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# Ventilation Behavior and Household Characteristics in New California Houses

Phillip N. Price and Max H. Sherman

## Contributed Report 10

Air Infiltration and Ventilation Centre
Operating Agent and Management
INIVE EEIG
Boulevard Poincaré 79
B-1060 Brussels
Belgium

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Ernest Orlando Lawrence Berkeley National Laboratory
1 Cyclotron Rd; MS 90-3074
Berkeley, CA 94720 - USA
http://www.lbl.gov/



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# Foreword by the AIVC

Before Bill Gates there were windows. Before low-E coatings there were windows. Even before glazing there were windows. Over 7000 years ago people were carving windows into their homes in order to let light and, more importantly, air into their homes. Even then people realized the need to have ventilation to exhaust indoor contaminants and provide fresh (or at least fresher) air into their buildings.

For most of the history of man, windows have been the primary design approach for providing ventilation in buildings. For over 400 years, building codes have required operable windows to give occupants the ability to ventilate, if they choose. A key question though is, "Do they choose?"

In the 1980s the IEA ECBCS (International Energy Agency – Implementing Agreement for Energy Conservation in Buildings and Community Systems) funded a project entitled "Annex 8 - Inhabitants behaviour with respect to ventilation" to look at five different countries to determine the ventilation-related behavior of inhabitants, to estimate the amount of energy due to such behavior, to study the motivation behind that behavior and to study how that behavior might be modified.

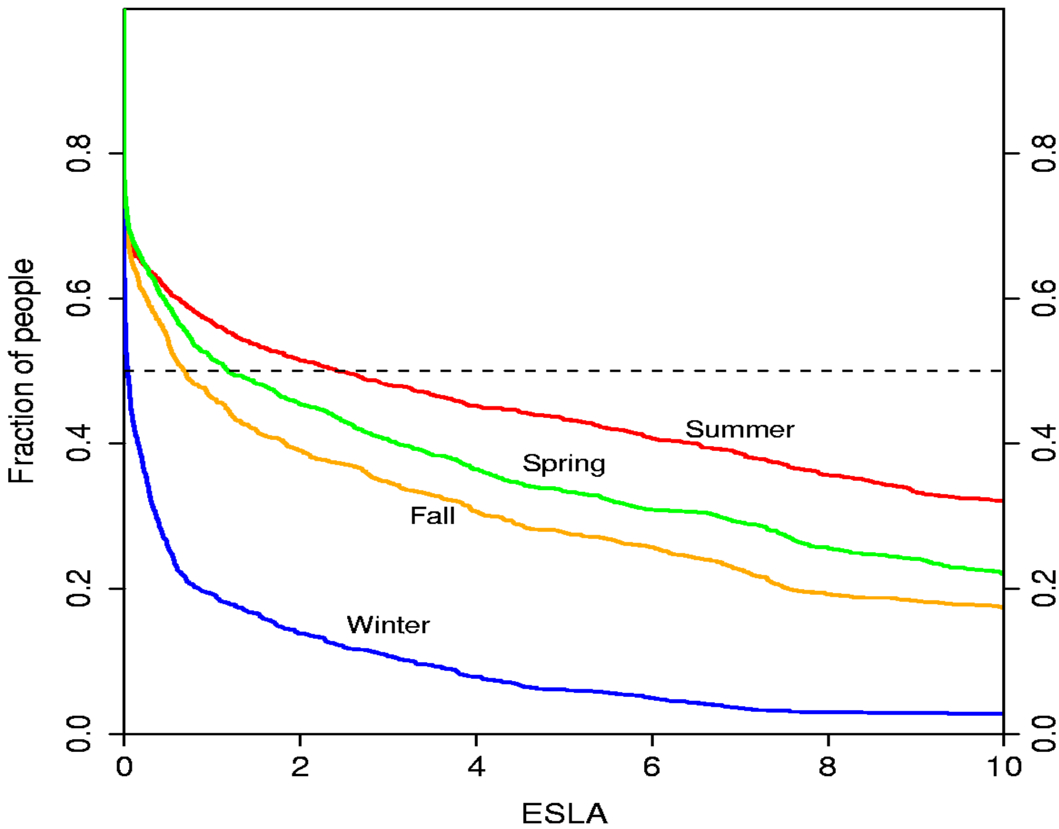
C. Dubrul (1988), the Operating Agent of Annex 8, details the results from this international effort. There was a great deal of variation from country to country because of climactic, cultural and construction differences, but there were some over-arching conclusions that could be inferred. The study showed no correlation between window use and the building size or its leakiness. There was some correlation between the heating system used and the room type, but the largest correlation was with outdoor conditions. Specifically, people operated windows to keep the indoor conditions within their comfort tolerances and to reduce energy use.

The results suggested that people would get from 15-70 cfm (25 – 150 $m^3/h$) from their windows when the windows were operated, but there were a variety of reasons, such as cold weather or noise, that would inhibit such operation. While hot, humid climates were not included in that study, one could imagine at least as many inhibiting factors for air conditioned buildings.

ASHRAE Standard 62.2-2004 allows window operation to be used to meet minimum requirements, in some cases, in mild climates. The rationale is presumably that when the climate is mild people may routinely operate their windows and get sufficient ventilation, so there is no reason to mandate mechanical systems. Is this assumption justified in modern homes?

For Standard 62.2 most houses that would qualify as being in a mild climate are in California. Not surprisingly, the State of California is quite interested to know if it can count on window operation for ventilation or if it should consider mandating mechanical ventilation. California recently funded a project to survey the occupants of over 1500 new homes to find this out.

Price and Sherman (2006) have analyzed the survey results and found several interesting results. The first is that very few, surprisingly few, households report dissatisfaction with their indoor environment. This is true even when more specific questions determine there are specific areas of concern. This result suggests that using occupant reports of satisfaction may dramatically under-estimate the frequency of problems with the HVAC or building systems.




The plot above shows the fraction of houses that have a given effective specific leakage area (ESLA). ESLA is a measure of the equivalent opening area throughout the season. For the climates of the study a house needs an ESLA in the range of 3-5 to get adequate ventilation from window operation. Less than 50% of houses get this even in summer, which is the season with the highest window operation.

The primary result from this study is that most households do not get sufficient ventilation from window openings, even in mild climates such as California. The distribution of window use, however, is quite broad – there is a small but significant number of "window-openers" who get a lot of ventilation, while an even larger number of "window-closers" who get virtually no ventilation from window operation.

As in previous studies the primary motivator for window operation appears to be thermal comfort. There is almost no information to suggest that window operation is dependent on indoor sources or health effects. Furthermore, households have a variety of exogenous reasons for keeping windows closed such as security, noise or dust.

It appears that most households do not adjust their windows as a function of indoor air quality. We might expect them to open a window when there is some high-polluting event such as cleaning or painting, but they do not appear to be sensitive to the lower pollutant levels one is concerned with in minimum ventilation standards such as ASHRAE 62.2. On the other hand, people are able to operate their windows to deal with over-heating and/or ventilative cooling concerns.

These results are obtained from new homes in California. Different regions and construction types may well yield different results. It may well be true that households will operate the windows less in more humid or more extreme climates. It is, however, unlikely that people will use windows more often to provide minimum ventilation in these climates.

The implication for the HVAC or building-science professionals is that one cannot assume that people will open their windows to provide minimum ventilation rates. It is up to that professional to provide mechanical, passive, natural or hybrid ventilation systems that will meet minimum requirements without regular window operation or other substantial occupant interactions.

As a result of this data ASHRAE Standard 62.2 is in the process of removing the allowance for open windows as a means to provide minimum ventilation. This change should be included in the next publication of the standard.

Perhaps the Banpo villagers of 7000 years ago got it right when they had large holes cut in their houses to provide continuous ventilation. Modern man has many more choices for providing ventilation now, but one thing is certain: We don't do windows.

