the airtight bag for safekeeping.

3. Push the narrow end of the formaldehyde sampler into the metal holder, as shown below.

4. Remove nitrogen dioxide sampler labeled “Kitchen” from its airtight bag (red dot). Push it into the white clip, as shown below.

5. Find the temperature sensor labeled “kitchen” and, using the magnet on the back, attach it to the open space inside the container, as shown below.

6. Put the container in the location selected when you spoke with a researcher on the phone. Specifically: *On the refrigerator, in a location that will be out of your way, and that is not too close to the cooktop and/or oven.*

7. Please take two pictures of the samplers: One picture close up, and one further away showing where the samplers are in the kitchen. If possible, please email pictures to Nasim Mullen (Nmullen@lbl.gov).

8. Below is an example picture of the sampling package on a refrigerator.

9. Keep the nitrogen dioxide *and* formaldehyde BLANKs (yellow dot) inside of their airtight bags. Do not open them.

10. Write the day and time that the samplers were removed from their airtight bags in the space below. It is very important to record the time that you set up the samplers.

DAY or DATE: **TIME:**

11. Put the now empty airtight bags and the nitrogen dioxide and formaldehyde BLANKs back inside the manila envelope. Place the envelope inside the prepaid mailer, and place the mailer in a location where you will be able to find it when preparing to mail back the samplers in one week.

12. Carry out your household activities as usual.

PACKING INSTRUCTIONS

1. Collect the container with samplers in the kitchen. Get the manila envelope marked KITCHEN samplers.

2. Remove the temperature sensor and put it in the manila envelope.

3. Remove the formaldehyde sampler from the metal holder. Find the caps inside the airtight bag (blue dot). Replace caps on both ends of each formaldehyde sampler. Caps should be on tightly.

4. Put the now recapped formaldehyde sampler into its airtight bag and close the bag tightly by pinching the seal like a Ziploc bag.

5. Remove the nitrogen dioxide sampler from the white clip. Place it in its airtight bag (red dot). Close the bag tightly by pinching the seal like a Ziploc bag.

6. Write the day and time that the samplers were sealed in their airtight bags in the space below. It is very important to record the time that you packaged the samplers.

DAY or DATE: **TIME:**

7. Open up the nitrogen dioxide **blank** (yellow dot). Pull the sampler out of the bag for about 10 seconds, and then put the sampler back in the bag and close it tightly by pinching the seal like a Ziploc bag.

8. Next, *cut* the bag for the formaldehyde sampler **blank** (yellow dot) *along the dotted line*. Pull formaldehyde sampler **blank** out from the bag and remove both caps. Hold the sampler in open air for about 10 seconds, and then replace the caps. Put the sampler back in the bag and close it tightly by pinching the seal like a Ziploc bag.

9. Place the 4 sealed airtight bags with the samplers into the manila envelope.

10. Put the manila envelope into the return mailer.

11. After you have also repackaged the bedroom air samplers, close the two containers up, so that they become one container. Put the closed container into the return mailer.

12. Put these instructions in the return mailer.

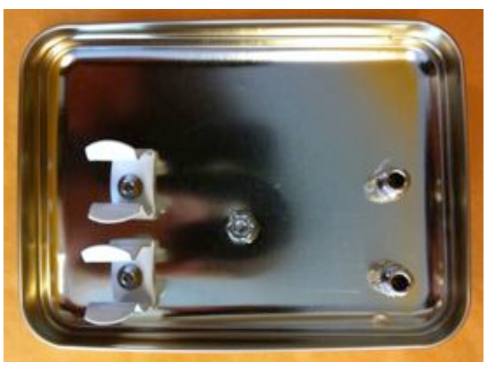
INSTRUCTIONS:
Setting up air quality samplers in your *BEDROOM*

Here is what is included in this package:

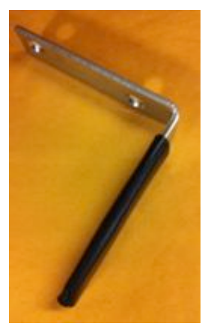
Formaldehyde sampler inside airtight bags

Nitrogen dioxide sampler inside airtight bags

Temperature Sensor



Bedroom Container



L-Bracket

SET-UP INSTRUCTIONS

1. Take the tin labeled "KITCHEN" on one side and "BEDROOM" on the other side. Separate the two pieces from each other. Put the bottom (KITCHEN container) aside. Follow the instructions below to set up the BEDROOM container.

2. Find the bags labeled "Formaldehyde (Bedroom)" (orange dot), and <u>cut top along dotted line</u>. Take the formaldehyde sampler out of the bag, and remove caps from both ends, as shown below. Put caps into the airtight bag for safekeeping.

3. Push narrow end of the sampler into one of the metal holders, as shown below.

4. Remove the nitrogen dioxide samplers from its airtight bag (green dot), and push it into the white clip, as shown below.

5. Write the day and time that the samplers were removed from their airtight bags in the space below. It is very important to record the time that you set up the samplers.

   DAY or DATE: **TIME:**

6. Attach the L-bracket to the magnet on the back of the bedroom container, so that it acts as a stand for the container (see picture below).

7. Find the temperature sensor labeled "Bedroom" and attach it to the back of the bedroom container on the magnet, as shown below.

8. Put the container in the location discussed with a researcher on the phone. Specifically: In your childn's bedroom, on a table or dresser that has *not* been recently polished or painted.

9. Please take two pictures of the samplers: One picture close up (showing the samplers on the front of the tin), and one further away showing where the samplers are located within the room. If possible, email the pictures to Nasim Mullen (Nmullen@lbl.gov)

10. Below is an example of the bedroom sampling package set-up on a flat surface.

11. Put the now empty airtight bags and these instructions inside of the manila envelope. Place the envelope inside the prepaid mailer, and place the mailer in a location where you will be able to find it when preparing to mail back the samplers in one week.

12. Carryout your household activities as usual.

PACKING INSTRUCTIONS

1. Collect the container with samplers from the bedroom. Get the manila envelope marked BEDROOM samplers.

2. Remove the temperature sensor from the bedroom container, and place it into the manila envelope.

3. Remove the formaldehyde sampler from the metal holder. Take the caps out of the airtight bag (orange dot). Replace caps on both ends of the formaldehyde sampler. Caps should be on tightly.

4. Replace the now recapped formaldehyde sampler in its airtight bag (orange dot) and close the bag tightly by pinching the seal like a Ziploc bag.

5. Remove the nitrogen dioxide sampler from the white clip. Place the nitrogen dioxide samplers in its airtight bags (green dot). Close the bag tightly by pinching the seal like a Ziploc bag.

6. Place the 2 sealed airtight bags with the samplers into the manila envelope labeled BEDROOM samplers.

7. Write the day and time that the samplers were sealed in their airtight bags in the space below. It is very important to record the time that you packaged the samplers.

   DAY or DATE: **TIME:**

8. Put the manila envelope into the return mailer.

9. Combine the bedroom container with the kitchen container, so they form one closed container. Place the closed container inside of the return mailer.

10. Put these instructions into the return mailer.

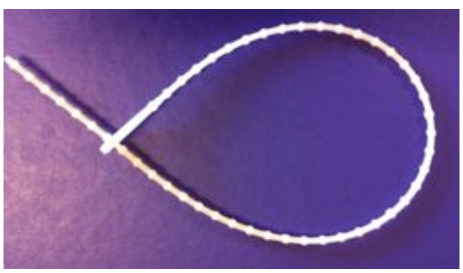
INSTRUCTIONS:
Setting up air quality samplers *OUTSIDE* your home

Here is what is included in the package:

Container with temperature sensor

Nitrogen dioxide sampler inside airtight bag

Formaldehyde sampler inside airtight bag


2 Releasable Ties
(For hanging container and holding it closed)

SET-UP INSTRUCTIONS:

1. Remove the lid of the outdoor container.

2. Remove the nitrogen dioxide sampler from the airtight bag (purple dot). Push the sampler into the white clip, as shown below.

3. Find the bags labeled "Formaldehyde (Outside)" (pink dot), and cut top along dotted line. Take the formaldehyde sampler out of the bag, and remove caps from both ends, as shown below. Put caps into the airtight bag for safekeeping.

4. Push the narrow uncapped end of the sampler into the metal holder on the side of the container, as shown below.

5. Write the day and time that the samplers were removed from their airtight bags in the space below. It is very important to record the time that you set up the samplers.

   DAY or DATE: **TIME:**

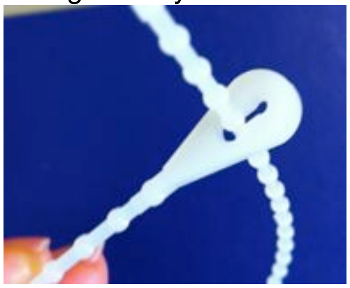
6. Put the lid back on the outdoor container.
7. Take a releasable tie and tighten it around the width of the container, as shown below. (*If you have trouble clasping the tie, please refer to the instructions on the next page. If you still have trouble, skip this step.)*

8. Put the container outside in a location where it will be secure and ideally has some protection from the elements (e.g. under a covered patio). It will also be ideal if it is not too close to the wall of the home, but it's okay to hang it from a doorknob if that is the best location.
9. Please take two pictures of the outdoor sampler: One picture close up, and one further away showing some of the surroundings. If possible, email the pictures to Nasim Mullen (Nmullen@lbl.gov)
10. There are many different ways that the releasable tie or magnet can be used to set-up the container. Pictures with different examples are shown below.

11. Put the now empty airtight bags and these instructions into the manila envelope. Place the envelope inside the prepaid mailer, and place the mailer in a location where you will be able to find it when repackaging the samplers next week.

Instructions for clasping the releasable tie

1. Thread the narrow end of the tie through the eyehole at the other end, as shown below.



2. Once you have the right sized loop, push a narrow segment of the tie into the notched end of the eyehole, as shown below.

PACKING INSTRUCTIONS

1. Remove the container from its outdoor location and find the return mailer and manila envelope labeled "OUTSIDE".
2. Release the tie from around the outdoor container and remove the lid. If you can't release it by hand, feel free to cut it with scissors.
3. Pull the formaldehyde sampler out of the metal holder. Locate the caps from inside of the airtight bag (pink dot). Replace caps on both ends of each formaldehyde sampler. Caps should be on tightly.
4. Place the now recapped formaldehyde sampler inside of its airtight bag. Close the bag tightly by pinching the seal like a Ziploc bag.
5. Remove the nitrogen dioxide sampler from the white clip, and put it in its original airtight bag (purple dot). Close the bag tightly by pinching the seal like a Ziploc bag.
6. Write the day and time that the samplers were sealed in their airtight bags in the space below. It is very important to record the time that you packaged the samplers.

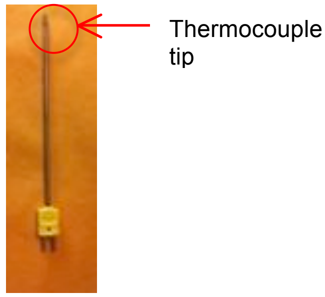
   DAY or DATE: **TIME:**

7. Place the sealed airtight bags into the same manila envelope
8. Place the manila envelope into the return mailer.
9. Replace the lid on the outdoor container and put it into the return mailer.
10. Put these instructions into the return mailer.

INSTRUCTIONS:
Setting up sensors on the WATER HEATER and FURNACE

<u>Here is what is included in this package</u>:

Temperature logger (bigger)



Thermocouple

Temperature sensor (smaller)

SET-UP INSTRUCTIONS

Furnace

12. Put this temperature sensor near a vent where warm air is supplied by your furnace, as discussed when you last spoke with a researcher on the phone. Specifically: *Put the sensor on one of the vents where warm air is supplied to the room.*

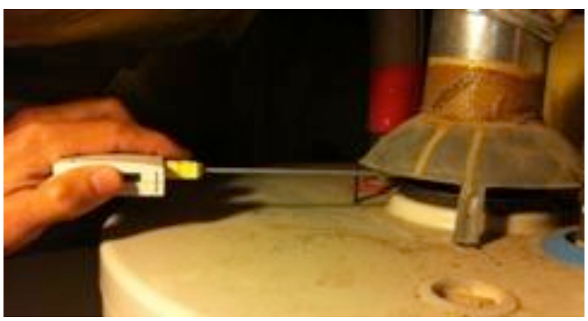
13. Please take two pictures of the temperature sensor: One picture close up, and one further away showing where the heater is located in the room.

14. Below are pictures of the temperature sensor placed on different types of furnace supply vents. You can make sure this is a warm air *supply* vent, by turning on the furnace and feeling for warm air.

Water Heater

1. Remove the thermocouple from its clear plastic case. **Make sure not to jam the tip of the thermocouple, or it will no longer work**
2. Insert the thermocouple into the logger as shown in the picture below. Make sure that the red and blue dots line up.

3. **The water heater and especially the metal exhaust cone above the water heater may be hot.** Wait for a time when the water heater burner is off to install the temperature logger and thermocouple. The best time is when the hot water has not been used in a while. The burner makes a loud whooshing noise when on. If you hear this noise check again after about 20 minutes.
4. When the water heater burner is *OFF*, hold the logger and position the thermocouple under the water heater exhaust cone, as shown below. **Do not touch the exhaust cone and NEVER put your hand underneath it even when the burner is off**.




5. Once the thermocouple is under the exhaust cone, carefully set the logger on top of the water heater tank. The magnet at the edge should help hold it in place. A picture is shown below for two different water heaters.


6. Put the thermocouple protective case back into the manila envelope, and put the manila envelop in the return mailer. Put the return mailer in a place where you will find it in 1-week.

7. Please take two pictures of the thermocouple and data logger: One picture close up, and one further away showing the full water heater tank.

8. Continue your household activities as usual for 1-week.

PACKING INSTRUCTIONS

1. Carefully rotate the logger on its side to pull the magnet away from the water heater surface, as shown below.

2. Carefully pull the thermocouple away from beneath the exhaust cone.

3. Remove the thermocouple from the temperature logger and put the thermocouple back into the plastic protective case.

4. Place the logger and thermocouple back into the manila envelope that they came in.

5. Remove the temperature sensor from the furnace supply and place it back in the manila envelope with the thermocouple.

6. Put the manila envelope in the return mailer.

B. Final report sent to participants

[Date]

Dear [Participant Name]

Thank you again for participating in the Healthy Homes Study. The indoor air quality measurements in your home are provided on the following pages. This first page presents background information intended to help you interpret the results.