*References*

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# Ventilation Behavior and Household Characteristics in New California Houses

Phillip N. Price and Max H. Sherman

Environmental Energy Technologies Division

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## Legal Notice



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# Ventilation Behavior and Household Characteristics in New California Houses

**Phillip N. Price and Max H. Sherman**

*Indoor Environment Department*
*Lawrence Berkeley Laboratory*
*University of California*
*February 2006*

**Abstract**

A survey was conducted to determine occupant use of windows and mechanical ventilation devices; barriers that inhibit their use; satisfaction with indoor air quality (IAQ); and the relationship between these factors.

A questionnaire was mailed to a stratified random sample of 4,972 single-family detached homes built in 2003, and 1,448 responses were received. A convenience sample of 230 houses known to have mechanical ventilation systems resulted in another 67 completed interviews.

Results:

- Many houses are under-ventilated: depending on season, only 10-50% of houses meet the standard recommendation of 0.35 air changes per hour.
- Local exhaust fans are under-utilized. For instance, about 30% of households rarely or never use their bathroom fan.
- More than 95% of households report that indoor air quality is “very” or “somewhat” acceptable,” although about 1/3 of households also report dustiness, dry air, or stagnant or humid air.
- Except households where people cook several hours per week, there is no evidence that households with significant indoor pollutant sources get more ventilation.
- Except households containing asthmatics, there is no evidence that health issues motivate ventilation behavior.
- Security and energy saving are the two main reasons people close windows or keep them closed.

**Key words**: Indoor Air Quality, IAQ, mechanical ventilation systems, ventilation standards, indoor pollutants, asthma, windows, natural ventilation, thermal comfort.

## Table of Contents



## Preface

The California Air Resources Board (ARB) carries out and funds research to reduce the health, environmental, and economic impacts of indoor and outdoor air pollution in California. This research involves four general program areas:

- Health and Welfare Effects
- Exposure Assessment
- Technology Advancement and Pollution Prevention
- Global Air Pollution

For more information about the ARB Research Program please see ARB's website at: http://www.arb.ca.gov/research/research.htm, or contact ARB's Research division at 916-445-0753. For more information about ARB's Indoor Exposure Assessment Program, please visit the website at: http://www.arb.ca.gov/research/indoor/indoor.htm.

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy service and products to the market place.

The PIER Program, managed by the California Energy Commission (Commission), annually awards up to $62 million to conduct the most promising public interest energy research by partnering with the Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy

- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Strategic Energy Research

For more information on the PIER Program, please visit the Commission's website at http://www.energy.ca.gov/research/index.html, or contact the Commission's Publications Unit at 916-654-5200.

What follows is a report on the "Survey of Ventilation Behavior and Housing Characteristics in New California Houses", ARB contract 03-326 and the Commission contract 500-02-023, conducted by the University of California at Berkeley Survey Research Center and the Lawrence Berkeley National Laboratory. The report is entitled "Survey of Ventilation Behavior and Housing Characteristics in New California Houses." This project contributes to the ARB Environmental Research Area and the PIER Environmental program.

**Introduction:**

Houses built within the last few years are designed to be very airtight in order to conserve energy. Concerns have been raised that the occupant use of windows, doors, and mechanical ventilation may not provide adequate ventilation with outdoor air, and may contribute to unacceptable indoor air quality (IAQ). In setting building energy design standards, the California Energy Commission (Commission) assumes a certain level of outdoor air ventilation from occupant use of windows and mechanical devices such as exhaust fans. The Commission needs to determine whether this assumed building ventilation is achieved through occupant practices. If the lack of ventilation contributes to substantial air quality problems in many new homes, changes in building codes or recommended design practices may be required to ensure adequate IAQ.

To determine whether such problems occur and how they might be remedied, data on household ventilation practices were needed. Policy makers need information on the patterns of ventilation behaviors and the key factors involved. For example: When, how often, and for how long do people open windows or use mechanical exhaust systems; what fraction of homes have and use mechanical ventilation systems; and what is the perceived IAQ in new homes? In addition to needing information about ventilation behavior, policy makers need information about the reasons for the occupant behavior. For example, Are occupants basing their ventilation decisions on concerns for thermal comfort, air pollution, outdoor noise, home security, privacy, convenience, local climate, or other important factors?

The Commission has as a funding priority a program of Research and Development (R&D) to advance the state of knowledge on residential ventilation in California. It will support this research through its Public Interest

Energy Research (PIER) program. An important goal of this effort is to identify changes to existing residential energy efficiency standards (i.e. Title 24) that can be incorporated into the 2008 standards to maintain or improve the indoor environment of new homes and reduce the energy-related impacts of these homes.

To advance the state of knowledge in this field the PIER program has established a three-part approach to the problem: 1) characterization of the indoor environment of homes built to current standards, 2) development of minimum requirements to achieve acceptable indoor air quality in future construction and 3) evaluation and development of technologies and associated descriptive algorithms for meeting minimum requirements.

These three elements act synergistically to provide the information the State needs to inform its efforts to modify Title 24. This survey has primarily addressed item (1), characterization of the indoor environment, and has provided data that can be used for (2) development of minimum requirements.

Information was also needed concerning some specific pollutant sources that are sometimes problematic or can contribute to indoor pollutant levels, such as new carpets, paint, cabinetry, and heating and cooking appliances. Such key information is also needed by ARB for assessment of Californians' exposures to indoor and outdoor air pollutants in new homes. Under HSC (Health and Safety Code) Section 39660.5, ARB is required to assess Californians' exposures to toxic air contaminants.

This report summarizes data on the presence and use of ventilation features, related occupant ventilation practices, and occupants' perceptions regarding IAQ in a sample of newly built California homes. The results were analyzed to meet the following specific objectives:

- Determine how occupants used windows, doors, and mechanical ventilation devices.

- Determine occupant perceptions of and satisfaction with IAQ in their homes.

- Determine the relationship among ventilation practices, perceived IAQ, and house and household characteristics; and

- Determine barriers that prevent or inhibit the use of windows, doors, and mechanical ventilation systems.

This was the first large survey of ventilation practices in new California homes. The information obtained is of immediate use for addressing the issues and needs for the Commission and ARB, as described above. It has provided a basis for planning a future field study that will measure pollutant concentrations and ventilation-related parameters in a sample of new California homes.

### 1.1 Project Objectives:

The goals of this larger project, which will support the programmatic goals of CEC and ARB, are to obtain some of the information needed to guide the development of future building standards that protect indoor air quality (IAQ) and comfort in California homes, and to obtain information to update and improve the exposure and risk assessments for indoor and outdoor air pollutants in California. This information will be used to begin assessing the adequacy of ventilation, indoor air quality, and thermal comfort in new California single-family homes. It will also be used to assess the effectiveness and problems of mechanical ventilation systems that are currently used in some new homes. A secondary goal is to collect information that will be useful for conducting a future survey that will measure indoor pollutant concentrations and ventilation rates in new homes.

This project was required because of the lack of available information about occupant ventilation-related behavior and IAQ in new California houses.

In companion papers Grimsrud and Hadlich (1999) and Hadlich and Grumsrud (1999) have reviewed the relationship between indoor pollutants, ventilation, and indoor air quality for typical pollutants in the residential environment. They have found that there is little known about the interactions of occupant behavior and exposures. Sherman and Hodgson (2003) used this information, in part, to develop minimum ventilation rates for the control of formaldehyde.

More broadly an international study of window opening behavior was completed in the 1980s, where it was concluded that window-opening behavior is highly dependent on culture, weather, construction type, education, climate and tradition, but not terribly dependent on health or energy considerations.

This current project collected information on ventilation-related behavior and IAQ in a sample of new California single-family homes built in 2003.

#### 1.1.1. Determine how occupants use windows, doors, and mechanical ventilation:

Ventilation in homes is achieved by opening windows and doors (natural ventilation), operating exhaust fans and whole house ventilation systems (mechanical ventilation), and (indirectly) by operating some heating and cooling systems (mechanical). We asked specific questions about how and when occupants use natural and mechanical ventilation.