The U.S. Environmental Protection Agency (EPA) and the California EPA each set air pollutant standards. The standards are designed to protect the health of the general population including groups of people that may be more sensitive to air pollution.

Standards are set for a concentration – an amount of pollutant in a volume of air – that should not be exceeded over some period of time. In this report, we present air pollutant concentrations, or levels, as parts per million (ppm) or parts per billion (ppb). A level of 100 ppb means that there are 100 molecules of pollutant for every 1 billion molecules of air.

Health problems can result from acute, short-term exposure to very high levels or from chronic, long-term exposure to lower levels of pollutants. Short-term pollutant standards can be for 1 hour, 8 hour, or 24 hour periods. Long-term air pollutant standards are often set for a period of 1 year or longer.

U.S. and California standards are generally similar but are not the same in all cases. This is because there is no specific level that is safe for everyone, and the process of choosing a level to protect public health involves both science and policy considerations.

The background information in this report is intended only as an introduction to air pollutant hazards and standards. Additional information can be obtained via these sites:
U.S. EPA Indoor Environments Division: http://www.epa.gov/iaq/
California Air Resources Board: http://www.arb.ca.gov/research/indoor/indoor.htm
California Dept. of Public Health: http://www.cal-iaq.org/

Listed on the following pages are U.S. and California standards and the concentrations of pollutants that were measured in your home.

Sincerely,

Dr. Brett C. Singer Dr. Nasim Mullen

The Healthy Homes Project Team

Carbon Monoxide (CO)

Carbon Monoxide (CO) is an odorless, colorless gas that is formed during the burning of fuels including natural gas. When combustion is complete, CO is entirely converted to carbon dioxide. Under many conditions, small amounts of CO may be emitted in the combustion products. CO can be toxic to humans and animals. The U.S. EPA and California EPA each set standards for carbon monoxide levels that should not be exceeded over 1-hour and 8-hour periods.

The device sent to your home recorded a CO reading every minute. From this, we calculated the highest 1-hour and 8-hour average levels in your kitchen. The table below presents the levels in your kitchen and also outdoors in your area during the same time period. The outdoor level was measured and reported by the government agency that is responsible for monitoring air quality in your area.

	Highest **1-hour**	Highest **8-hour**
U.S. Standard	35 ppm	9 ppm
California Standard	20 ppm	9 ppm
Outdoors in your area		Not reported
CO in your Kitchen		

How to use this information

[Select one of three responses provided at end of this document]

Nitrogen Dioxide (NO_2 – pronounced "N-Oh-2")

Nitrogen Dioxide (NO_2) is formed during combustion. Outdoors it gives "smog" its characteristic brown tint. It irritates the lungs and respiratory tract. The U.S. EPA and California EPA each set NO_2 standards for 1-hour and annual periods. Our samplers collected NO_2 throughout the time they were set up in your home. We measured the total amount of NO_2 collected to calculate the average level over the sampling period. This measurement should be compared to the annual rather than the 1-hour standard because it is more representative of long-term than of peak conditions. The concentrations in your home over a full year may be lower or higher than the value measured during the study.

The table below presents the levels measured in your home and also outdoors in your area during the same time period. The outdoor level was measured with one of our samplers placed outside in your area over roughly the same period as the sample in your home.

U.S. Annual Standard	53 ppb
California Annual Standard	30 ppb
Outdoors in your area*	
NO_2 in your Kitchen	
NO_2 in your Bedroom	

How to use this information?
If concentrations in your home are much higher than outdoors, there is a major source of NO_2 in your home. The most common source in California homes is a natural gas stove. If you have a gas stove, you should use a kitchen exhaust fan or range hood that exhausts to outdoors every time you use your stove. If you don't have an exhaust fan or range hood, you can open windows when cooking to increase ventilation. Vent-free fireplaces and heaters also emit NO_2 but these are uncommon in California.

Formaldehyde
Formaldehyde is a colorless gas that has a pungent, irritating odor at levels that are much higher than those seen in homes. Most people cannot smell it at levels common in homes. Formaldehyde is emitted from many different materials found in homes. It is also produced during combustion and from some cooking. It can be toxic to humans and animals when encountered in high concentrations. Standards for formaldehyde have a somewhat different form than those for CO and NO_2. The California EPA sets acute and chronic "reference exposure levels" (RELs) as the concentration to which sensitive subgroups can be exposed without noticeable harm. The 8-hour and chronic RELs are both set at 7 ppb.

The table below presents the concentrations measured in your home and also outdoors in your area during the same time period. The outdoor level was measured with one of our samplers placed outside in your area over roughly the same period as your home sample.

California 8-h Reference Exposure Level	7 ppb
California Chronic Reference Exposure Level	7 ppb
Outdoors in your area*	
Formaldehyde in your Kitchen	
Formaldehyde in your Bedroom	

How to use this information?
Unfortunately, it is very common for homes to have formaldehyde concentrations higher than the reference exposure levels noted above. In a recent study of new homes in California, almost all of the homes had formaldehyde concentrations higher than 7 ppb. Usually, the largest source of formaldehyde in homes is emissions from composite wood products. These materials are often built into the home and cannot easily be removed. Cooking burners, cooking of food and chemical reactions involving some air fresheners and cleaning products can add formaldehyde. If you are concerned about the level in your home, one action you can take is to avoid sealing the house without any ventilation for long periods of time and using kitchen exhaust when cooking. Since formaldehyde levels outdoors are usually much lower, daily ventilation can help reduce concentrations indoors.

CO Interpretations:

[Response for homes with few or no CO concentration spikes that would indicate indoor source(s), i.e. no more than one spike above 7 ppm.]
The measured concentrations were low and suggest that there are no regular sources of CO in your home. Still, California law requires that all homes have working carbon monoxide alarms. We recommend that you install an alarm in your home as soon as possible. Having this alarm will ensure that you are alerted if CO levels increase in the future.

[Response for homes with at least one concentration spike above 10 ppm or at least 2 spikes above 7 ppm, and no exceedances of 1-h or 8-h standard levels.]
The measured concentrations were below standards but they suggest that there may be a source of carbon monoxide in your home. California law requires that all homes have working carbon monoxide alarms. We recommend that you install an alarm in your home as soon as possible. Having this alarm will ensure that you are alerted if CO levels increase in the future.

[Response for homes with: 1-h mean ≥ 10 ppm]
The measured concentrations were at a level that result only when there is a substantial source of CO in your home. A common source of CO in the home is exhaust from a gas stove, gas oven, or any other gas appliance being used in the home without proper venting. If you have a venting range hood, we recommend that you use it each time you operate any cooking burner. CO can also come from an idling vehicle in an attached garage, smoking, incense, or any other combustion process occurring in the home. California law requires that all homes have working carbon monoxide alarms. We recommend that you install an alarm in your home as soon as possible. . If the concentration exceeded one or more of the air quality standards, we strongly recommend that you contact PG&E at 1-800-PGE-5000 and tell them that you are concerned about a source of CO in your home.

C. Participant Questionnaires

All participants of this study conducted by LBNL completed three questionnaires. The first was intended for screening purposes and was completed online. This “screening” survey collected basic information regarding the household, home and types of appliances presented. The second questionnaire is the longest of the three, and features questions about the home and appliances as well as activities and occupancy patterns. This was administered to all participants by telephone roughly 1-2 weeks prior to sampling and took roughly 20-30 minutes to complete. The third questionnaire was administered at the end of the sampling week. It was administered by telephone for homes with mail-out samplers or in person for homes that are visited to collect samplers. This second questionnaire took roughly 10-20 minutes to complete. Within the documents that follow, notes to researcher conducting the interview are in italics.

1. SCREENING SURVEY

(Telephone script; will adapt for web site.)

Upon learning that the call is related to the Exposure Study:

Thank you for calling about our study.

Do you understand that this is a study about indoor air quality in California homes, that in this study we will gather information through air sampling in the homes and by asking questions about the homes, and that once you have completed your participation in the study you will receive $75 payment? _____Yes _____No

If not, note the items mentioned on the announcement and website.

If you are interested in participating, the first step is a quick screening survey. I will ask you a few questions about your home and appliances. The purpose is to confirm your eligibility and to provide the information needed to characterize your home for selection. The information may be used to characterize the groups of people who responded with interest in this study. This will be done anonymously and only in groups; no individuals will be identified. You may stop the screening survey at any time. If you are eligible and interested, I will ask for your contact information at the end of this call. This information will be used only to contact you about this study or about follow-ups to this study. It will not be shared with anyone.

Do you have any questions before we start the screening survey?

Answer any questions.

May we proceed with the screening survey? ____Yes _____No → Go to “thank you”.

1. Are you 18 years or older?
   _____Yes _____No → The study requires involvement of an adult resident of the home. Is there someone available who is 18 or older?

2. Is this home located in California?
   _____Yes _____No → Not eligible, go to “thank you”.

3. Is smoking prohibited in the home?
   _____Yes _____No → Not eligible, go to “thank you”.

4. Which fuel is used to power your cooktop?
   a. Natural gas
   b. Propane
   c. Electricity
   d. Don’t know
   e. Don’t have one

5. Which fuel is used to power your oven?
   a. Natural gas
   b. Propane
   c. Electricity
   d. Don’t know

e. Don't have one

6. Which fuel is used to power your water heater?
   a. Natural Gas
   b. Propane
   c. Electricity
   d. Don't know
   e. Don't have one

7. On average, how often do you use your cooktop, including for activities like boiling water?
   _____Less than once per week
   _____1 to 3 times per week
   _____4 to 7 times per week
   _____More than 7 times per week (meaning, more than once per day)

8. On average, how often do you use your oven?
   _____Less than once per week
   _____1 to 3 times per week
   _____4 to 7 times per week
   _____ More than 7 times per week

9. Is there a range hood or other exhaust fan in your kitchen, and if so, which kind?
   _____Range hood
   _____Exhaust fan on ceiling or wall above cooktop
   _____Exhaust fan in kitchen but not above cooktop
   _____Downdraft exhaust
   _____No range hood or exhaust fan
   _____I don't know

10. If there is an exhaust fan, does it work (is it operational)?
   _____Yes
   _____No
   _____I don't know

11. If you have a range hood, does it blow air outside or back into the kitchen?
   _____Outside
   _____Back into the kitchen
   _____I don't have a range hood
   _____I don't know

12. How often is a range hood or other kitchen exhaust fan used when cooking occurs on the *cooktop* in your home?
   _____Always or often used with cooktop
   _____Used as needed with cooktop
   _____Rarely or never used with cooktop
   _____Exhaust fan is broken
   _____No kitchen exhaust fan

13. How often is a range hood or other kitchen exhaust fan used when the *oven* is used in your home?
   _____Always or often used with oven
   _____Used as needed with oven

_____Rarely or never used with oven
_____Exhaust fan is broken
_____No kitchen exhaust fan

14. Where is your water heater located?
_____Outside
_____Basement or garage under living space
_____Side-attached garage
_____Closet in main living area
_____Laundry room
_____Attic
_____Other location in the main living area

15. Which of the following types of heaters is used as the main source of heat in your home?
_____Gas powered forced-air furnace
_____Wall furnace
_____Floor furnace
_____Cooking oven or stove
_____Gas fireplace or room heater
_____Wood or pellet stove or fireplace
_____Heat pump or electric forced air furnace
_____Baseboard electric
_____Electric space heater
_____Other. Please describe:
_____Don't know

16. Where is your main heater located?
_____Outside
_____Basement or garage under living space
_____Side-attached garage
_____Closet in main living area
_____Laundry room
_____Other location in the main living area
_____Don't know

17. Do you use any other heaters in addition to your primary heater? Please indicate which of the following are used. These will be referred to as supplemental heaters
_____Gas powered forced-air furnace
_____Wall furnace
_____Floor furnace
_____Cooking oven or stove
_____Gas fireplace or room heater
_____Wood or pellet stove or fireplace
_____Heat pump or electric forced air furnace
_____Baseboard electric
_____Electric space heater
_____Other. Please describe:
_____No supplemental heater used
_____Don't know

18. How often is your *supplemental heater* used in January and February. If you don't know for sure, please feel free to estimate:
    _____Few times or more each day
    _____Few times each week but not every day
    _____Less than a few times each week
    _____I don't recall

19. [*If gas fireplace is present]* Is your gas fireplace vented or is it "vent-free"?
    _____Vented
    _____Vent-free
    _____Don't know

20. To your knowledge, has the home or building been renovated by a contractor to reduce air leakage. Common air sealing measures include weather-stripping on doors and windows, caulking to seal cracks, addition of insulation, and sealing of heating ducts.
    _____Yes
    _____No
    _____Don't know
    If yes, was this done as part of a government Weatherization program?
    _____Yes
    _____No
    _____Don't know

21. To your knowledge, was your home designed and/or constructed to be any of the following (check all that apply):
    _____ Passive House
    _____Net-Zero Energy home
    _____Green certified home
    _____None of these
    _____I don't know

The next questions are about the building and about your household. We are asking these questions to help us select a sample of homes that captures the diversity of California.

22. In what kind of building do you live?
    _____Single, detached house
    _____Townhouse or Side-by-Side Duplex
    _____Apartment building with 2-4 units
    _____Apartment building with 5 or more units
    _____Mobile home

23. In what year was the building constructed? If you are unsure it is okay to make your best guess and to note that you are "unsure".
    ______Before 1980
    ______Between 1980 and 1994
    ______Between 1995 and 2005
    ______2006 or newer
    ______Unsure
    ______I have no idea

24. Do you own or rent your home?
    _____Own
    _____Rent
    _____Other

25. How large is the floor area of your home in the units of square feet (sq. ft.)? If you are unsure it is okay to make your best guess or to let me know that you are “unsure”.
    _____Less than 500
    _____500 to 1000
    _____1000 to 1500
    _____1500 to 2000
    _____Greater than 2000
    _____Unsure
    _____I have no idea

26. How many people live in your home?
    _____1-2
    _____3-4
    _____5 or more
    _____I would rather not say

27. What is the combined annual income of all members of your household? If you are unsure, please feel free to make your best guess and also note that you are “unsure”.
    _____Less than $30,000
    _____Between $30,000 and $60,000
    _____More than $60,000
    _____Unsure
    _____I would rather not say

If you are still interested in participating there are just a few last questions to confirm your eligibility.