#### 1.1.2. Determine occupants' perceptions of and satisfaction with (IAQ) in their homes:

Occupant perceptions regarding IAQ are often useful indicators of actual IAQ problems. Occupant satisfaction with IAQ and with the performance of their natural and mechanical ventilation devices can be strong determinants of how occupants use those devices and the resultant IAQ in their home. Contaminant concentrations and ventilation rates cannot be measured with a mail-out survey; however, information can be obtained on indicators that are related to indoor contaminant concentrations:

#### 1.1.3. Determine the relationships among ventilation practices, perceived IAQ, and house and household characteristics:

We examined how perceived IAQ, comfort, and satisfaction are related to ventilation system characteristics and practices, window and door use, household characteristics, and climate. To accomplish this we asked additional questions about the following characteristics of the house and household:

#### 1.1.4. Determine barriers that prevent or inhibit the use of windows, doors, and mechanical ventilation systems:

There are several reasons why people may not use their windows, their bath fans, their kitchen fans, or their mechanical ventilation systems. To understand these barriers to providing ventilation, questions were asked about the following topics.

#### 1.1.5 Other Household Characteristics:

Some of the questions and topics mentioned above have their primary value in helping focus efforts for the future field study of IAQ in new California homes, rather than in answering the more immediate questions for California's 2008 building energy design standards. To better prepare for the field study, more information was needed on the characteristics of the occupants themselves. Questions about the households' general socioeconomic status

(SES) were asked to help to identify differences among SES groups that may need to be considered in designing the field study.

### 1.2. Report Organization:

Section 2, labeled “Project Approach / Materials and Methods,” outlines the overall design of the study, which includes a discussion of the target population, and the sample frame. Two samples were selected for this project, a Statewide Probability Sample and a Supplemental Builders’ Sample. Following the discussion of the samples, the processes for the selection of dwellings, the questionnaire design, the mail effort, the eligibility criteria, as well as the calculation of sample weights for analysis, will be discussed. This section will conclude with a discussion of the quality assurance procedures and the steps involved in data processing.

Section 3 of the report will be devoted to the analysis of the questionnaire data. The results for each of the study objectives will be discussed in full, followed by the conclusions of the project, future recommendations, and how this study benefits California.

## 2. Project Approach / Materials and Methods:

Because occupant perceptions of indoor air quality are important indicators of actual indoor air quality problems, a self-administered questionnaire was the methodology used to collect data for this project. While self-reports of ventilation practices in the home cannot measure actual contaminants in the home, a self administered questionnaire can provide valuable information regarding how an occupant uses windows, doors, and mechanical ventilation systems, their perceptions of and satisfaction with indoor air quality in their home, and what barriers exist that may prevent or discourage the use of windows, doors, and mechanical ventilation systems.

All survey logistics described below were conducted by the Survey Research Center at the University of California, Berkeley: they compiled the address lists, formatted the survey questionnaire, etc., then collected the data, performed the data entry, and calculated the sampling weight for each response.

### 2.1. Target Population:

This study surveyed owner-occupants and renters of single-family detached homes in California that were built in 2003. “Detached” was defined as no shared walls with another house. English speaking owners and renters who had lived in the home for at least nine months were eligible to be interviewed.

## 2.2. General Design of the Sample:

Since part of the analysis was to compare results from sampling strata for oversampling, the population of new single-family detached houses was divided into three strata, each of which was defined by a set of zip codes provided by ARB. A separate random sample was drawn in each stratum. In addition, because there was special interest in new homes that contain the new mechanical fresh air ventilation systems, a small supplementary sample was drawn from lists of such homes built in 2003. These lists came primarily from builders.

## 2.3. Constructing the Sampling Frames:

### 2.3.1. Statewide Probability Sample:

For new homes in California, the most accessible sampling frame was the Realty file. That file was complied from public records, including warranty and security deeds. It included the following fields:

- Type of dwelling (single family, etc.)
- Year the home was built,
- Name of the current owner
- Address
- Telephone number (when available)

Many companies compile these types of dwelling records. After some evaluation, it was determined that a California company named “DataQuick” had the most adequate collection of records that met our needs.

The Commission and ARB defined two specific climate regions of interest on the basis of historical wind data: the Sacramento-Delta region and the Southern California coastal region. There were 104 zip codes with significant nighttime wind influence in the Sacramento-Delta region and 353 such zip codes in the Southern California coastal region. Based on the zip codes defined for these two areas, the whole state was divided into three mutually exclusive geographic strata: the Sacramento-Delta region, the Southern California coastal region, and the rest of the State. The number of houses built in 2003 in the DataQuick database for each stratum was as follows: for the Sacramento-Delta region, there were 3,042 houses; for the Southern California coastal region, there were 6,239 houses, for the rest of the State, there were 15,415 houses. The total number of 2003 DataQuick listings was 24,696. DataQuick drew separate random samples from each of the three strata and sent them to SRC.

The single family housing listings compiled by DataQuick were known to be incomplete. We were informed that some counties take longer than others to report data on the sales of new homes. Nevertheless, since the survey was to be based on new homes, we could not use listings from past years that presumably would have been more complete by the time of the 2004 sample.

The degree to which the 2003 DataQuick listings were incomplete is difficult to assess without contacting each county assessor's office, which was beyond the scope of the present project. One might compare the number of listings to the number of housing starts in the preceding year, 2002. That number, obtained from ARB, was 108,467. If all of those houses were completed and sold in 2003, and if they all were detached homes, the DataQuck listings would only cover 23% of those housing starts.

In any case, the 2003 DataQuick listings were the best available sampling frame for the survey. We ended up using 4,972 of the 24,696 records in the database for 2003.

### 2.3.2. Supplemental Builders' Sample:

The supplementary sample of new houses known to have mechanical fresh air ventilation systems installed was based on addresses provided by two sources:
Beutler Builders (McClellan, California) provided a list of 2,000 addresses in Northern California, predominantly in the Sacramento-Delta region, of homes that were built within the last two years. They were grouped into three subgroups: (1) Standard ventilation, which was a normal bath fan only application; (2) 5MHRVFB which is their code for a Modular Heat Recovery Ventilation (MHRV) that runs continuously 24 hours a day, seven days a week; (3) 5FV5, which is their code for the Freshvent system, whish is a fresh air duct, connected to the HVAC return with a “Cycler” control. The list included 1,200 homes that had the standard bath fan installed, 400 homes with the MHRV system, and 400 homes with the Freshvent system installed. For the purposes of this study, we only sampled from the 800 in the second and third groups. We did not include the 1,200 addresses that had only the standard ventilation.

The Meyers Group, a private company that provides data and consulting services for residential real estate developments and new home construction (now owned by Hanley Wood Corp., Costa Mesa, California) provided the addresses for houses in Southern California in the following counties: Los Angeles (N=691), Orange (N=437), Riverside (N=267), and Ventura (N=41). The stipulations to the Meyers

Group were that the sample include only single-family detached homes that were built in 2003 or later. Furthermore, it was stipulated that all houses in the sample were built as part of the Building America program, since the majority of those homes were known to have installed mechanical ventilation systems.

Finally, eight homes forwarded to us by ARB were included as part of the builder supplementary sample. All homes from the supplementary frame were divided into the same three geographic strata as the statewide probability sample.

## 2.4. Selection of the Dwellings

### 2.4.1. Statewide Probability Sample:

DataQuick drew a random sample of the houses in their database for each of the three geographic strata and sent the addresses to SRC. DataQuick drew 2,000 homes from their database for Sacramento-Delta, 2,000 homes from Southern California, and 6,000 from the rest of the state. SRC sorted each stratum sample by zip code and selected every other home after a random start for inclusion in the initial sample. The other half was set aside as a reserve sample, to be used as needed.

A total of 999 addresses were initially sent questionnaires in the Sacramento-Delta stratum; 973 in the Southern California stratum; and 3,000 throughout the rest of the State for a total of 4,972 general sample questionnaires. This initial sample turned out to be sufficient for the study, except for a few additional cases selected at random from the reserve sample.