28. Are you willing to complete two telephone surveys that will take between 10-30 minutes each?
    _____Yes   _____No → Not eligible, go to “thank you”.

29. If you are selected to participate, how would you like to receive samplers? (Would you prefer to have us send samplers to you in the mail OR visit your home to deliver and pick up the samplers OR are you fine with either option?)
    _____Only interested in samplers sent by mail
    _____Only interested if research team visits home to set up sampler
    _____Interested in either approach

30. *(If interested in sampler by mail)*: Are you willing to return to us a small package of monitoring devices that we will send to you in the mail? (If you choose to set-up the samplers yourself, we will provide detailed instructions and will help you by phone.)
    _____Yes   _____No → Not eligible for this option, go to next question or “thank you”.

31. *(If interested in sampler by mail)*: If air samplers are mailed to your house, they should be set up on Tuesday and repackaged on Monday. Would you have 30 minutes of time on a Monday and Tuesday to do this?
    _____Yes. I have time on Mondays and Tuesdays.

_____No. I would like to participate, but on different days.
_____I don't know

32. *(If interested in researcher visit):* Is the head of the household willing to have researchers visit the home to set-up and later retrieve the air sampling devices?
_____Yes _____No → Not eligible for this option, go to "thank you".

33. *(If interested in researcher visit):* If researchers visit, they will set up samplers on a Tuesday and pick them up on a Monday. Could you be home for 90 minutes from 8:00am to 8:00pm on a Monday and Tuesday for these visits?
_____Yes. The researchers can visit my home on a Monday and Tuesday.
_____No. I would need the researchers to visit on different days.
_____I don't know.

Thank you for calling (visiting our website) and taking the time to respond.

Your home is eligible for participation in this study. If you would like to have your home added to the list of potential study homes please provide your contact info below. Homes from the eligible list will be selected based on geographic location and appliance and household characteristics. We will notify you no later than March 16, 2012, to let you know whether or not you have been selected to participate in this study.

If you are interested in continuing, please provide the following information.

Name: ____________________________

Street address of home: _____________________________

Daytime telephone: __________________ *Type*: home office cell

Evening telephone: __________________ *Type*: home office cell

Preferred email _____________________

Back-up email (optional): _____________________

Preferred mode of contact: Telephone Email

2. INITIAL QUESTIONNAIRE

{INITIAL GREETING}
Hello, is (*insert name of resident contact*) home?
Hi (*insert name of resident*), this is (*insert name of researcher*) from Lawrence Berkeley National Lab. Is now a good time to do the 20-30 minute phone interview we had scheduled to do today?

Yes→Great! Then let's begin.
No→Okay… *schedule another time, ideally on the same day, to call back.*

A. GENERAL HOME CHARACTERISTICS

{INTRODUCTION}

I am going to ask you questions about your household, about the physical characteristics of your home, about the appliances in your home, and about how you use appliances, exhaust fans and windows. These questions will help us analyze the measurements we make in your home to better understand the air quality in other homes and households with similar characteristics. You are welcome to say that you don't know or that you decline to answer in response to any of the questions that you are asked.

A.1 Do you rent or own your home? __Own __Rent

A.2 How many years have you lived in this home? ____________

A.3 In what kind of building do you live?

__Single, detached house
__Townhouse or Side-by-Side Duplex
__Apartment building with 2 to 4 units
__Apartment building with 5 or more units
__Mobile home
__ Other (Please describe): ___________________________

A.4 In what year was this building constructed? _____________

{Record exact year if known or ask about these ranges.}

If you don't know the exact year, was it…

__ Before 1950
__ 1950 to 1979
__ 1980 to 1995
__ 1996 to 2005
__ 2006 or newer
__ Don't know

A.5 *If the home is a house, townhouse or side-by-side duplex…*

__ Not Applicable

A.5.1 How many stories are there in your home?

- __ 1 story
- __ 1 ½ story split level
- __ 2 stories
- __ 2 ½ story split level
- __ 3 stories
- __ more than 3 stories

A.5.2 Does the home have a garage, and if so, where is it located?

- __ Attached at side with interior door
- __ Under part of house with interior door
- __ Under part of house with no interior door
- __ Garage not attached, or attached at side without interior door
- __ No garage

A.5.3 *If there is an attached garage…*
Is the garage used regularly for vehicle parking?
__ Yes __ No

A.6 *If home is in a building with multiple units…*

__ Not Applicable

A.6.1 On what story of the building is your home located? _____
A.6.2 How many stories in the building? ______
A.6.3 How many sides of your apartment are on outside walls? _______
A.6.4 Is there a garage in the building? ____________
(removed question A.6.4.1)

A.7 What is the floor area of your home, in square feet? If you are unsure, please feel free to estimate and note that you are unsure.

Exact if known: _______________
__ Less than 500
__ 500 – 750
__ 751 – 1000
__ 1001 – 1250
__ 1251 – 1500
__ 1501 – 2000
__ 2001 – 2500
__ 2501 – 3000
__ More than 3000
__ Unsure
__ No idea

A.8 How many bedrooms are in the home?
__ 1 __ 2 __ 3 __ 4 __ 5 __ >5

A.9 How many bathrooms are in the home? *[Toilet only is ½ bath]*
__ 1 __ 1.5 __ 2 __ 2.5 __ 3 __ >3

A.10 How many bathroom exhaust fans in the home, including those that don't work?
__ None present __ 1 __ 2 __ 3 __ >3

A.11 Do you have any bathroom fans that don't work well or don't work at all?
__ Don't work well. How many? ___ __
__ Don't work at all. How many? _____
__ All present work well
__ Not applicable; no fans present

A.12 Which *best* describes how the kitchen is connected to other parts of the home?
__ The kitchen is very open: At least one side of the kitchen is open to a large area of the home.
__ The kitchen is mostly open: There is a large doorway or pass-through open to large areas of the home.
__ The kitchen is a separate room with doors that can be closed.

A.12.1 If a separate room, are doors to the kitchen usually kept closed or open?
__ Open __ Closed

A.13 To your knowledge, has the home or building been renovated within the past 5 years to reduce air leakage, for example, is there new caulking or weatherstripping, was their specific air sealing done to the walls, attic, basement or ducts?
__ Yes __ No __ Don't know

A.13.1 *If yes*, was a contractor involved in the renovations?
__ Yes __ No __ Don't know

A.13.2 *If yes*, was it done through a government sponsored Weatherization program?
__ Yes __ No __ Don't know

A.14 Does your home use propane as a fuel for your furnace, hot water heater or another appliance?

__ No propane
__ All combustion appliances use propane
__ Some combustion appliances use propane
__ Don't know

A.15 Does your home have air-conditioning?

__ Yes __ No

A.15.1 *If yes*, how often do you use it in the middle of the summer?

__ Every day __ Few times per week __ Other (explain)

A.16 Do you have a service contract with a heating and air-conditioning company?

__ Yes
__ No
__ I don't know

A.17 Have any of the following changes been made to your home in the last year?

A.17.1 New vinyl flooring:	__ Yes	__ No
A.17.2 New carpet:	__ Yes	__ No
A.17.3 New furniture:	__ Yes	__ No
A.17.4 New cabinets:	__ Yes	__ No
A.17.5 New paint:	__ Yes	__ No

Only ask questions A.18- A.20 for "High Performance" homes (determined from screening survey).

A.18 Have you achieved or pursued any building certifications for your home? If so, which of the following apply?

__ LEED for Homes
__ Green Point Rated New Home
__ Green Point Rated Existing Home
__ Certified Green Home - NAHB National Green Building Program
__ Environments for Living by MASCO
__ Earth Advantage certified home
__ EPA Indoor Air Plus
__ Living Building Challenge
__ Passive House
__ EarthCraft
__ Energy Star for Homes
__ Deep Energy Retrofit
__ ACI Thousand Home Challenge
__ Other; Please Describe:
__ No building certifications achieved or pursued

A.19 Were healthy building material goals incorporated into your home's design and construction, possibly as part of a green home certification?

__ Yes __ No __ I don't know

A.19.1 If yes, which of the following is the most appropriate designation?

__ Living Building Challenge Red List chemical/material avoidance
__ EPA Indoor Air Quality Plus certification
__ U.S. Green Building Council's LEED or other green building rating system's healthy materials credits
__ Tried to avoid VOC's and toxins in paints and other materials
__ Not sure

A.20 Was your home tested for air tightness using a blower door test? This may have been done by your contractor, energy auditor, or HVAC technician as part of a green building, Energy Star or Passive House program.
__ Yes __ No __ I don't know

A.20.1 If yes, do you know the result of the blower door test?
__ Yes, it is:
__ I do not know the result, but you may contact my contractor/builder for this information at:
__ I do not know, and please do not contact my building/contractor.

A.21 Were you given a guide by your builder or contractor describing how to operate your home, including equipment and warranty information?
__ Yes __ No __ I don't know

B. GENERAL INDOOR AIR QUALITY

The next few questions are about your general indoor air quality and respiratory health.

B.1 How often do you smell cooking or smoking fumes from neighboring homes?
__ Never
__ Rarely (once per month or less)
__ Somewhat often (a few times per month)
__ Very often (several times per week or more)

B.2 Is there anything outside of your home that you think might affect your indoor air quality, such as a bus stop, busy road or factory?
__ No
__ Yes. Please describe: ___________________________

B.3 Does anyone in your household have asthma or another medical condition that affects breathing?
____ Yes ___ No

The next few questions address features of your home and actions that you take to manage indoor air quality.

B.4 Which features of your home most contribute to good indoor air quality? List up to five.

B.5 Are there any features of your home that contribute to bad indoor air quality? If so, list up to five.

B.6 What actions do you take to improve or manage indoor air quality in your home? List up to five.

(3 questions removed regarding perceived “stuffiness” in home or presence of lingering odors)

The next two questions ask about dampness and mold in your home environment. Dampness or mold may result from leaks, flooding, or condensation on windows or walls.

B.7 Signs of dampness or moisture may include water stains, peeling paint, or rotten wood. In the past 12 months, have there been any signs of continual or repeated dampness or moisture in your home?

____ Yes ___ No ___ Don't know

B.7.1 *If yes*, in what parts of your home?

__ Main bathroom
__ Second bathroom
__ Basement or garage
__ Bedroom
__ Other location: __________________________
__ Decline to state

B.8 In the past 12 months, has anyone SEEN mold or SMELLED moldy or musty odors inside your home? Do not include mold on food [*small amount of mold in shower (such as on tile grout, shower curtain or shower doors) counts as "No"]*.

____ Yes ___ No ___ Don't know

B.8.1 *If yes*, in what parts of your home?

__ Main bathroom
__ Second bathroom
__ Basement or garage
__ Bedroom
__ Other location: ________________________________
__ Decline to state

C. HEATING CHARACTERISTICS

The next set of questions is about how you heat your home.

C.1 Which of the following types of heater is used as the main source of heat in your home? In the questions that follow, this will be referred to as your primary heater.

Heating System	Primary
Forced-air furnace (Blows warm air from several locations) – § D	__
Wall furnace – § E	__
Floor furnace – § F	__
Oven or stove – § G	__
Gas fireplace (gas fireplace does not burn wood) – § H	__
Vent-free blue flame wall heater – § I	__
Portable space heater – § J	__
Heat Pump	__
Baseboard electric	__
Hot water radiator	__
Wood fireplace or wood stove	__
Other. Please describe:________________________________	__

C.2 Do you use any other heaters in addition to your primary heater? Please indicate which of the following are used, in order of the frequency that they are used. These will be referred to as supplemental heaters.

Heating System	Supplemental
Forced-air furnace (Blows warm air from several locations) – § D	__
Wall furnace – § E	__
Floor furnace – § F	__
Oven or stove – § G	__
Gas fireplace (gas fireplace does not burn wood) – § H	__
Vent-free blue flame wall heater – § I	__
Portable space heater – § J	__
Heat Pump	__
Baseboard electric	__
Hot water radiator	__
Wood fireplace or wood stove	__
Other. Please describe:________________________________	__

If primary heater was marked with a § for follow-up….

C.1.1 How often is your primary heater used during the middle of winter?
__ Every day __ Few times per week __ Other (explain)

C.2.1 *If relevant*…how often is your first supplemental heater used during the middle of winter?
__ Every day __ Few times per week __ Other (explain)

C.2.2 *If relevant*…how often is your second supplemental heater used during the middle of winter?
__ Every day __ Few times per week __ Other (explain)

C.2.3 *If relevant*…how often is your third supplemental heater used during the middle of winter?
__ Every day __ Few times per week ___ Other (explain)

D. CENTRAL FORCED AIR FURNACE *(Repeat for each forced air furnace.)*

D.1 *Interviewer indicates here if this is primary or supplemental heater:*
__ Primary __ Supplemental

D.2 Is this furnace powered by natural gas, electricity or propane?
__ Gas __ Electricity __ Propane __ Don't know
If not sure, provide the following guidance:
If you are not sure, one way to tell is if your gas bill goes up a lot in the winter compared to the summer. If the gas bill goes up a lot, the furance is probably gas.

[If powered by electricity, skip to next section]

D.3 Where is this furnace located?
__ Attic or roof
__ Crawl space, basement, or garage under living space
__ Side-attached garage
__ Closet in main living area
__ Don't know

D.4 Approximately how many years old is this furnace? If you are unsure, please feel free to estimate and note that you are unsure.
__ 0-5
__ 6-10
__ 11-15
__ 16+
__ Unsure
__ Don't know

D.5 If you don't know, has it been replaced since you moved in?
__ Yes __ No __ Don't recall

D.6 Has this furnace been checked or serviced by a professional in the past 3 years?
__ Yes __ No __ Not sure about 3; but not during the past ___ years

D.7 How often do you change your furnace filter?
__ Every 1-3 months
__ Every 3-6 months
__ Every 6-12 months
__ Less than once a year
__ Never
__ I don't know

E. WALL FURNACE

Repeat for each wall furnace.