Since homes in the three strata were sampled at different rates, it is necessary to use weights to compensate for different probabilities of selection whenever cases are pooled across strata. Sample weights are described in section 2.10 below.

### 2.4.2. Supplementary Builders' Sample:

All housing units in the frame of the supplementary sample were sorted by zip code within each stratum, and several dozen homes were selected by systematic sampling with a random start from each stratum to ensure obtaining a reasonable number of completed interviews from occupants of homes with a mechanical fresh air ventilation system. A total of 58 questionnaires were mailed out to the Sacramento-Delta area, 68 to the Southern California coastal region, and 104 to the rest of the State, for a total of 230 questionnaires mailed in this frame.

Note that this small supplementary sample of homes with new ventilation systems is not intended to represent all such homes in the State. Its purpose was only to provide some extra cases for analysis, since it was uncertain how many homes with new mechanical ventilation systems would be encountered in the statewide probability sample.

## 2.5. Questionnaire Design and the Project Objectives:

Before beginning the data collection phase of the study, a self-administered questionnaire was developed to ask occupants to report their family's behavior regarding the use of windows, doors, and other mechanical ventilation systems; their perceptions of, and satisfaction with, indoor air in their homes; and what concerns, if any, they have that may limit their use of windows, doors, and mechanical ventilation systems.

As part of the development of the questionnaire, a focus group was conducted for residents of Walnut Creek, Concord, and San Ramon. Six respondents took part in the focus group and gave feedback on all aspects of the questionnaire, from formatting and question wording, to the comprehensibility of the instrument. The final questionnaire was revised accordingly and can be seen in Appendix III. Questions were asked about the following four objectives:

### 2.5.1. Determine How Occupants Use Windows, Doors, and Mechanical Ventilation:

- **Windows and doors**. The key questions are how much, how often, and when occupants open their doors and windows during different seasons. Several questions were asked to determine patterns of window operation and the extent it varies by season.

- **Exhaust fans** can be a key part of assuring good indoor air quality. If exhaust fans are not available or are not used to remove local contaminants such as those from kitchen and bathroom activities, then minimum building ventilation rates may not be sufficient. We asked questions to determine the use of exhaust fans.

- **Forced heating and air systems**. The use of forced heating and/or air conditioning systems can affect building ventilation, IAQ, indoor moisture levels, and the occupants' perceptions of stuffiness and the need for window opening. We asked about the home's temperature settings for control systems, the manual operation of central fans, and other related heating and cooling practices.

- **Whole-house ventilation systems**: Some houses known to have outdoor air ventilation systems for the whole house were selected for special study. Information was obtained regarding the system's characteristics, its performance to date, and how the occupants used the system.

- **Natural and mechanical ventilation levels**: The Commission's building energy design standards assume certain levels of natural and/or mechanical ventilation, which are presumed to provide acceptable outdoor air flow rates if the standards are followed. We asked questions to determine whether new home occupants operate the windows, doors, and mechanical ventilation as assumed. Also, questions were asked that allow comparison of ventilation practices to the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) Standard 62.2 criteria.

  Standard 62.2 or modifications thereof is being evaluated for inclusion in Title 24 and one question to ask is how significant a change that would be or, equivalently, how close is current construction to meeting it. We can use the survey data to qualitatively evaluate this issue.
  Standard 62.2 has several requirements. It has a whole-house ventilation requirement; it has an exhaust ventilation requirement in kitchens and bathrooms; it has various source control requirements including such items as appliance venting and particle filtration. Not all of the requirements in 62.2 can be evaluated from the survey data, but quite a few can.

  For most of California the 62.2 whole-house ventilation requirement can, in principle be met by the code-required windows already installed. Thus the issue of meeting that requirement may be moot, so we will not discuss it in this section. The issues around window opening and mechanical whole-house ventilation will be dealt with separately.

### 2.5.2. Determine Occupants' Perceptions of and Satisfaction with (IAQ) in Their Homes:

- **Occupant perceptions**: We asked people if they find the IAQ acceptable or not, and why. Questions addressed perceptions such as "stuffiness," thermal comfort, odors, and other indicators.

- **Mold and other specific odors**: Musty odors are indicators of unacceptably high moisture levels and possible mold growth. Certain odors can indicate unacceptable levels of volatile organic compounds (VOCs). Chemical odors may result from formaldehyde emissions from pressed wood cabinets, or chemicals from carpets or other sources. Questions were asked about perceptible odors.

### 2.5.3. Determine the Relationships Among Ventilation Practices, Perceived IAQ, and House and Household Characteristics:

- **Size**: House size; household size, and house configuration. These factors can affect the amount and effectiveness of natural and mechanical ventilation, for example, by affecting the air flow rates, cross drafts, and air stratification. Attached garages can also be sources of motor vehicle emissions and emissions from heating appliances.

- **Sources of indoor pollutants**: Smoking, presence and use of unvented combustion appliances, cooking, heating, sources of organic chemicals (VOCs) such as pressed wood products and so-called air fresheners, excessive VOC use (consumer products, pesticides), and other major indoor pollutant sources can cause unacceptable IAQ, even if there is nominally sufficient ventilation. We asked questions about these sources.

- **Health status of household members**: In households that have persons susceptible to air pollutants, such as persons with asthma, allergies, or odor sensitivities, their ventilation practices, home designs, and perceived IAQ may differ greatly from those persons in the general population. Questions were asked to identify households with health conditions that might affect their ventilation practices and perception of IAQ, in order to understand better the ventilation behaviors and purchasing decisions of households.

- **Energy efficiency characteristics of house**: Houses have different levels of energy efficiency and features such as heating system types, duct sealing, and building shell tightness. Such differences could impact ventilation rates and indoor air quality. Only those features that could be easily and reliably reported by study participants were included.

### 2.5.4. Determine Barriers that Prevent or Inhibit the Use of Windows, Doors, and Mechanical Ventilation Systems:

- **Comfort, draft, and outdoor air quality**: Opening windows or using mechanical ventilation systems may cause asthma and allergy symptoms, thermal discomfort, and soiling of interiors because of wind, drafts, dust, pollen, and air pollutants. Large ventilation fans can cause local thermal discomfort as well.

- **Noise, security**: Fans and open windows can increase indoor noise. Fans generate noise themselves, while open windows let in outdoor sounds such as traffic, wind noises, etc. Opening windows and doors can also be a security concern.

- **Cost (first, operating):** Mechanical ventilation systems can represent an increased first cost. Any kind of mechanical ventilation system can also increase operating costs, both directly by increasing electricity use for fan operation and indirectly by increasing the need for heating and cooling due to increased air exchange rates.

- **Convenience, complexity, serviceability**: Complex control systems and maintenance needs for mechanical systems can be inhibiting. Some people are confused or frustrated when setting control devices and routine maintenance (such as replacing filters) may be inconvenient. Modern windows can be difficult for some people to open or access.

### 2.6. Mail Effort

- **Two Batches:** In order to assess respondent comprehension of the questionnaire and to project the number of expected returns, questionnaires were sent out in two batches. The first batch of 1,657 packets containing a cover letter, a ballpoint pen with the study logo imprint, and a copy of the questionnaire, was mailed out in mid-December 2004. After reviewing the first 200 questionnaires with ARB, a few minor changes were made to the instrument before mailing the second batch. The revisions to the instrument were predominantly improvements in respondent instructions to minimize confusion. The second batch of 3,315 questionnaires was mailed out at the end of January 2005.

- **Reminder Effort:** In addition to the initial mailings for each batch, there were two additional “reminder mailings”. One week after the mailing of the first packet, a reminder postcard was sent to each respondent. Three weeks after the reminder postcard was sent, a second packet with a reminder letter, a second pen, and a second questionnaire was sent to those respondents who had not yet returned a completed questionnaire.