E.1 *Interviewer indicates here if this is primary or supplemental heater:*

__ *Primary* __ *Supplemental*

E.2 Is this furnace powered by natural gas, electricity or propane?

__ Gas __ Electricity __ Propane __ Don't know

E.3 *If single family home or townhouse with more than one story…*

On which story is this furnace located?

__ 1st floor __ 2nd floor __ 3rd floor __ Not applicable

E.4 Is this a tall furnace set into the wall or a short, wide furnace that sits next to the wall?

__ Tall – set into wall __ Short, wide – next to wall

E.5 In which room is the furnace located? ___________________________________

E.6 Approximately how many years old is this furnace? If you are unsure, please feel free to estimate and note that you are unsure.

__ 0-5
__ 6-10
__ 11-15
__ 16+
__ Unsure
__ No idea

E.6.1 If you can't estimate, has it been replaced since you moved in?

__ Yes __ No __ Don't recall

E.7 Has this furnace been checked or serviced by a professional in the past 3 years?

__ Yes __ No __ Not sure about 3; but not during the past ______ years

E.8 *If wall furnace is gas or propane…*

Does this furnace have a pilot burner? A pilot burner is a small flame that always burns and is used to light the main burner when the furnace turns on.

__ Yes __ No ___ Don't know __ Not applicable

E.9 Are there now or have there been in the past, any black deposits on the wall just above the furnace?

__ Yes __ No __ Don't know

E.10 In the past 3 years, have there been any periods when your furnace has not operated properly?

___ Yes __ No __ Not sure

E.10.1 *If yes…b*riefly describe the problem: ________________.

F. FLOOR FURNACE

Repeat for each floor furnace.

F.1 *Interviewer indicates here if this is primary or supplemental heater:*
__ *Primary* __ *Supplemental*

F.2 Approximately how many years old is this furnace? If you are unsure, please feel free to estimate and note that you are unsure.
__ 0-5
__ 6-10
__ 11-15
__ 16+
__ Unsure
__ No idea

F.2.1 If you can't estimate, has it been replaced since you moved in?
__ Yes __ No __ Don't recall

F.3 Has this furnace been checked or serviced by a professional in the past 3 years?
__ Yes __ No __ Not sure about 3; but not during the past _________ years

F.4 In which room is the furnace located? ______________________________

F.4.1 *[If single family home or townhouse with more than one story]* On which story is this furnace located? __ 1st floor __ 2nd floor __ 3rd floor __ Not applicable

F.5 In the past 3 years, have there been any periods when your furnace has not operated properly?
__ Yes __ No __ Not sure

F.5.1 *If yes…*briefly describe the problem: ___________________.

G. OVEN AND STOVE USED FOR HEATING

G.1 *Interviewer indicates here if this is primary or supplemental heater:*
__ *Primary* __ *Supplemental*

G.2 Which of your cooking appliances do you use most often for heat?
__ Stovetop
__ Oven
__ Both

G.3 Why do you use your stove and/or oven for heat?
__ Other heater broken
__ Other heater doesn’t provide enough heat
__ Just to heat the kitchen
__ Other, explain: ____

H. GAS FIREPLACE

Repeat for each gas fireplace.

H.1 *Interviewer indicates here if this is primary or supplemental heater:*
__ *Primary* __ *Supplemental*

H.2 Is this gas fireplace powered by natural gas or propane?
__ Gas __ Propane __ Don't know

H.3 Is this gas fireplace controlled by a thermostat?
__ Yes __ No

H.4 If you live in a house or townhouse with more than one story, on which story is this gas fireplace located? __ 1st floor __ 2nd floor __ 3rd floor

H.5 In which room is the fireplace located? ____

H.6 Is this gas fireplace set into the wall or does it sit in the room?
__ Inside wall __ Out in room

H.7 Approximately how many years old is this gas fireplace? If you are unsure, please feel free to estimate and note that you are unsure.
__ 0-5
__ 6-10
__ 11-15
__ 16+
__ Unsure
__ No idea

H.8 Has this furnace been checked or serviced by a professional in the past 3 years?
__ Yes __ No __ Not sure about 3; but not during the past _________ years

H.9 Is this fireplace vented or vent-free?
__ Vent-free __ Vented

H.10 Did you buy this furnace? If so, do you recall how and where you bought it?
__ Not applicable; did not buy it
__ Internet from retailer
__ Internet from private seller
__ Store outside of California
__ Store inside of California

H.11 In the past 3 years, have there been periods when your furnace has not operated properly?
__ Yes __ No __ Not sure

H.11.1 *If yes…b*riefly describe the problem: ___________________________________.

I. VENT-FREE BLUE FLAME WALL HEATER

Repeat for each wall heater. (These are uncommon in CA.)

I.1 *Interviewer indicates here if this is primary or supplemental heater:*
__ *Primary* __ *Supplemental*

I.2 If you live in a house or townhouse with more than one story, on which story is this gas fireplace located? __ 1st floor __ 2nd floor __ 3rd floor

I.3 In which room is the furnace located? ____________________________________

I.4 Approximately how many years old is this wall heater? If you are unsure, please feel free to estimate and note that you are unsure.
__ 0-5
__ 6-10
__ 11-15
__ 16+
__ Unsure
__ No idea

I.5 Has this wall heater been checked or serviced by a professional in the past 3 years?
__ Yes __ No __ Not sure about 3; but not during the past _______ years

I.6 Did you buy this furnace? If so, do you recall how and where you bought it?
__ Not applicable; did not buy it
__ Internet, from retailer
__ From private seller outside of California
__ From private seller inside of California
__ Store outside of California
__ Store inside of California

I.7 In the past 3 years, have there been any periods when your furnace has not operated properly?
__ Yes __ No __ Not sure

I.7.1 *If yes…b*riefly describe the problem: ____________________________.

J. PORTABLE SPACE HEATER
Repeat for each space heater.

J.1 *Interviewer indicates here if this is primary or supplemental heater:*
__ *Primary* __ *Supplemental*

J.2 Is this PORTABLE heating appliance powered by natural gas, propane or kerosene?
__ Electricity
__ Propane
__ Kerosene
__ Don't know
__ Other

J.3 Approximately how many years old is this portable heater? If you are unsure, please feel free to estimate and note that you are unsure.
__ 0-5
__ 6-10
__ 11-15
__ 16+
__ Unsure
__ No idea

J.4 If this is used for supplementary heat, why do you use it?
__ Other heater broken
__ Other heater doesn't provide enough heat
__ Other, explain: ____

J.5 [*If heater is propane or kerosene*] Did you buy this heater? If so, do you recall how and where you bought it?
__ Not applicable; did not buy it
__ Internet, from retailer
__ From private seller outside of California
__ From private seller inside of California
__ Store outside of California
__ Store inside of California

J.6 In the past 3 years, have there been any periods when your furnace has not operated properly?
__ Yes __ No __ Not sure

J.6.1 *If yes…b*riefly describe the problem: ____________________________________.

K. WATER HEATER CHARACTERISTICS

K.1 Please note all of the following types of water heaters that you use in your home. A storage water heater is the most common type; it has a large tank that stores heated water. On-demand or "tankless" water heaters heat water as needed.

__ Storage water heater
__ On-demand water heater that serves much or all of the home→ *Skip to §L*
__ Solar water heating system (may be combined with storage water heater)
__ Other (describe)

K.2 Is this water heater powered by natural gas, electricity or propane?
[If not sure, can ask if there is a large exhuast duct atop the water heater]

__ Natural gas
__ Propane
__ Electric→ *Skip to §L*

K.3 Do you have more than one storage water heater?

__ Yes __ No *[If yes, repeat all of the following questions for each.]*

K.4 Does this water heater provide most of the hot water for your home?

__ Yes (primary) __ No (supplemental)

K.5 Where is this water heater located?

__ Outside
__ Basement or garage under living space
__ Side-attached garage
__ Closet in main living area
__ Laundry room
__ Other location in main living area

K.6 Approximately how old is this water heater? If you are unsure, please feel free to estimate and note that you are unsure.

__ 0-5
__ 6-10
__ 11-15
__ 16+
__ Unsure
__ No idea

K.6.1 If you can't estimate, has it been replaced since you moved in? __ Yes __ No

K.7 Has this WATER HEATER been checked or serviced by a professional in the past 3 years?

__ Yes __ No __ Not sure about 3; but not during the past _________ years

K.8 Is this water heater a "power vent" water heater? One way to tell is that a power vent water heater has a noisy fan or blower on top. __ power vent water heater __ *not* power vented

L. CLOTHES DRYER CHARACTERISTICS

L.1 Do you have a clothes dryer in your residence?

__ Yes __ No

L.2 If yes, is this dryer powered by natural gas, electricity or propane?
__ Gas __ Electricity __ Propane __ Don't know

[If dryer is electric, skip to §M]

L.3 Approximately how old is this dryer? If you are unsure, please feel free to estimate and note that you are unsure.
__ 0-5
__ 6-10
__ 11-15
__ 16+
__ Unsure
__ No idea

L.4 Where is this dryer located?
__ Basement or garage under living space
__ Side-attached garage
__ Closet or laundry room in main living area
Is the door to this room typically open, or does the door have louvered openings?
__ Typically open or lovered openings __ Not open
__ Other location in main living area

L.5 Is this dryer vented to the outdoors? In other words, is there an exhaust duct that directs air from the dryer to the outside of the house?
__ Yes __ No __ Don't know

M. KITCHEN APPLIANCE CHARACTERISTICS

The next few questions are about appliances in your kitchen. The questions may be easier to answer if you are in the kitchen, looking at the appliances.

M.1 Are your COOKTOP and OVEN part of the same appliance – a cooking range – or separate?
__ Together __ Separate

M.2 Is the COOKTOP powered by natural gas, electricity or propane?
__ Natural Gas __ Electricity __ Propane

If the cooktop is natural gas or propane, please ask questions M.2.1-M.2.3 below.

M.2.1 Do the cooktop burners have a pilot light, electronic ignition or light by match? Electronic ignition uses a small spark to light the flame. If the COOKTOP makes a clicking sound when you turn the knob to start the flame, it is electronic ignition.
__ Electronic __ Pilot __ Match light

M.2.2 Are the burners sealed or open? Open burners have openings around the burner, such that food can fall through.
__ Sealed __ Open

M.2.3 How many burners are on the cooktop? (Central griddle or grill counts as 1 burner)
__ 1 __ 2 __ 4 __ 5 __ 6

M.3 Approximately how old is the cooktop? If you are unsure, please feel free to estimate and note that you are unsure.
__ 0-5
__ 6-10
__ 11-15
__ 16+
__ Unsure
__ No idea

M.3.1 If you can't estimate, has it been replaced since you moved in? __ Yes __ No

M.4 When cooking, do you more often use the front or back burners, or do you use all the burners equally?
__ Front burners __ Back burners __ Use both equally __ I don't know

M.5 If separate from the cooktop, is the OVEN powered by natural gas, electricity or propane?
__ Natural Gas __ Electricity __ Propane

If the oven is natural gas or propane, please ask questions M.4.1 and M.4.2 below.

M.5.1 Does the oven burner have a pilot light, electronic ignition or do you light it by match?
__ Electronic __ Pilot __ Match light

M.5.2 Does the oven have a broiler with controls that are separate from the rest of the oven?
__ Yes __ No __ Don't know

M.6 Does the oven have a self-clean setting? __ Yes __ No __ Don't know

M.7 Do you cook using your stove or oven more often in the winter compared to other seasons?
__ Yes __ No

M.8 Do you have any of the following types of KITCHEN EXHAUST fans in the home? Please indicate all that apply.
__ Range hood above the cooktop
__ Microwave and exhaust fan combination above the cooktop
__ Downdraft exhaust at the back of the cooktop
__ Downdraft exhaust in the middle of the cookop
__ Exhaust fan in ceiling or wall above cooktop
__ Exhasut fan in ceiling or wall not above the cooktop
__ Other. Please describe:
__ There is no exhaust system in the kitchen

M.9 If you have a range hood or microwave exhaust fan above the cooktop, does it exhaust to the outdoors or does it have grills or holes in the front where it blows air back into the kitchen?
__ Exhaust to the outdoors
__ Blows air back to the kitchen
__ Doesn't work
__ Don't know
__ No hood

If uncertain, provide this guidance. If you can feel air being blown back out from the device through a grill or set of holes at the top, it probably does not exhaust. If you can see a duct going from the top of the hood up toward the roof or back into the wall, it exhausts. This duct may be inside a cabinet above the range hood.

M.10 How many fan settings does your range hood or microwave have?
__ 1 __ 2 __ 3 __ 4 __ Continuously variable control knob

M.11 How noisy is the <u>lowest</u> fan setting on your range hood?
__ Quiet, barely noticeable
__ Noticeable but does not interfere with conversation
__ Interferes with conversation or radio or TV but can talk over it
__ Loud; can't have conversation or hear radio or TV

M.12 How noisy is the <u>highest</u> fan setting on your range hood?
__ Quiet, barely noticeable
__ Noticeable but does not interfere with conversation
__ Interferes with conversation or radio or TV but can talk over it
__ Loud; can't have conversation or hear radio or TV

N. OTHER EXHAUST SYSTEMS CHARACTERISTICS

The next few questions are about OTHER EXHAUST SYSTEMS in your home.

N.1 To your knowledge, does your home have a ventilation fan that operates continuously or on a set schedule? These devices are most commonly found in very new houses, in homes that have been “air sealed” for energy efficiency and in some apartment buildings.

__ Yes __ No __ I don’t know

N.1.1 *[If yes]*, please describe: ___________________________

Can give these options:

__ Continuous exhaust fan
__ Heat or energy recovery ventilator
__ “Fresh Vent” that directs outdoor air into the heating and cooling system

N1.2 *[If yes]* Have you ever disabled or turned off your ventilation system?

__ Yes __ No __ I don’t know

N1.2 *[If yes]* Why did you disable or turn off the ventilation system?

__ Not needed
__ Too noisy
__ Wastes energy
__ Doesn’t work well
__ Open window instead
__ Causes a cold draft in winter
__ Other (explain)

N1.3 *[If answer to N.1 is “yes”, and home is a “High Performance Home”*] Does your home’s continuous ventilation system have any of the following?