## 2.7. Eligibility:

Two screening questions at the beginning of the questionnaire were used to help the respondent determine whether or not he or she should continue with the questionnaire:

- "Is the house at this address a **detached** single-family house built in 2003? By detached we mean no shared walls with another house."

- "Have you lived in this home since at least January 2004?"

If the respondent answered "no" to either of the screening questions, he or she was not eligible for the study and was asked to return the questionnaire in the enclosed envelope, but keep the pen as a gift. If the respondent answered "yes" to both screening questions, the respondent was eligible and was asked to complete the questionnaire and return it in the enclosed envelope. Once the completed questionnaire arrived at the SRC office, the respondent was sent a $30 check as a token of appreciation.

## 2.8. Outcome of the Statewide Probability Sample:

Table 1 shows the various outcomes for all the selected addresses in this Statewide Probability Sample. In each of the three strata, between 5 and 10 percent of the addresses were determined to belong to ineligible households, for the following reasons:

- The house was vacant

- The occupant had resided at that address for less than 9 months

- The housing unit was not a detached unit

- Residents were not able to complete an English questionnaire

- The Post Office returned the packet with a determination that there was no such address.

Overall, 324 selected addresses were determined to be ineligible for the study, leaving 4,648 eligible addresses. Completed questionnaires were received from 1,448 of the eligible addresses for an overall response rate of 31.2%. The response rates did not vary substantially between strata. The rates ranged from 30.2% (Southern California) to 32.8% (Sacramento-Delta).

The overall response rate of 31.2% far exceeded our expectations. We had planned for a response rate in the neighborhood of 10-15%, given the length and difficulty of this self-administered survey. Apparently, however, our persistence in pursuing respondents and the freshness of the topic for new homeowners combined to boost the response rate. This higher response rate should add somewhat to the reliability of the results obtained from the survey. See Table 1 for the outcome of the Statewide Probability Sample.

Note that the demographic characteristics of the respondents to the survey are quite different from those of the California population as a whole. Recent home buyers can be expected to have higher incomes and larger families than households in the general population. A comparison of our sample with the 2000 Census bears this out. In the sample, 59 percent of the households have incomes of $100,000 or more, compared to 17 percent for the State as a whole. Also, 70 percent have three or more persons in the household, compared to 47 percent for the State as a whole.

On the other hand, the ethnic composition of the sample is not so different from the State as a whole, except that the sample is 20 percent Asian, compared to 13 percent in the most recent census. There are corresponding reductions in the percent white (58 percent versus 66 percent) and the percent black (6 percent versus 7 percent in the State as a whole).

**Table 1: Outcome of the Statewide Probability Sample by Stratum**

| | **Sacramento -Delta N** | **Southern Calif. Coastal Region N** | **Rest of the State N** | **Total N** |
|---|---|---|---|---|
| **SELECTED** | 999 | 973 | 3,000 | 4,972 |
| **KNOWN INELIGIBLES** | 60 | 63 | 201 | 324 |
| (Vacant) | (8) | (5) | (30) | (43) |
| (< 9 months) | (31) | (39) | (111) | (181) |
| (Not Detached) | (12) | (13) | (36) | (61) |
| | | | | |

| | | | | |
|---|---|---|---|---|
| (Language Barrier) | (2) | (0) | (0) | (2) |
| (No Such Address) | (7) | (6) | (24) | (37) |
| **Eligible Households** | 939 | 910 | 2,799 | 4,648 |
| **Non-Response** | 631 | 635 | 1,934 | 3,200 |
| **Completed Questionnaires** | 308 | 275 | 865 | 1,448 |
| **Response Rate *** | 32.8% | 30.2% | 30.9% | 31.2% |

*(Completed Questionnaires) / (Eligible Households) * 100

## 2.9. Outcome of the Supplementary Builders' Sample:

Table 2 shows the various outcomes for all the selected addresses in the supplementary builders' sample. About a sixth of the sampled addresses turned out to be ineligible, mostly because the residents had lived in the house less than 9 months. Of the 192 eligible households, completed questionnaires were received from 67 households for an overall response rate of 34.9%.

**Table 2: Outcome of the Builders' Sample by Stratum**

| | **Sacramento -Delta N** | **Southern Calif. Coastal Region N** | **Rest of the State N** | **Total N** |
|---|---|---|---|---|
| **SELECTED** | 58 | 68 | 104 | 230 |
| **KNOWN INELIGIBLES** | 16 | 2 | 20 | 38 |
| (Vacant) | (5) | (0) | (4) | (9) |
| (< 9 months) | (8) | (2) | (12) | (22) |

| | | | | |
|---|---|---|---|---|
| (Not Detached) | (2) | (0) | (1) | (3) |
| (Language Barrier) | (0) | (0) | (0) | (0) |
| (Not a Real Address) | (1) | (0) | (3) | (4) |
| **Eligible Households** | 42 | 66 | 84 | 192 |
| **Non-Response** | 23 | 47 | 55 | 125 |
| **Completed Questionnaires** | 19 | 19 | 29 | 67 |
| **Response Rate *** | 45.2% | 28.8% | 34.5% | 34.9% |

* (Completed Questionnaires) / (Eligible Households) * 100

## 2.10. Calculation of Weights for Analysis:

In the Statewide Probability Sample the three geographic areas used as strata (Sacramento-Delta region, Southern California coastal region, and the rest of the State) were sampled at different rates. And among the households sampled, the response rate was somewhat different in the three areas. For purposes of combining results for the three areas and generating statistics for the State as a whole, a sampling weight was created. The various steps are summarized in Table 3.

The first row of Table 3 shows, for each of the three strata, the number of households in the sampling frame. The second row shows the number of completed interviews in each stratum. The ratio of the first to the second row gives the expansion factor, which is the number of households in each stratum represented by each completed household interview in the sample. As we see in the table, each household in the Sacramento-Delta stratum that completed a questionnaire represents 9.8766 households on the list from which the sample was drawn. The corresponding figures for the other two strata are 22.6873 and 17.8208.

When Statewide analyses are being run, the expansion factor could be used as a weight variable. However, tables that are run using that weight would appear to be based on 24,696 cases (the total in the sampling frame). In general it is preferable to scale the expansion factor down and create a relative weight, which preserves the proportionality between strata but produces weighted tables that reflect the actual number of cases in the data file. If we multiply the expansion factor for each stratum by the constant factor .058633, we get the relative weight, shown in the final row of Table 3 (rounded to three decimal places). That final relative weight is the sampling weight available in the data file for each completed case in the Statewide Probability Sample. Note that the 67 cases in the Supplementary Builders' Sample have a value of 0 on this weight, since they should not be used to calculate statewide estimates.

**Table 3: Calculation of Weights**

| | Sacramento -Delta | Southern Calif. Coastal Region | Rest of the State | Total |
|---|---|---|---|---|
| **NUMBER IN THE FRAME** | 3,042 | 6,239 | 15,415 | 24,696 |
| **COMPLETED QUESTIONNAIRES** | 308 | 275 | 865 | 1,448 |
| **Expansion Factor** | 9.8766 | 22.6873 | 17.8208 | |
| **Sample Weight** | .579 | 1.330 | 1.045 | |

## 2.11. Quality Assurance & Quality Control Procedures:

Several procedures were put in place to check for quality assurance and quality control.

- **Multiple Mailings:** An introductory letter and questionnaire were sent to all households in the sample. If the household did not return a completed questionnaire within approximately 2 weeks, a reminder postcard was sent out. If the household still did not return a completed questionnaire within another 2 weeks, we mailed a second letter and another blank questionnaire. These multiple mailings were carried out in an effort to obtain as high a response rate as possible.

- **Revision of Instrument:** The first 200 completed questionnaires were reviewed to check for comprehension of the instrument and to establish data entry conventions for ambiguous responses or response categories that were outside of the expected range. It was clear that there was some confusion with a few of the questions. Revisions were made to the instrument in consultation with LBNL and ARB to clarify respondent instructions and to reduce the number of ambiguous responses. Both versions of the questionnaire can be found in Appendix III.