__ Thermostat
__ Humidity controller (in the bathroom for example)
__ Speed control (for changing from low to high speed for example)
__ Motion sensor
__ CO_2 sensor
__ No controls that I know of
__ I don’t know

N1.4 *[If answer to N.1 is “yes”, and home is a “High Performance Home”*] Do you or a service technician perform maintanance on your home’s continuous ventilation system?

__ Yes __ No __ I don’t know

N1.4.1 *[If yes]* which of the following do you perform?

__ Changing filters
__ Cleaning filters
__ Replacing heat exchanger elements (the “core”) of the ERV/HRV
__ I don’t know
__ Other. Please describe:

N.2 In the most used full bathroom, how is the exhaust fan used? *Mark all that apply*.

__ Fan operates continuously
__ Always when showering or bathing
__ As needed to remove steam when showering or bathing

__ Used by some but not everyone when showering or bathing
__ As needed to remove odors
_ Not very often or never
_ Fan doesn't work
_ No fan in this bathroom

N.3 If your main bathroom exhaust fan is not used routinely, why not? Check all that apply.
__ Don't think about it
__ Not needed
__ Too noisy
__ Wastes energy
__ Broken
__ Doesn't work well
__ Open window instead
__ Other (explain)

O. HOUSEHOLD OCCUPANY, ACTIVITY, and DEMOGRAPHICS

The next few questions ask about activities that could impact air quality in your home.

O.1 During a typical week, on how many days does anyone in your household use the cooktop or oven for meals or at other times? Please include using the cooktop to boil water.

	All (7)	Most (4-6)	Some (1-3)	Rarely or never (<1)
BREAKFAST	__	__	__	__
LUNCH	__	__	__	__
DINNER	__	__	__	__
Any other time	__	__	__	__

O.2 How often do you cook with these other appliances inside your home?

	1+ times per day	Few times per week	<1 time per week	Never
Microwave	__	__	__	__
Toaster oven	__	__	__	__
Toaster	__	__	__	__
Electric wok	__	__	__	__
Electric grill	__	__	__	__
Propane grill	__	__	__	__
Rice Cooker	__	__	__	__
Electric Crokpot	__	__	__	__
Other (specify)	__	__	__	__

O.3 Do you ever cook indoors with charcoal briquettes? __ Yes __ No

O.4 Do you ever use a power generator indoors that burns fuel? __ Yes __ No

The next few questions ask about window opening in your home.

O.5 How often do you have windows open in your house during this time of year?
- __ More than half the time
- __ Several hours per day
- __ Less than an hour each day
- __ Usually closed all day

O.6 Which windows are opened most often (indicate all that apply)?
- __ Bedroom
- __ Bathroom
- __ Kitchen
- __ Common room (living room, entryway, etc.)
- __ Other

We will end with a few questions about your <u>household</u>. This information will help us relate what we measure in your home to other homes across California.

O.7 How many people live in your home at this time? _______

O.8 How many people in your home are in each age group?

0-5 years:	__ 0	__ 1	__ 2	__3	__ 4	__ 5
6-17 years:	__ 0	__ 1	__ 2	__3	__ 4	__ 5
18-30 years:	__ 0	__ 1	__ 2	__3	__ 4	__ 5
31-64 years:	__ 0	__ 1	__ 2	__3	__ 4	__ 5
65+ years:	__ 0	__ 1	__ 2	__3	__ 4	__ 5

O.9 What is the highest education level of anyone in the household?

__ Grade school
__ Some high school
__ Completed high school
__ Some college or trade school
__ Associates degree or trade school completion
__ College degree
__ Graduate degree

O.10 Please indicate all races and/or ethnicities of people living in your household.

__ American Indian, Alaska Native
__ Asian or Pacific Islander
__ Black, African American
__ Hispanic / Latino
__ White, Caucasian
__ Other; please list if you wish: ______________________________.
__ Prefer not to answer

O.11 What is the total income for all members of your household combined?

__ Less than $25,000
__ $25,000 - $49,999
__ $50,000 - $74,999
__ $75,000 - $99,999
__ $100,000 - $150,000
__ >$150,000
__ Prefer not to answer

[If home is owned by residensts]
O.12 If your furnace were to break, and required $200 worth of repairs, how soon would you be able to afford these repairs?
__ Right away __ Within a week __ Within a month __ Not sure

O.13 If your furnace were to break beyond repair, and cost $1000 to replace or repair, how soon would you be able to afford to afford to do this?
__ Right away __ Within a week __ Within a month __ Not sure

[If home is rented by residents]
O.14 How reliable is your landlord at making repairs to appliances when needed?

__ HARDLY or NOT reliable:

The landlord is generally unresponsive when we request that an appliance in the home be inspected or repaired.

__ SOMEWHAT reliable:

The landlord responds eventually to requests to have appliances repaired, but not always right away.

__ VERY reliable:

The landlord can be counted on to make repairs to appliances in a timely manner when needed.

O.13 *Note the gender of the resident responding to the survey:*
__ Male __ Female __ Unclear from voice

O.14 Is there anything more you would like to say about your house related to this study?
____

O.15 This study will continue for another year after this one, and we may make some changes to this survey. Are there any changes that you recommend we make to this survey to make the questions easier to understand or to make taking the survey more convenient?
If yes, describe: ____________________________________

Thank you very much for your time and help.

3. EXIT INTERVIEW: QUESTIONS ABOUT WEEK OF SAMPLING

1. During the past week (WEEKDAYS), was anyone in the home during the following periods? Please count anyone in the home even if they don't live there. Answer "usually" if 3 or more days; "sometimes" if 1-2 days.

After breakfast and before lunch	__ Usually	__ Sometimes	__ Rarely
During lunch	__ Usually	__ Sometimes	__ Rarely
After lunch until dinner	__ Usually	__ Sometimes	__ Rarely
During dinner	__ Usually	__ Sometimes	__ Rarely
After dinner until bedtime	__ Usually	__ Sometimes	__ Rarely

(removed two time categories)

2. During the past WEEKEND, was anyone in the home during the following periods? Please count anyone in the home even if they don't live there.

After breakfast and before lunch	__ Saturday	__ Sunday
During lunch	__ Saturday	__ Sunday
After lunch until dinner	__ Saturday	__ Sunday
During dinner	__ Saturday	__ Sunday
After dinner until bedtime	__ Saturday	__ Sunday

(Changed options from "usually" "sometimes" and "rarely" to "Saturday" and "Sunday." Also, removed two time categories)

3. During the past week, were any of the following used to heat your home? Check all that apply.

__ Central forced-air furnace
__ Wall furnace
__ Floor furnace
__ Gas oven or stove
__ Electric oven or stove
__ Gas fireplace
__ Wood fireplace
__ Wood stove
__ Heat Pump
__ Baseboard electric
__ Portable electric space heater
__ Portable space heater that burns fuel
__ Other. Please describe:

Please can you tell me a bit more about how you used these heating devices?

4. MOST used heater: ______________________________

4.a How often was it used? __ Every day __ 4-6 days __ 1-3 days

4.b When was it used? *Check all that apply.*
__ Weekday morning __ Weekday afternoon __ Weekday evening
__ Weekend morning __ Weekend afternoon __ Weekend evening
__ Overnight

5. SECOND most used heater: ________________________

5.a How often was it used? __ Every day __ 4-6 days __ 1-3 days

5.b When was it used? *Check all that apply.*
__ Weekday morning __ Weekday afternoon __ Weekday evening
__ Weekend morning __ Weekend afternoon __ Weekend evening
__ Overnight

6. THIRD most used heater: ___________________________

6.a How often was it used? __ Every day __ 4-6 days __ 1-3 day

6.b When was it used? *Check all that apply.*
__ Weekday morning __ Weekday afternoon __ Weekday evening
__ Weekend morning __ Weekend afternoon __ Weekend evening
__ Overnight

The next few questions ask how often you opened your windows over the past week.

7. On how many nights did you leave any windows open OVERNIGHT?
__ All __ Most (4-6) __ Some (1-3) __ None
7.a Typically how many windows were open? _______________________

8. On how many days did you open any windows in the MORNING?
__ All __ Most (4-6) __ Some (1-3) __ None
8.a Typically how many windows were open? _______________________

9. On how many days did you leave any windows open during the DAY?
__ All __ Most (4-6) __ Some (1-3) __ None
9.a Typically how many windows were open? ______________________

10. On how many days did you have any windows open during the EVENING?
__ All __ Most (4-6) __ Some (1-3) __ None
10.a Typically how many windows were open? _______________________

(deleted question: "During the past week, what was the weather during the middle of the DAY/Night?")

11. During the past week, on how many days did anyone in the household use the COOKTOP to cook during the following times:

BREAKFAST	__ 7	__ 5-6	__ 3- 4	__ 1-2	__ <1
LUNCH	__ 7	__ 5-6	__ 3- 4	__ 1-2	__ <1
DINNER	__ 7	__ 5-6	__ 3- 4	__ 1-2	__ <1
Any other time	__ 7	__ 5-6	__ 3- 4	__ 1-2	__ <1

12. During the past week, on how many days did anyone in household use the OVEN to cook during the following times:

BREAKFAST	__ 7	__ 5-6	__ 3- 4	__ 1-2	__ <1
LUNCH	__ 7	__ 5-6	__ 3- 4	__ 1-2	__ <1
DINNER	__ 7	__ 5-6	__ 3- 4	__ 1-2	__ <1
Any other time	__ 7	__ 5-6	__ 3- 4	__ 1-2	__ <1

13. Did you use the self-cleaning cycle of your oven during the past week? __ Yes __ No

13.a *(If yes)* Do you remember when? ________________________

14. During the past week, how often did any smoking, candle or incense use occur in the home?

__ More than 3 times per DAY
__ 1 to 3 times per DAY
__ 3 to 6 times over the course of the WEEK
__ 1 to 2 times over the WEEK
__ None

15. How many loads of laundry did you dry in your dryer during the past week?

__ >10 __ 6-10 __ 1-5 __ None

16. Did anyone in your home use the cooktop or oven to cook in the past 24 h? __ Yes __ No

16.1 *[If yes]* How many times?

17. Please tell me about the FIRST cooking event. Approximately what time did it occur?

__ Before 9:00 am
__ 9:00 am – 11:00 am
__ 11:00 am – 2:00 pm
__ 2:00 pm – 5:00 pm
__ 5:00 pm – 8:00 pm
__ After 8:00 pm
__ Not applicable

17.a Was the oven used? __ Yes __ No

17.b *If oven used…*What was the oven temperature setting?

__ Not used
__ <300 °F
__ 300-400 °F

__ >400 °F

17.c *If oven used…*How many minutes was the oven used?
__ <30 __ 30-60 __ 60-90 __ >90

17.d How many cooktop burners were used?
__ 1 __ 2 __ 3 __ 4

17.e *If relevant…*How many minutes was the first burner used?
__ <10 __ 10-30 __ 30-60 __ >60

17.f *If relevant…*How many minutes was the second burner used?
__ <10 __ 10-30 __ 30-60 __ >60

17.g *If relevant…*How many minutes was the third burner used?
__ <10 __ 10-30 __ 30-60 __ >60

17.h *If relevant…*How many minutes was the fourth burner used?
__ <10 __ 10-30 __ 30-60 __ >60

17.i Did you use the exhaust fan during cooking?
__ For entire time __ Part of time __ Not at all

17.j Did you open any windows specifically to remove cooking fumes, smoke or odors?
__ For entire time __ Part of time __ Not at all

18. Please tell me about the SECOND cooking event. Approximately what time did it occur?
__ Before 9:00 am
__ 9:00 am – 11:00 am
__ 11:00 am – 2:00 pm
__ 2:00 pm – 5:00 pm
__ 5:00 pm – 8:00 pm
__ After 8:00 pm
__ Not applicable

18.a Was the oven used? __ Yes __ No

18.b *If oven used…*What was the oven temperature setting?
__ Not used
__ <300 °F
__ 300-400 °F
__ >400 °F

18.c *If oven used…*How many minutes was the oven used?
__ <30 __ 30-60 __ 60-90 __ >90

18.d How many cooktop burners were used?
__ 1 __ 2 __ 3 __ 4

18.e *If relevant…*How many minutes was the first burner used?
__ <10 __ 10-30 __ 30-60 __ >60

18.f *If relevant…*How many minutes was the second burner used?
__ <10 __ 10-30 __ 30-60 __ >60

18.g *If relevant…*How many minutes was the third burner used?
__ <10 __ 10-30 __ 30-60 __ >60

18.h *If relevant…*How many minutes was the fourth burner used?
__ <10 __ 10-30 __ 30-60 __ >60

18.i Did you use the exhaust fan during cooking?
__ For entire time __ Part of time __ Not at all

18.j Did you open any windows specifically to remove cooking fumes, smoke or odors?
__ For entire time __ Part of time __ Not at all

19. Please tell me about the THIRD cooking event. Approximately what time did it occur?

__ Before 9:00 am
__ 9:00 am – 11:00 am
__ 11:00 am – 2:00 pm
__ 2:00 pm – 5:00 pm
__ 5:00 pm – 8:00 pm
__ After 8:00 pm
__ Not applicable

19.a Was the oven used? __ Yes __ No

19.b *If oven used…*What was the oven temperature setting?

__ Not used
__ <300 °F
__ 300-400 °F
__ >400 °F

19.c *If oven used…*How many minutes was the oven used?

__ <30 __ 30-60 __ 60-90 __ >90

19.d How many cooktop burners were used?

__ 1 __ 2 __ 3 __ 4

19.e *If relevant…*How many minutes was the first burner used?

__ <10 __ 10-30 __ 30-60 __ >60

19.f *If relevant…*How many minutes was the second burner used?

__ <10 __ 10-30 __ 30-60 __ >60

19.g *If relevant…*How many minutes was the third burner used?

__ <10 __ 10-30 __ 30-60 __ >60

19.h *If relevant…*How many minutes was the fourth burner used?

__ <10 __ 10-30 __ 30-60 __ >60

19.i Did you use the exhaust fan during cooking?

__ For entire time __ Part of time __ Not at all

19.j Did you open any windows specifically to remove cooking fumes, smoke or odors?