- **Data Entry Conventions**: The following data entry conventions were approved by ARB, LBNL, and SRC.

  - **Conflict with Screening Question**: Sometimes there was a conflict between the screening question # B, “Have you lived in this home since at least January 2004?” and question #3, “When did you move into this house?” It was agreed that the screening question # B would be accepted as true. If the date the respondent moved in conflicted with the screening question B, the date in question 3 was changed to Missing Data.

  - **Answers Outside of Acceptable Range**: Sometimes answers were outside of the maximum acceptable range. It was agreed that all answers would be entered as answered, even if outside the acceptable range, and would be handled in the analysis.

  - **Editing:** All completed questionnaires were edited before data entry to check for eligibility and to follow data entry conventions. Once the editing was completed, cases were sent to the Data Management Unit of the Survey Research Center for Data Processing.

### 3.12 Steps for Data Processing:

- After receiving completed self-administered questionnaires from the field, the cases were numbered sequentially and filed according to work assignments.

- A direct data entry (DDE) instrument using CASES (Computer Assisted Survey Execution System) software was designed specifically for this collection instrument. The entry program accepts only valid codes, and logical checks were added to enforce the coding conventions.

- Two different coders entered each case into the computer, at different times. Paired cases were then compared by a computer program, which identified any discrepancies between the two entries. These differences were then checked against the original questionnaire. Once the correction was made to one of the paired entries, the duplicate entry was discarded.

- The "cleaned" batch of data cases was then checked yet again by another computer program, which is very similar to the entry program (i.e., only valid codes are accepted and all logical checks are enforced). The cases, which successfully complete this process, are not only considered "cleaned" but "certified."

- Certified data cases were then submitted for output. The cases became part of an ASCII data file in which each variable was stored in a fixed set of columns.

3. **Project Outcomes / Results and Discussion:**

To find more information about types of questions asked in the questionnaire which help to assess the project objectives, please see section 2.5 Questionnaire Design, and Appendix III, which contains the questionnaire.

Summary statistics for a few of the questions are reproduced here for convenient reference; all are adjusted for the sampling weight, so that if the respondents are representative of the entire eligible population – that is, if there is no bias due to non-coverage or non-response - these would be valid estimates of the situation for new single-family California homes.

17% of homes are below 2000 square feet,
20% are between 2001 and 2500 square feet,
27% are between 2501 and 3000 square feet,
23% are between 3001 and 3700 square feet,
14% of homes exceed 3700 square feet.

27% of homes are 1-1.5 stories,
71% are 2-2.5 stories,
3% are 3 stories or higher.

51% of new homeowners are White,
23% are Asians or Pacific Islanders
10% are Hispanics,
5% are Blacks,
11% are Mixed Race or Other.

8.5% report annual household income under $50K,
14% have annual household income between $50-$74.9K
19% have annual household income between $75-$99.9K
31% have annual household income between $100-$149.9K
27% have annual household income of $150K or greater.

90% of households include no adult smokers
7% include 1 adult smoker
3% include 2 or more adult smokers
2% include 1 or more children or young teens that smoke.

17 of the 1515 surveys indicated that the household contains a smoker who is age 0-5, a result of which we are extremely skeptical. These respondents may have filled in the wrong box: perhaps these should be in the “6-17 year old” category (the box immediately to the left on the survey instrument). Or perhaps this is the number of children in the 0-5 age range in those homes rather than the number of smokers in that age range (the box immediately above this question on the survey instrument).

Ventilation-related questions are summarized and discussed in subsequent sections.

**Discussion of Some Statistical Issues**

Throughout this report we will often report either “r-squared” values, “p-values”, or both, to summarize the statistical or practical significance of a result. The r-squared value is the square of the “correlation”, r, between two sets of parameter values, or between predictions and observations. R-squared is usually quoted, rather than r, because r-squared can be directly interpreted as the fraction of the variance in the observed parameter that is “explained” by the predictive variable or variables. R-squared quantifies the *practical* significance of the predictive variables: given the values of the predictive variables for everyone in the state, how accurately can we predict the value of the parameter I am trying to predict? A high value of r-squared usually indicates that a relationship is of practical importance, *assuming* it is not accidental, as we discuss next.

The p-value, in contrast, quantifies how likely it is that random chance would have produced a relationship between predictions and observations that is as strong as the one observed. As described below, a low p-value means it is very unlikely that the observed relationship would arise by chance.

To illustrate both r-squared and p-values, we consider an example. Suppose there are two groups of 100 people, and that the people in group A have an average height of 170cm while those in group B have an average height of 174 cm. Further suppose that in each group there are people with a variety of heights, with a standard deviation of 10 cm. It is possible to calculate the answer to the following question: *if* people were assigned randomly to two groups of 100 people each how likely is it that we would see a difference of at least 4 cm in the average height? For this example the p-value is 0.005: if we were to divide people at random in this way, there is only a 0.5% chance that the groups would differ by as much as 4 cm difference in average height. This suggests that the people were not assigned randomly to the groups. Low p-values indicate high “statistical significance”: they usually indicate that a relationship is not accidental.

What about the r-squared value for the example above? As it turns out, the r-squared value is only about 0.04: there is so much variability within each group that even though the difference in average height between the groups is statistically significant, knowing what group someone is in tells us very little about how tall they are.
As this example illustrates, if there is a lot of variation in the parameter of interest (height) then even an explanatory variable that has high statistical significance (what group the person is in) can have little practical significance (i.e. explains little of the variation between people).

There is another circumstance in which high “statistical significance” (i.e. low p-value) can occur even when r-squared is very low: this can occur if a characteristic is shared by very few data entries, even if it is highly predictive. For instance, suppose we have a third group of people, Group C, who are all between 205 and 210 cm tall (perhaps they are all professional basketball players). But suppose this group has only 10 people in it. In this case, if we know that someone is in Group C we know their height quite precisely, but since this is true of only 10 out of the 210 people in the sample, it does little to explain the total variation of height among the people.

In this report, many of the analyses have one or more of the characteristics of the examples above: (1) a lot of variability among responses, so that in many cases even a “statistically significant” relationship, unlikely to be the result of chance variation, still has little practical value in explaining the overall variation; and sometimes (2) a relationship that is statistically significant and perhaps of practical significance, but applies to only a small number of people. One example is the relationship between mold and satisfaction with indoor air quality: almost all of the people who report mold in multiple places in their house are less than completely satisfied with their indoor air quality, but since this describes only a few people in the survey, it does little in terms of letting us predict who, out of the entire sample, is extremely satisfied with their indoor air quality.

Another important point is that all of the statistical estimates presented – of p-values, r-squared values, standard errors, and so on – are based on the assumption that there are no systematic errors or biases in the responses. For example, if people tend to mis-remember or mis-characterize their window-opening behavior in systematic ways, that will lead to errors in the estimated ventilation parameters that are *not* included in the uncertainty estimates. Or, if people tend to be particularly sensitive of certain phenomena (such as mold) because they are in a new house, or conversely if they tend to be particularly satisfied with their indoor air quality because of a high-satisfaction “honeymoon period” after buying the house, then their answers to questions related to these factors may not correctly represent the situation in the house. These effects (if they occur) are not included in the statistical uncertainty estimates or other quantities.

### 3.1. Determine How Occupants Use Windows, Doors, and Mechanical Ventilation:

**Use of Local Exhaust Fans**:

Standard 62.2 requires that each kitchen and bathroom have an exhaust fan that vents outside. In some jurisdictions this is code, but in others it is not. We can, however, get an estimate of the frequency of installation from the survey.

Question 67 can be used to determine whether or not bath fans are installed ***and used***:

27% always use the bathroom fan when someone takes a shower or bath, 16% use one frequently, 19% use one sometimes, and the rest use a fan rarely (16%) or never (13%) or don’t have a fan (9%).

We can assume that the kitchen requirement is met if there is fan either for the stovetop or the oven.

Question 61 tells us whether the stovetop has an exhaust fan or range hood:

13% have a range hood that blows air back into the room,
80% have a range hood that exhausts to outdoors,
4% have a downdraft ventilator,
1% has no kitchen exhaust,
and 2% don’t know.
Question 64 tells us whether the oven is vented to the outside:

35% of respondents say their most frequently used *oven* vents to the outdoors, 34% say it doesn’t, and 30% don’t know. Since 30% don’t know, it’s hard to draw any conclusions from this. The people who *do* know are split about 50-50 between the two types, so if the “don’t knows” follow the same pattern then about half of ovens vent to the outdoors.

Standard 62.2 requires that the fans installed meet certain performance specifications. While many models of fans meet these specifications, the cheapest ones often do not. We do not know whether the fans responded to in the survey meet the specifications.

**Use of Filtration:**

Standard 62.2 requires that there be a MERV 6 or higher filter on the air handling equipment. System air handlers with no filters, or systems with “traditional inexpensive fiberglass” filters, would not meet the requirement. Other configurations presumably would. Questions 37 addresses this issue – see Table 4 below:

**Table 4: Types of Filters**

| **Q37: Filter type** | **Percent of homes** |
|---|---|
| Traditional inexpensive fiberglass | 26 |
| Medium-efficiency pleated | 15 |
| High-efficiency pleated | 21 |
| Electrostatic | 6 |
| Electronic | 1 |
| Other | 1 |
| Don’t know | 7 |
| Don’t have one | 4 |

Even if “traditional inexpensive fiberglass” filters are assumed to be the only category that fails to provide adequate filtration, a substantial fraction of houses have systems that do not have adequate filters. Depending on the disposition of the households for which “don’t know” was the answer, somewhere between 25-30% of new homes do not have filtration that is adequate under Standard 62.2.

**Use of Vented Combustion Appliances**:

When naturally aspirated combustion appliances are inside the building’s pressure boundary, Standard 62.2 has special requirements. In some cases these requirements may be difficult to meet. Therefore, the presence of the equipment is important.

Question 35 asked whether or not the central heater is inside the home. Because central gas heating is the most common, in this exploratory analysis we ignore the fact that the central system may not be gas or that a gas system may not be central.

69% of respondents said their central heater is in the attic,
3% said crawlspace,
10% said garage,
4% said other space inside the house,
6% said other space outside the house,
7% don't know or did not answer
Although power-vented and condensing furnaces are becoming more common, most domestic water heaters are naturally aspirated, so having them inside the house is more likely to trigger the requirements of 62.2. Question 42 addresses this issue: Out of people who answer the question, 94% of have a gas water heater.
87% of these are in the garage,
5% are in another space outside the house, and only
3% are inside the house.

**Use of Windows:**

One of the most important functions of this project is to determine what roles windows do and should play in ventilation and indoor air quality. It is not surprising that more pages of the questionnaire were devoted to window-related questions than any other topic.

**Reasons for Opening Windows:**

Respondents were asked about the importance of various reasons were for why they opened their windows in Question 26. The data can be found in Tables 5A (statewide probability sample) and 5B (builder's sample). For each reason and each degree of importance, the percentage of respondents is summarized for the Sacramento area, Southern California, the rest of the state, and the state as a whole (adjusted for sampling weights).

Calculations summarize responses of people who answered the question (e.g. if 4 of the 19 people in the Builders' Sample in the Sacramento Delta region failed to give any answer for Q26A, we summarize the result only of the 15 households that responded). Alternatively we might speculate that "no answer" should be "not at all important" or "never open for this reason," but we did not make that assumption. We assumed if the question was not answered it was to be classified as "missing data". The rationale for handling missing data in this way was based on the way the question was formatted. This was a "check the box" question (see Appendix III). It is impossible to tell if a respondent meant to code "never open for this reason", or if the respondent missed the question. It is safer to assume that the respondent missed or skipped the question rather than answer the question for them. Missing data rates were around 5% in this section.

**Table 5A: Reasons for Opening Windows: Statewide Probability Sample**

| Reasons to open windows (Percent, adjusted by sampling weight)<br><br>Sacramento Area, Southern California, Rest of State, **Total** | Very Important | Somewhat Important | Slightly Important | Not at all important | Never open for this reason |
|---|---|---|---|---|---|
| Cool the house | 55,62,57,**59** | 21,25,22,**23** | 11,8,10,**10** | 4,1,3,**3** | 7,4,6,**6** |
| Warm the house | 9,11,12,**11** | 13,11,12,**12** | 14,12,13,**13** | 15,14,16,**16** | 41,48,44,**47** |
| Provide air movement | 55,53,57,**56** | 27,31,28,**29** | 9,11,10,**10** | 2,1,2,**2** | 7,3,4,**5** |
| Remove odors | 47,40,39,**40** | 28,30,28,**28** | 13,19,19,**18** | 4,7,6,**6** | 8,5,7,**7** |
| Remove moisture | 22,16,18,**18** | 17,17,12,**14** | 21,16,17,**17** | 12,15,19,**17** | 27,36,35,**33** |
| Air out the house during cleaning | 40,31,33,**34** | 26,27,27,**27** | 18,20,23,**21** | 6,6,8,**7** | 10,16,9,**11** |
| Remove smoke | 21,13,16,**16** | 8,10,8,**8** | 8,9,9,**9** | 11,10,10,**10** | 53,57,57,**56** |
| Provide draft for fireplace etc. | 19,14,11,**13** | 9,15,12,**12** | 15,15,17,**16** | 13,14,13,**13** | 45,42,47,**46** |
| Save energy | 52,45,46,**46** | 21,26,24,**24** | 14,14,13,**13** | 3,2,4,**4** | 11,13,13,**13** |
| Allow pet access | 11,8,9,**9** | 4,6,8,**6** | 4,6,8,**7** | 6,6,8,**7** | 75,75,69,**71** |

**Table 5B: Reasons for Opening Windows: Builders' Sample**

| Reasons to open windows (Percent, adjusted by sampling weight)<br><br>Sacramento Area, Southern California, Rest of State, **Total** | Very Important | Somewhat Important | Slightly Important | Not at all important | Never open for this reason |
|---|---|---|---|---|---|
| Cool the house | 52,53,46,**50** | 27,11,25,**21** | 0,16,14,**11** | 0,5,7,**5** | 20,16,7,**13** |
| Warm the house | 0,5,7,**5** | 8,5,11,**8** | 15,32,25,**25** | 0,21,14,**13** | 78,37,43,**48** |
| Provide air movement | 56,42,55,**52** | 13,37,24,**25** | 0,11,10,**8** | 6,0,3,**3** | 25,11,7,**13** |
| Remove odors | 20,26,36,**29** | 13,42,18,**24** | 20,11,18,**16** | 13,5,14,**11** | 33,16,14,**19** |
| Remove moisture | 14,6,17,**14** | 0,20,10,**10** | 14,25,21,**20** | 21,13,7,**12** | 50,38,45,**44** |
| Air out the house during cleaning | 31,37,46,**39** | 0,11,19,**12** | 19,16,12,**15** | 13,11,12,**12** | 38,26,12,**23** |
| Remove smoke | 7,17,11,**12** | 7,11,11,**10** | 14,11,4,**8** | 0,6,11,**7** | 71,56,64,**63** |
| Provide draft for fireplace etc. | 7,11,0,**5** | 0,11,22,**14** | 7,17,19,**15** | 0,11,0,**3** | 86,50,59,**63** |
| Save energy | 33,37,45,**40** | 33,21,31,**29** | 13,16,7,**11** | 0,0,3,**2** | 20,26,14,**19** |
| Allow pet access | 7,11,7,**8** | 0,5,14,**8** | 0,16,7,**8** | 0,16,0,**5** | 93,53,71,**71** |

These data show a strong preference for opening the windows to cool the house and save energy. Providing air movement, which may be related to providing a breeze to cool the occupants, was also high. Removing odors also seemed to be important, but the more direct IAQ questions of removing smoke, providing draft and airing out the house were not as high.