__ For entire time __ Part of time __ Not at all

20. Please tell me about the FOURTH cooking event. Approximately what time did it occur?
__ Before 9:00 am
__ 9:00 am – 11:00 am
__ 11:00 am – 2:00 pm
__ 2:00 pm – 5:00 pm
__ 5:00 pm – 8:00 pm
__ After 8:00 pm
__ Not applicable

20.a Was the oven used? __ Yes __ No

20.b *If oven used…*What was the oven temperature setting?
__ Not used
__ <300 °F
__ 300-400 °F
__ >400 °F

20.c *If oven used…*How many minutes was the oven used?
__ <30 __ 30-60 __ 60-90 __ >90

20.d How many cooktop burners were used?
__ 1 __ 2 __ 3 __ 4

20.e *If relevant…*How many minutes was the first burner used?
__ <10 __ 10-30 __ 30-60 __ >60

20.f *If relevant…*How many minutes was the second burner used?
__ <10 __ 10-30 __ 30-60 __ >60

20.g *If relevant…*How many minutes was the third burner used?
__ <10 __ 10-30 __ 30-60 __ >60

20.h *If relevant…*How many minutes was the fourth burner used?
__ <10 __ 10-30 __ 30-60 __ >60

20.i Did you use the exhaust fan during cooking?
__ For entire time __ Part of time __ Not at all

20.j Did you open any windows specifically to remove cooking fumes, smoke or odors?
__ For entire time __ Part of time __ Not at all

21. If you have a kitchen exhaust fan or range hood, how often is it used?
- __ Most times (*75% or more*) when cooktop or oven is used
- __ Most times when cooktop is used but not when oven is used
- __ About half the time
- __ Infrequently; only when needed
- __ Never

22. When the range hood is used, which fan speed is most commonly selected?
- __ Lowest setting
- __ Medium setting
- __ Highest setting
- __ Only one speed available
- __ Varies or changes depending on what is being cooked
- __ Don't know or prefer not to say

23. If you use your range hood sometimes or only when needed, do you use it for any of the following reasons? Check all that apply.
- __ Remove smoke
- __ Remove heat
- __ Remove odors
- __ Remove steam / moisture
- __ During oven cleaning
- __ Other (explain)

24. If your range hood is not used routinely, why not? Check all that apply.
- __ Don't think about it
- __ Not needed
- __ Too noisy
- __ Wastes energy
- __ Broken
- __ Doesn't work well
- __ Open window instead
- __ Other (explain)

25. How often do you clean the grease screens?
- __ Each week
- __ Each month
- __ As needed
- __ Never
- __ No grease screens

26. Does your kitchen exhaust fan have a carbon/charcoal filter?
__ Yes __ No __ I don't know

26.a *[If yes]* Does this filter need to be periodically replaced?
__ Yes __ No __ I don't know

Have you ever had any of the following problem with any of the cooktop burners?

27. Burners slow to ignite or won't ignite? __ Yes __ No

27.a *If yes,* How many burners? __ 1 __ 2 __ 3 __ 4 __ 4+

28. Burners can't be turned down from the highest setting? __ Yes __ No

28.a *If yes,* How many burners? __ 1 __ 2 __ 3 __ 4 __ 4+

29. Other. Please describe: ___________________________________.

30. *If yes to any of the questions above,* How was this issue resolved?

__ Hasn't been resolved
__ Was serviced by a professional
__ Was serviced by a resident
__ Appliance was replaced
__ Issue resolved iteself

Have you ever had any of the following problem with the oven or broiler burners?

31. Burners slow to ignite or won't ignite? __ Yes __ No
32. Thermostat doesn't work properly? __ Yes __ No
33. Use is accompanied with a burning smell? __ Yes __ No
34. Other. Please describe: ___________________________________.

35. *If yes to any of the questions above,* How was this issue resolved?

__ Hasn't been resolved
__ Was serviced by a professional
__ Was serviced by a resident (including cleaning)
__ Appliance was replaced
__ Issue resolved iteself

Please describe the quality of each cooktop flame; check all that apply:

How does the flame look *without* a pot?
36. Left Front: __ Mostly blue OR __ Lots of orange; __ Steady OR __ Wobbly
37. Left Rear: __ Mostly blue OR __ Lots of orange; __ Steady OR __ Wobbly
38. Right Front: __ Mostly blue OR __ Lots of orange; __ Steady OR __ Wobbly
39. Right Rear: __ Mostly blue OR __ Lots of orange; __ Steady OR __ Wobbly

40. How would you rate the air quality in your home over the past week?
__ Very good
__ Acceptable
__ Barely acceptable
__ Not acceptable

41. Over the past week, how often did you smell cigarette smoke from other nearby homes or apartments, or from the hallways?
__ Never
__ A few days
__ Every day
__ Don't know [Don't read]

42. Over the past week, how much of the time did you smell other odors (for example, cooking) nearby homes or apartments, or from the hallways?
__ Never
__ A few times
__ Every day
__ Don't know [Don't read]

43. Were there any pollution events that occurred outdoors over the last week that may have affected the air quality inside of your home (for example, outdoor fires, fireworks or construction etc.)
__ No
__ Yes. Please describe:

44. Is there anything more you would like to say about your house related to this study?
____

45. Do you have any questions? _________________________

46. This study will continue for another year after this one, and we may make some changes to this survey. Are there any changes that you recommend we make to this survey to make the questions easier to understand or to make taking the survey more convenient?. *If yes,* describe:

Thank you very much for your time and help. After we receive the samplers back in our lab, we will begin processing the $75 payment. You should receive it within 1 month. If you do not receive it, please get in touch with us.

D. Responses to Initial and Final Survey Questions

Table set A: Initial Questionnaire

Table D.1. Rent/Own status of respondent homes (A.1)

Status	Number	Percent
Rent	50	32.3%
Own	105	67.7%
Total	155	100.0%

Table D.2. Respondent years lived at current home (A.2)

Years Lived	Number	Percent
0-4 years[1]	79	51.0%
5-9 years	29	18.7%
10-14 years	21	13.5%
15-19 years	9	5.8%
20-24 years	6	3.9%
25-29 years	4	2.6%
30-34 years	5	3.2%
35-39 years	2	1.3%
Total	155	100.0%

[1]Interval includes half-year period (i.e. 0-4 years includes 4.5 years)

Table D.3. Type of building in which the respondent resides (A.3)

Type of Home	Number	Percent
Single, detached house	105	67.7%
Townhouse or side-by-side duplex	11	7.1%
Apartment building, 2-4 units	21	13.5%
Apartment building, 5 or more units	18	11.6%
Mobile home	0	--
Other	0	--
Total	155	99.9%

Table D.4. Year building was built (A.4)

Years Built	Number	Percent
Before 1950	73	47.1%
1950-1979	30	19.4%
1980-1995	13	8.4%
1996-2005	11	7.1%
2006 or newer	19	12.3%
Don't know	9	5.8%
Declined to state/blank	0	--
Total	155	100.1%

Table D.5. Number of stories in residence's house or apartment building (A.5, A.6)

Type of Home	House		Apartment (building with multiple units)			
Stories	Number	Percent	Number	Percent	**Floor of apt**	Number
1	60	51.7%	4	10.3%	**1**	10
1.5	11	9.5%	0	--	**2**	14

2	36	31.0%	16	41.0%	**3**	8
2.5	2	1.7%	0	--	**4**	1
3	7	6.0%	12	30.8%	**5**	0
3.5	0	--	0	--	**6**	0
4	0	--	3	7.7%	**7**	1
4.5	0	--	0	--	**>7**	0
5	0	--	3	7.7%	**1-2**	3
>5	0	--	1	2.6%	**2-3**	2
Total	116	99.9%	39	100.1%	Total	39

Table D.6. Garage location and usage in residence's house (A.5)

Garage Location	Number	Percent	Regularly Used[1]	Percent
Attached at side with interior door	25	21.6%	12/25	20.0%
Under part of house with interior door	28	24.1%	19/28	31.7%
Under part of house, no interior door	7	6.0%	3/7	5.0%
Garage not attached, or attached at side without interior door	29	25.0%	--	--
No garage	27	23.3%	--	--
Total	116	100.0%	34/60	56.7%/ 100.0%

[1]only if garage is attached to house

Table D.7. Floor area of residence's house or apartment complex (A.7)

Floor area	Number	Percent
Less than 500	3	1.9%
500-750	11	7.1%
751-1000	27	17.4%
1001-1250	26	16.8%
1251-1500	21	13.5%
1501-2000	30	19.4%
2001-2500	16	10.3%
2501-3000	6	3.9%
>3000	8	5.2%
Unsure/Don't know	7	4.5%
Total	155	100.0%

Table D.8. Number of bedrooms in residence's home (A.8)

Bedrooms	Number	Percent
One	24	15.5
Two	41	26.5
Three	55	35.5
Four	29	18.7
Five	4	2.6
Six	2	1.3
Total	155	100.1%

Table D.9. Number of bathrooms and bathroom fans in residences' homes (A.9, A.10)

Number of	Number of bathroom fans	% Homes without

bathrooms	0	1	2	3	4	**Total**	bath fans
1	**33**	31	0	0	0	**64**	51.6%
1.5	**1**	5	3	0	0	**9**	11.1%
2	**12**	7	29	0	0	**48**	25.0%
2.5	**1**	2	3	8	1	**15**	6.7%
3	**2**	0	1	10	0	**13**	15.4%
3.5	**0**	0	0	0	0	**0**	0.0%
4	**0**	0	0	0	6	**6**	0.0%
Total	**49**	45	36	18	7	**155**	31.6%
% Fans don't work	0.0%	4.4%	0.0%	0.0%	0.0%	1.3%	

Table D.10. Kitchen connection to rest of respondent's residence (A.12)

Kitchen Design		Number	Percent
The kitchen is very open: At least one side of the kitchen is open to a large area of the home		69	44.5%
The kitchen is mostly open: There is a large doorway or pass-through open to large areas of the home		41	26.5%
The kitchen is a separate room with doors that can be closed	Door open	43	27.7%
	Door closed	2	1.3%
Total		155	100.0%

Table D.11. Air Conditioning use in respondent's home (A.15)

AC use	Number	Percent
No air conditioning	104	67.1%
Everyday	17	11.0%
Few times per week	12	7.7%
Few times per month	2	1.3%
Few times per summer	7	4.5%
Few times per year	3	1.9%
Rare	4	2.6%
Never	4	2.6%
Other	2	1.3%
Total	155	100.0%

Table D.12. Structural and content changes to respondent's home, in the last year (A.17)

Changes	Number	Percent
New Floor	13	8.4%
New Carpet	20	12.9%
New Furniture	40	25.8%
New Cabinets	15	9.7%
New Paint	56	36.1%
New Drywall	1	0.6%
New Windows	2	1.3%
New Door	1	0.6%

None	7	4.5%
Total	155	99.9%

Table D.13. Cooking or smoking fumes from neighboring homes smelled by respondent (B.1)

Frequency	Number	Percent
Never	106	68.4%
Rarely (once per month)	25	16.1%
Somewhat often (a few times per month)	17	11.0%
Very often (several times per week or more)	7	4.5%
Total	155	100.0%

Table D.14. Existence of asthmatic or other breathing conditions in household (B.3)

	Numbers	Percent
Someone in home has medical condition pertaining to breathing	42	27.1%

Table D.15. Signs and places of dampness, moisture, and mold in respondent's residence (B.5, B.6)

	Dampness and Moisture		Mold	
Places of condition[1]	Number	Percent	Number	Percent
All rooms	2	1.3%	2	1.3%
Attic	0	--	2	1.3%
Basement	3	1.9%	3	1.9%
Bedroom	6	3.9%	13	8.4%
Dining area	1	0.6%	0	--
Family rooms	3	1.9%	1	0.6%
Kitchen	4	2.6%	3	1.9%
Hallway/Closet	2	1.3%	1	0.6%
Laundry room	1	0.6%	0	--
Main bathroom	9	5.8%	13	8.4%
Exterior	2	1.3%	2	1.3%
No signs of such condition	122	78.7%	115	74.2%
Total	155	100.0%	155	100.0%

[1]Certain homes listed more than one place for dampness and moisture, however; only one place is taken into consideration in this table

>>Home heating system
*Hot water radiator, baseboard electric, wood fireplace, and heat pump were not included in all heater characteristic analysis.
**Oven or stove also not included in characteristic analysis because only one home indicated usage of its gas oven to avoid use of its forced air furnace, which produces a lot of dust.

Table D.16. Primary and secondary[1] heater type (C.1, C.2)

	Main source		Secondary source	
Type of heater	Number	Percent	Number	Percent
Forced-Air furnace	98	63.2%	6	3.9%
Wall furnace	21	13.5%	7	4.5%
Floor furnace	5	3.2%	0	--
Oven or stove	0	--	1	0.6%
Gas fireplace (does not burn wood)	6	3.9%	7	4.5%
Heat pump	5	3.2%	0	--
Portable space heater	6	3.9%	40	25.8%
Baseboard electric	2	1.3%	4	2.6%
Hot water radiator	2	1.3%	0	--
Wood fireplace or wood stove	1	0.6%	10	6.5%
Gas boiler radiant	6	3.9%	1	0.6%
Gas boiler forced	3	1.9%	0	--
Other	0	--	3	1.9%
No secondary heater	--	--	76	49.0%
Total	155	100.0%	155	100.0%

[1]Only one home had a **third** heating system: a wall furnace

Table D.17. Primary and secondary heater usage frequency (C.1, C.2)

	Main source		Secondary source	
Usage frequency	Number	Percent	Number	Percent
Every day	119	76.8%	17	11.0%
Few times per week	19	12.3%	33	21.3%
Few times per month	5	3.2%	10	6.5%
Few times per winter	2	1.3%	3	1.9%
Few times per year	1	0.6%	6	3.9%
Rare	3	1.9%	5	3.2%
Never	2	1.3%	2	1.3%
Other	4	2.6%	3	1.9%
No secondary heater	--	--	76	49.0%
Total	155	100.0%	155	100.0%

Table D.18. Characteristics of different types of heaters in respondents' homes – fuel type* (D.2, E.2, H.2, J.2)

Fuel type	Forced Air[1 3]		Wall[4]		Gas fireplace[2 5]		Portable	
	N	%	N	%	N	%	N	%
Electric	2	1.8%	6	23.1%	0	--	46	100.0%
Gas	102	93.6%	20	76.9%	12	85.7%	0	--
Alcohol	0	--	0	--	2	14.3%	0	--
Don't know	5	4.6%	0	--	0	--	0	--
Total	**109**	**100.0%**	**26**	**100.0%**	**14**	**100.0%**	**46**	**100.0%**
Not applicable	**46/155**	**--**	**129/155**	**--**	**141/155**	**--**	**109/155**	**--**

*Floor furnaces are not included
[1]Includes forced gas boiler and radiant gas boiler
[2]Includes two homes with "other" types of heaters, which are fueled by alcohol
[3]There were five homes that had two gas forced air furnaces (i.e. 109 homes with 114 forced air furnaces)
[4]The house with a third heater is included; three houses had two gas wall furnaces (i.e. 29 wall furnaces in 26 homes)
[5]There was one house with two gas fireplaces (i.e. 14 homes with 15 gas fireplace or other heating system)

Table D.19. Characteristics of different types of heaters in respondents' homes – age* (D.4, E.6, F.2, H.7, J.3)

Age	Forced Air		Wall		Floor		Gas fireplace		Portable	
	N	%	N	%	N	%	N	%	N	%
0-5 years	21	19.6%	3	15.0%	0	--	8	57.1%	33	71.7%
6-10 years	22	20.6%	2	10.0%	0	--	1	7.1%	11	23.9%
11-15 years	14	13.1%	3	15.0%	3	60.0%	2	14.3%	1	2.2%
16+ years	21	19.6%	7	35.0%	2	40.0%	2	14.3%	0	--
Blank/do not know	29	27.1%	5	25.0%	0	--	1	7.1%	1	2.2%
Total	**107**	**100.0%**	**20**	**100.0%**	**5**	**100.0%**	**14**	**100.0%**	**46**	**100.0%**
Not Applicable	**48/ 155**	**--**	**135/ 155**	**--**	**150/ 155**	**--**	**141/ 155**	**--**	**109/ 155**	**--**

*Does not include *electric* forced air furnaces and *electric* wall furnaces

Table D.20. Characteristics of different types of heaters in respondents' homes – location* (D.3, E.5, F.4, H.5)

Location	Forced Air		Wall		Floor		Gas fireplace	
	N	%	N	%	N	%	N	%
Attic or roof	12	11.2%	0	--	0	--	0	--
Crawl space	48	44.9%	0	--	0	--	0	--
Side garage	8	7.5%	0	--	0	--	0	--
Closet	29	27.1%	0	--	0	--	0	--
Bathroom	0	--	1	5.0%	0	--	0	--
Bedroom	0	--	2	10.0%	0	--	1	7.1%
Dining room	0	--	2	10.0%	1	20.0%	0	--
Family room	0	--	12	60.0%	3	60.0%	13	92.9%
Hallway	0	--	3	15.0%	0	--	0	--
Kitchen	0	--	0	--	1	20.0%	0	--
Blank/do not know	10	9.3%	0	--	0	--	0	--
Total	**107**	**100.0%**	**20**	**100.0%**	**5**	**100.0%**	**14**	**100.0%**
Not Applicable	**48/ 155**	**--**	**135/ 155**	**--**	**150/ 155**	**--**	**141/ 155**	**--**

*Does not include *electric* forced air furnaces, *electric* wall furnaces, and portable space heaters
**Only one floor heater was placed on second floor of home, the others were not

Table D.21. Characteristics of different types of heaters in respondents' homes – Operation and services* (D.6, E.7, F.3, F.5, H.8, H.11, J.6)

	Forced Air		Wall		Floor		Gas fireplace		Portable	
	N	%	N	%	N	%	N	%	N	%
Furnace did not operated properly at some point in the past 3 years	--	--	1	0.05	0	--	3	21.4%	2	4.3%
Works fine	--	--	18	0.9	5	100.0%	10	71.4%	44	95.7%
Don't know/Not sure	--	--	1	0.05	0	--	1	7.1%	0	--
Total	**--**	--	**20**	**1**	**5**	**100.0%**	**14**	**100.0%**	**46**	**100.0%**
Has been checked or serviced in the past 3 years	50	46.7%	7	35.0%	1	20.0%	6	42.9%	--	--
Never in the past 3 years	38	35.5%	9	45.0%	3	60.0%	7	50.0%	--	--
Don't know/Not sure	19	17.8%	4	20.0%	1	20.0%	1	7.1%	--	--
Total	107	100.0%	20	100.0%	5	100.0%	14	100.0%	--	--

*Does not include *electric* forced air furnaces, *electric* wall furnaces

Table D.22. Water heaters and their fuel type (K.1)

	Storage water heater		On-demand water heater that serves much or all of the home		Solar water heating system (may be combined with storage WH)		Boiler		Total
	N	%	N	%	N	%	N	%	
Electric	7	5.7%	0	0.0%	2	11.8%	0	0.0%	9
Gas	112	91.8%	13	100.0%	11	64.7%	1	100.0%	137
Propane	0	0.0%	0	0.0%	1	5.9%	0	0.0%	1
Don't know/blank	3	2.5%	0	0.0%	3	17.6%	0	0.0%	6
Total	122	100.0%	13	100.0%	17	100.0%	1	100.0%	153[1]

[1]two homes were unable to identify water heater type, and therefore not included in table

Table D.23. Location of residences' water heaters (K.4)

Location	Number	Percent	Percent of applicable (n=133)
Outside	20	12.9%	**15.0%**
Basement or garage under living space	52	33.5%	**39.1%**
Side-attached garage	15	9.7%	**11.3%**
Closet	14	9.0%	**10.5%**
Laundry	15	9.7%	**11.3%**
Kitchen	7	4.5%	**5.3%**
Bedroom	2	1.3%	**1.5%**
Attic	4	2.6%	**3.0%**
Don't know	4	2.6%	**3.0%**
Not applicable[1]	22	14.2%	**--**
Total	155	100.0%	100.0%

[1]Homes with electric fueled water heaters or with on demand water heaters

Table D.24. Age of residences' water heaters (K.5)

Age	Number	Percent	Percent of applicable (n=133)
0-5 years	39	25.2%	29.3%
6-10 years	23	14.8%	17.3%
11-15 years	15	9.7%	11.3%
16+ years	14	9.0%	10.5%
Don't know	42	27.1%	31.6%
Not applicable[1]	22	14.2%	--
Total	155	100.0%	100.0%

[1]Homes with electric fueled water heaters or with on demand water heaters

Table D.25. Number of water heaters in residences' homes (K.2)

	Number	Percent	Percent of applicable
More than one heater	27	17.4%	20.3%
Only one heater	99	63.9%	74.4%

Don't know	7	4.5%	5.3%
Not applicable[1]	22	14.2%	--
Total	155	100.0%	100.0%

[1]Homes with electric fueled water heaters or with on demand water heaters

Table D.26. Service checks of residences' water heaters (K.6)

	Number	Percent	Percent of applicable (n=33)
Has been checked or serviced in the past 3 years	41	26.5%	30.8%
Never in the past 3 years	61	39.4%	45.9%
Don't know/Not sure	31	20.0%	23.3%
Not applicable[1]	22	14.2%	--
Total	155	100.0%	100.0%

[1]Homes with electric fueled water heaters or with on demand water heaters

(+: Other individual characteristics can be listed/tabulated later if needed)

Table D.27. Presence of clothes dryer in residence (L.1)

Clothes dryer present	115	74.2%
Clothes dryer not present	40	25.8%
Total	155	100.0%

Table D.28. Clothes dryer fuel types (L.2)

	Number (n=115)	Percent
Electric	44	38.3%
Gas	58	50.4%
Propane	1	0.9%
Don't know/blank	12	10.4%
Total	115	100.0%

Table D.29. Age of residences' clothes dryer (L.3)

Age	Number	Percent	Percent of applicable (n=71)
0-5 years	27	17.4%	38.0%
6-10 years	21	13.5%	29.6%
11-15 years	9	5.8%	12.7%
16+ years	12	7.7%	16.9%
Don't know	2	1.3%	2.8%
Not applicable[1]	84	54.2%	--
Total	155	100.0%	100.0%

[1]Homes with electric fueled clothes dryer or with no dryers

Table D.30. Location of residences' clothes dryer (L.4)

Location		Number	Percent	Percent of applicable (n=71)
Basement or garage under living space		14	9.0%	19.7%
Side-attached garage		7	4.5%	9.9%
Closet or laundry room in main living area	Door open	13	8.4%	18.3%
	Door close	30	19.4%	42.3%
Bedroom		2	1.3%	2.8%
Kitchen/bathroom		2	1.3%	2.8%
Others		3	1.9%	4.2%
Not applicable		84	54.2%	--
Total		155	100.0%	100.0%

Table D.31. Ventilation of clothes dryer (L.5)

Dryer vented to the outdoors	62	87.3%
Dryer has no exhaust duct that directs air from dryer to the outside	3	4.2%
Don't know/Unsure	6	8.5%
Total	71	100.0%

>> Cooking Appliances

Table D.32. Cooktop and oven characteristic (M.1)

Cooktop and oven are together	122	78.7%
Cooktop and oven are separate	33	21.3%
Total	155	100.0%

Table D.33. Cooktop and oven fuel type (M.2, M.5)

Fuel type	Cooktop		Oven	
	Number	Percent	Number	Percent
Electric	36	23.2%	56	36.1%
Gas	118	76.1%	98	63.2%
Propane	1	0.6%	1	0.6%
Don't know/blank	0	0.0%	0	0.0%
Total	155	100.0%	155	100.0%

Table D.34. Cooktop and oven burners light (M.2, M.5)

Burner light	Cooktop			Oven		
	Number	Percent	Percent applicable	Number	Percent	Percent applicable
Electronic	103	66.5%	86.6%	71	45.8%	71.7%
Match Light	4	2.6%	3.4%	2	1.3%	2.0%
Pilot	11	7.1%	9.2%	12	7.7%	12.1%
Don't know	1	0.6%	0.8%	14	9.0%	14.1%
Not Applicable[1]	36	23.2%	--	56	36.1%	--
Total	155	100.0%	--	155	100.0%	--

[1]Homes with electric cooktop or oven are excluded

Table D.35. Number of cooktop burners and burners most frequently used (M.2, M.4)

Number of burners	Back burners	Front burners	Both Front and back	Total
3	0	1	0	**1**
4	5	79	32	**116**
5	1	19	10	**30**
6	0	6	2	**8**
Total	6	105	44	155

Table D.36. Age of cooktop (M.3)

Age	Number	Percent
0-5 years	60	38.7%
6-10 years	26	16.8%
11-15 years	26	16.8%
16+ years	36	23.2%
Blank/do not know	7	4.5%
Total	155	100.0%

Table D.37. Oven self-cleaning setting (M.6)

	Number	Percent
Oven has self-cleaning setting	91	58.7%
Oven does not have self-clean	45	29.0%
Don't know	19	12.3%
Total	155	100.0%

Table D.38. Cooking in winter compared to other seasons (M.7)

Use oven or stove more often in winter	59	38.1%
Do not use oven or stove more in winter	96	61.9%

Table D.39. Residences' kitchen exhaust system (M.8, M.9)

Kitchen Exhaust fans		Number	Percent
Range hood above the cooktop	**Exhaust out**	66	42.6%
	Blows air back	19	12.3%
	Don't know	4	2.6%
Microwave and exhaust fan combination above the cooktop	**Exhaust out**	12	7.7%
	Blows air back	6	3.9%
	Don't know	2	1.3%
Downdraft exhaust at the back of the cooktop		4	2.6%
Downdraft exhaust in the middle of the cooktop		3	1.9%
Exhaust fan in the ceiling or wall above cooktop		11	7.1%
Exhaust fan in ceiling or wall not above cooktop		--	--
There is no exhaust system in the kitchen		25	16.1%
There are more than two exhaust fans		2	1.3%
Other		1	0.6%
Total		155	100.0%

Table D.40. Weekly cooktop or oven use frequency (number of days per week) (O.1)

Meal	All (7)	Most (4-6)	Some (1-3)	Rare or Never (<1)	Total
Breakfast	29.0%	18.7%	38.1%	14.2%	100.0%
Lunch	5.2%	8.4%	49.7%	36.8%	100.0%
Dinner	36.1%	54.8%	7.1%	1.9%	100.0%
Other	11.0%	10.3%	29.0%	49.7%	100.0%

Table D.41. Frequency of window openings in residences' homes (O.5)

Open times	Number	Percent
More than half the time	25	16.1%
Several hours per day	27	17.4%
Less than an hour each day	38	24.5%
Usually closed all day	64	41.3%
Blank/did not answer	1	0.6%
Total	155	100.0%

Table D.42. Rooms that have windows most often opened (O.6)

Room	Number	Percent (n=155)
Dining	1	0.6%
Bedroom	48	31.0%
Bathroom	47	30.3%
Kitchen	40	25.8%
Common rooms	44	28.4%
Doors	4	2.6%

Table D.43. Number of residents in household, by age (O.8)

Number of residents	0-5 yrs		6-17 yrs		18-30 yrs		31-64 yrs		65+ yrs	
0	125	80.7%	123	79.4%	104	67.1%	26	16.8%	128	82.6%
1	25	16.1%	21	13.6%	25	16.1%	38	24.5%	18	11.6%
2	2	1.3%	6	3.9%	13	8.4%	83	53.6%	6	3.9%
3	1	0.7%	2	1.3%	5	3.2%	7	4.5%	0	--
4	2	1.3%	3	1.9%	5	3.2%	1	0.7%	3	1.9%
5	0	--	0	--	2	1.4%	0	--	0	--
6	0	--	0	--	1	0.7%	0	--	0	--
7	0	--	0	--	0	--	0	--	0	--
Total	155	100.0%	155	100.0%	155	100.0%	155	100.0%	155	100.0%

Table D.44. Number of total residences in household (O.7)

Number of residences	Number	Percent
1	27	17.4%
2	50	32.3%
3	35	22.6%
4	26	16.8%
5	15	9.7%
6	1	0.6%
7	1	0.6%
Total	155	100.0%

Table D.45. Highest education level in household (O.9)

Education Level	Number	Percent
Some College	3	1.9%
Associate Degree	6	3.9%
College Degree	48	31.0%
Graduate Degree	98	63.2%
Total	155	100.0%

Table D.46. All races and/or ethnicity of people living in respondent's household (O.10)

Ethnicity	Number	Percent of all homes (n=155)
American Indian, Alaskan Native	2	1.3%
Native Asian/Islander	47	30.3%
Black, African American	7	4.5%
Hispanic/Latino	21	13.5%
White, Caucasian	118	76.1%
Prefer not to answer	3	1.9%

Table D.47. Income for all members of respondent's household (O.11)

Income	Number	Percent
Less than $25,000	10	6.5%
$25,000 - $49,999	20	12.9%
$50,000 - $74,999	24	15.5%
$75,000 - $99,999	21	13.5%
$100,000 - $150,000	38	24.5%
>$150,000	28	18.1%
Prefer not to answer	14	9.0%
Total	155	100.0%

Table D.48. Soonest that repairs to a furnace could be afforded – Owned homes (O.12, O.13)

	If $200 required for repair		If $1000 required for repair	
	Number	Percent	Number	Percent
Right away	103	98.1%	89	84.8%
Within a week	1	1.0%	6	5.7%
Within a month	1	1.0%	5	4.8%
Not sure	0	--	5	4.8%
Total	105	100.0%	105	100.0%
Not applicable	**50/155**	**--**	**50/155**	**--**

Table D.49. Landlord reliability at making repairs to appliances when needed – Rented homes (O.14)

Landlord reliability	Number	Percent
Hardly or not reliable	1	2.0%
Somewhat reliable	20	40.0%
Very reliable	26	52.0%

Blank	3	6.0%
Total	**50**	**100.0%**
Not applicable	**105/155**	**--**

Table D.50. Gender of respondents to initial questionnaire (O.15)

	Number	Percent
Female	98	63.2%
Male	57	36.8%

Table D.51. Number of high performance homes

Number of homes	**Number**	**Percent**
High Performance	24	15.5%
Normal	131	84.5%
Total	**155**	**100.0%**

EXIT SURVEY QUESTIONS

Table D.52. Residence weekday occupancy during different periods of day (Q1)

	Usually		Sometimes		Rarely		Blank/Don't know		Total	
	N	%	N	%	N	%	N	%	N	%
After breakfast and before lunch	78	50.3%	40	25.8%	32	20.6%	5	3.2%	155	100.0%
During lunch	67	43.2%	46	29.7%	36	23.2%	6	3.9%	155	100.0%
After lunch until dinner	62	40.0%	48	31.0%	40	25.8%	5	3.2%	155	100.0%
During dinner	128	82.6%	20	12.9%	4	2.6%	3	1.9%	155	100.0%
After dinner until bedtime	139	89.7%	11	7.1%	2	1.3%	3	1.9%	155	100.0%

Table D.53. Residence weekend occupancy (Q2)

	Neither		Saturday		Sunday		Both		Blank/Don't know		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
After breakfast and before lunch	12	7.7%	22	14.2%	12	7.7%	106	68.4%	3	1.9%	155	100.0%
During lunch	18	11.6%	16	10.3%	20	12.9%	96	61.9%	5	3.2%	155	100.0%
After lunch until dinner	26	16.8%	21	13.5%	14	9.0%	89	57.4%	5	3.2%	155	100.0%
During dinner	15	9.7%	11	7.1%	22	14.2%	104	67.1%	3	1.9%	155	100.0%
After dinner until bedtime	9	5.8%	7	4.5%	18	11.6%	118	76.1%	3	1.9%	155	100.0%

Table D.54. Heaters used during week of sampling (Q4, Q5)

Heaters	Most used heater (n=131)			Second heater used (n=18)		
	Number	Percent	Percent of applicable	Number	Percent	Percent of applicable
Central forced-air furnace	88	56.8%	67.2%	1	0.6%	5.6%
Wall furnace	13	8.4%	9.9%	3	1.9%	16.7%
Floor furnace	3	1.9%	2.3%	0	--	--
Gas oven or stove	0	--	--	1	0.6%	5.6%
Gas fireplace	2	1.3%	1.5%	0	0.0%	0.0%
Wood fireplace	0	--	--	2	1.3%	11.1%
Wood stove	2	1.3%	1.5%	0	--	--
Heat pump	4	2.6%	3.1%	0	--	--
Baseboard electric	2	1.3%	1.5%	0	--	--
Portable electric space heater	6	3.9%	4.6%	6	3.9%	33.3%
Portable space heat that burns fuel	1	0.6%	0.8%	1	0.6%	5.6%
Other	10	6.5%	7.6%	4	2.6%	22.2%
Did not use heater/Not applicable	24	15.5%	--	137	88.4%	--
Total	155	100.0%	100.0%	155	100.0%	100.0%

Table D.55. Most used heaters – number of uses per day (Q4)

	Weekday Usage (n=131)			Weekend Usage (n=131)		
	Number	Percent	Percent of applicable	Number	Percent	Percent of applicable
Not used anytime of day	1	0.6%	0.8%	8	5.2%	6.1%
Used for one period of day	34	21.9%	26.0%	29	18.7%	22.1%
Used for two periods of day	75	48.4%	57.3%	68	43.9%	51.9%
Used for three periods of day	10	6.5%	7.6%	15	9.7%	11.5%
Blank/don't know	11	7.1%	8.4%	11	7.1%	8.4%
Not applicable	24	15.5%	--	24	15.5%	--
Total	155	100.0%	100.0%	155	100.0%	100.0%

Table D.56. Second heater – number of uses per day (Q5)

	Weekday Usage (n=18)			Weekend Usage (n=18)		
	Number	Percent	Percent of applicable	Number	Percent	Percent of applicable
Not used anytime of day	1	0.6%	5.6%	4	2.6%	22.2%
Used for one period of day	10	6.5%	55.6%	7	4.5%	38.9%
Used for two periods of day	3	1.9%	16.7%	3	1.9%	16.7%
Used for three periods of day	0	--	--	0	--	--
Blank/don't know	4	2.6%	22.2%	4	2.6%	22.2%
Not applicable	137	88.4%	--	137	88.4%	--
Total	155	100.0%	100.0%	155	100.0%	100.0%

Table D.57. Heater frequency of use during daytime for week of sampling (Q4, Q5)

Days	Most used heater (n=131)			Second heater used (n=18)		
	Number	Percent	Percent of applicable	Number	Percent	Percent of applicable
Every day	87	56.1%	66.4%	8	5.2%	44.4%
4-6 days	26	16.8%	19.8%	2	1.3%	11.1%
1-3 days	16	10.3%	12.2%	4	2.6%	22.2%
Blank/don't know	2	1.3%	1.5%	4	2.6%	22.2%
Not applicable	24	15.5%	--	137	88.4%	--
Total	155	100.0%	100.0%	155	100.0%	100.0%

Table D.58. Heater frequency of overnight use during week of sampling (Q4, Q5)

	Most used heater (n=131)			Second heater used (n=18)		
	Number	Percent	Percent of applicable	Number	Percent	Percent of applicable
Overnight usage	70	45.2%	53.4%	13	8.4%	72.2%
Heater was not used for overnight	50	32.3%	38.2%	1	0.6%	5.6%
Blank/don't know	11	7.1%	8.4%	4	2.6%	22.2%
Not applicable	24	15.5%	--	137	88.4%	--
Total	155	100.0%	100.0%	155	100.0%	100.0%

Table D.59. Number of Windows left open during week of sampling (Q7 – Q10)

Number of windows	Overnight		Morning		Day		Evening	
	N	%	N	%	N	%	N	%
All	19	12.3%	20	12.9%	24	15.5%	13	8.4%
Most (4-6)	2	1.3%	7	4.5%	7	4.5%	7	4.5%
Some (1-3)	8	5.2%	26	16.8%	69	44.5%	18	11.6%
None	123	79.4%	99	63.9%	52	33.5%	114	73.5%
Blank/Don't know	3	1.9%	3	1.9%	3	1.9%	3	1.9%
Total	155	100.0%	155	100.0%	155	100.0%	155	100.0%

Table D.60. Cooktop usage at different periods of day during week of sampling (Q11)

Meals	7 days		5-6 days		3-4 days		1-2 days		<1		Total
	N	%	N	%	N	%	N	%	N	%	
Breakfast	45	29.6%	20	13.2%	28	18.4%	31	20.4%	28	18.4%	152
Lunch	6	3.9%	7	4.6%	26	17.1%	44	28.9%	69	45.4%	152
Dinner	46	30.3%	46	30.3%	39	25.7%	16	10.5%	5	3.3%	152
Any other time	12	7.9%	5	3.3%	19	12.5%	23	15.1%	93	61.2%	152

Table D.61. Oven usage at different periods of day during week of sampling (Q12)

Meals	7 days		5-6 days		3-4 days		1-2 days		<1		Total
	N	%	N	%	N	%	N	%	N	%	
Breakfast	2	1.3%	1	0.7%	0	0.0%	8	5.3%	141	92.8%	152
Lunch	0	0.0%	0	0.0%	0	0.0%	9	5.9%	143	94.1%	152
Dinner	3	2.0%	8	5.3%	25	16.4%	53	34.9%	63	41.4%	152
Any other time	0	0.0%	0	0.0%	0	0.0%	19	12.5%	133	87.5%	152

Table D.62. Frequency of candle or incense use during week of sampling (Q14)

Frequency of use	Number	Percent
More than 3 times per day	2	1.3%
1-3 times per day	6	3.9%
3-6 times over the course of the week	9	5.9%
1-2 times over the week	26	17.1%
None	109	71.7%
Total	152	100.0%
Not applicable	3	--

Table D.63. Loads of laundry dried during week of sampling (Q15)

Q15	Number	Percent
>10 loads	1	0.9%
6-10 loads	21	18.3%
1-5 loads	77	67.0%
None	11	9.6%
Blank	5	4.3%
Total	115	100.0%
Not applicable	40	--

Table D.64. Use of kitchen exhaust fan or range hood (Q21)

Frequency	Number	Percent
Most times (75% or more) when cooktop or oven is used	19	14.6%
Most times when cooktop is used but not when oven is used	23	17.7%
About half the time	20	15.4%
Infrequently; only when needed	51	39.2%
Never	8	6.2%
Blank/Don't know	9	6.9%
Total	130	100.0%
Not applicable	25	--

Table D.65. Most common fan speed for exhaust fan or range hood use (Q22)

Settings	Number	Percent
Lowest setting	28	21.5%
Medium setting	17	13.1%
Highest setting	33	25.4%
Only one speed available	15	11.5%
Varies or changes depending on what is being cooked	17	13.1%
Don't know or prefer not the say	20	15.4%
Total	130	100.0%
Not applicable	25	--

Table D.66. Frequency of cleaning grease screens of fans or range hood (Q25)

Frequency	Number	Percent
Each week	2	1.5%
Each month	7	5.4%
As needed	55	42.3%
Never	35	26.9%
No grease screens	10	7.7%
Don't know/blank	21	16.2%
Total	130	100.0%
Not applicable	25	--

Table D.67. Existence and use of carbon/charcoal filter in kitchen (Q26)

		Number	Percent
Have carbon/charcoal filter	Need to be periodically replaced	2	1.5%
	Does not need to be periodically replaced	1	0.8%
	Don't know	2	1.5%
Does not have carbon/charcoal filter		106	81.5%
Don't know		19	14.6%
Total		130	100.0%
Not applicable		25	--

Table D.68. Cooktop and oven burner problems (Q27, 28, 32, 33, 34)

	Cooktop	Oven		
	Ignition	Ignition	Thermostat	Burning Smell
Has problem	47	7	6	2
Does not have any problems	73	103	101	101
Blank/Didn't answer	35	45	48	52
Total	155	155	155	155

Table D.69. Number of cooktop burners that won't ignite (Q27)

Number of burners	Number	Percent
1	17	36.2%
2	17	36.2%
3	1	2.1%
4	8	17.0%
4+	2	4.3%
Blank/Don't know	2	4.3%
Total	47	100.0%
Not applicable	108	--

Table D.70. Manner in which burner ignition problems were resolved (Q30, Q36)

Cooktop	Oven

	Number	Percent	Number	Percent
Hasn't been resolved	29	61.7%	2	28.6%
Was serviced by a professional	4	8.5%	1	14.3%
Was serviced by a resident	4	8.5%	2	28.6%
Appliance was replaced	0	--	0	--
Issue resolved itself	9	19.1%	2	28.6%
Blank/don't know	1	2.1%	0	0.0%
Total	47	100.0%	7	100.0%
Not applicable	108		148	

Table D.71. Flame appearance without pot on top (Q37)

	Mostly blue		Lots of orange		Blank/No response		Total
	Number	Percent	Number	Percent	Number	Percent	
Left Front	105	67.7%	2	1.3%	48	31.0%	155
Left Rear	105	67.7%	2	1.3%	48	31.0%	155
Right Front	103	66.5%	3	1.9%	49	31.6%	155
Right Rear	104	67.1%	2	1.3%	49	31.6%	155

Table D.72. Flame appearance with pot on top (Q38)

	Steady		Wobbly		Blank/No response		Total
	Number	Percent	Number	Percent	Number	Percent	
Left Front	103	66.5%	2	1.3%	50	32.3%	155
Left Rear	103	66.5%	2	1.3%	50	32.3%	155
Right Front	103	66.5%	2	1.3%	50	32.3%	155
Right Rear	103	66.5%	2	1.3%	50	32.3%	155

Table D.73. Respondent's rating of home's air quality during week of sampling (Q39)

	Number	Percent
Very good	63	40.6%
Acceptable	83	53.5%
Barely acceptable	4	2.6%
Not acceptable	2	1.3%
Blank/no response	3	1.9%
Total	155	100.0%

Table D.74. Smell of cigarette smoke from other nearby homes or apartments, or from hallways, during week of sampling (Q40)

	Number	Percent
Never	136	87.7%
A few days	16	10.3%
Every day	0	0.0%
Blank/Don't	3	1.9%

know		
Total	155	100.0%

Table D.75. Smell of other odor in week of sampling (Q41)

	Number	Percent
Never	132	85.2%
A few days	18	11.6%
Every day	1	0.6%
Blank/Don't know	4	2.6%
Total	155	100.0%