Although moisture control was not a major reason for opening windows throughout the house, a more specific question was asked about using the bathroom window for ventilation. Question 71 addresses that issue:

8% of homes have at least one bathroom window open all the time,
18% usually have one open,
38% sometimes open one for ventilation,
19% rarely open a bathroom window,
15% never open a bathroom window, and
3% did not answer the question.

**Contribution of Window Opening to Ventilation:**

Questions 10-33 all ask about window opening behavior. Questions 10-25 ask how many hours windows are left open in specific locations, times, and seasons.

Appendix I quantifies the reported hours that houses had windows open in various rooms, by season and time of day. Reported differences between weekend and weekday window-opening behavior are rather small during the evening and night, but somewhat different during the day (6AM-6PM), with fewer people reporting 0 hours with windows open, in every room and during every season.

Nighttime window-open behavior (11PM-6AM) changes substantially from season to season. Although about half of the houses don't have any windows open at night in any season, the other half of houses do have open windows – principally bedroom windows or bathroom/utility windows -- for much of the night in summer, and to some extent in fall. Few houses have windows open for more than an hour or two at night in winter.

Information about which windows are open, and when, is not sufficient to determine ventilation rates because windows may be open a little or a lot. Survey questions 28-31 attempted to capture both the duration for which windows were open, and the amount that they were open. Four levels of ventilation were defined:

- No ventilation: all windows and doors closed.
- Low: One or two windows or doors open just a crack.
- Medium: Several windows or doors open at least a crack, or one or two windows open at least several inches.
- High: Some windows or doors open fully, or several windows or doors open partway, or almost all windows or doors open at least a crack.

Respondents were asked the number of hours in each season that their house ventilation was best described as No, Low, Medium, or High. They were also asked, in questions 32 and 33, how often they provide cross-ventilation and how often they provide high-low ventilation to improve airflow.

Figure 1 shows the cumulative distribution function of reported hours of high ventilation per day, and of hours of high ventilation plus hours of medium ventilation, for each season, for the Statewide Probability Sample. Sharp features at 6 hours and 12 hours indicate a preference for choosing these values; we suspect that this is a reflection of peoples' choices when filling out the questionnaire rather than an indication that people actually open their windows for exactly these numbers of hours.

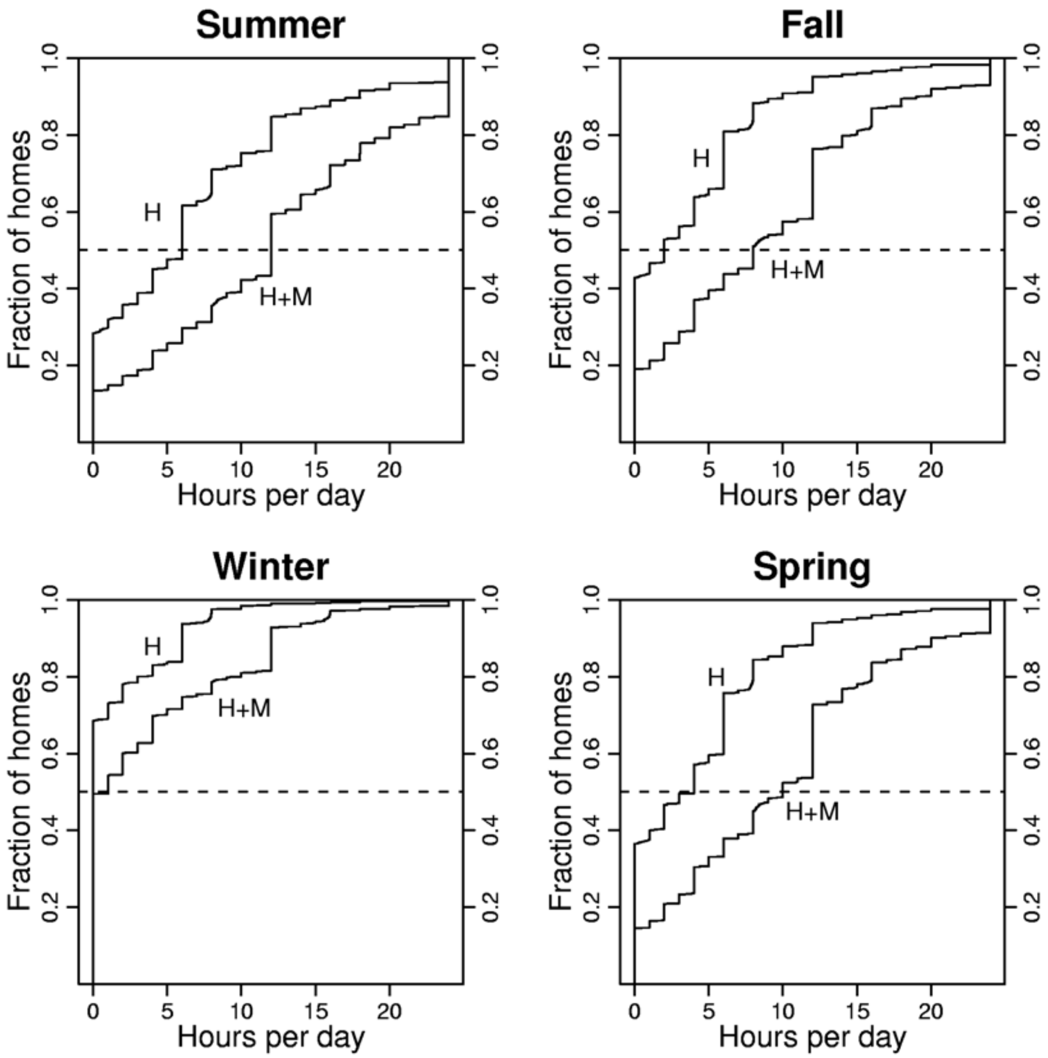


**Figure 1: Cumulative Distribution Function of Reported Hours of Ventilation per day, by season.** Cumulative distribution function (the fraction of homes that

received less than or equal to the hours of ventilation on the x axis) for High ventilation, and for (High or Medium) ventilation. Dashed line is at fraction = 0.5.

**Problems With the Usage Data:**

Within each season, some people reported a non-zero number of window-open hours for some periods of the day or for some rooms, but left other questions blank; in these cases we interpreted blanks as zeros. For questions 10 to 25, where respondents were requested to report a specific number of hours, if the respondent entered nothing in an entire section we defined such cases as missing data. On the other hand, if there was at least one number entered in a given cell of a series, we assumed that the respondents entered only the hours that were relevant to his or her behavior, and left those not relevant blank. For this reason we coded blank answers to questions formatted such as these, as zero (See Appendix III).

For any given season, about 3% - 4% of respondents left *all* of the questions related to that season blank. Many others had other problems: there are substantial inconsistencies between ventilation behavior reported in questions 10-25 versus questions 28-31. (Questions 10-25 ask about the times of day and durations that various windows were left open, but not how widely they were open; questions 28-31 ask how many hours of no/low/medium/high ventilation were provided, but not the times of day.) These issues are discussed below, along with the way we handled them.

In each time period of each season, it is possible to determine from questions 10-25 the maximum and minimum number of hours of non-zero ventilation that could have been provided. For instance, Questions 10A-13A ask about hours of ventilation in the kitchen, bedrooms, bathrooms/laundry/utility rooms, and other rooms, for summer weekdays from 6AM to 6PM. Suppose someone filled in zero hours for kitchen and bath/laundry/utility rooms, 6 hours for the bedrooms, and 4 hours for "all other rooms." In this case, we know that the least number of hours of ventilation during this time period was six hours (if the bedroom and "other rooms" ventilation were provided at the same time), and that the largest possible number of ventilation hours was ten (if the bedroom and "other room" ventilation were provided at different times). By adding the minimum and maximum hours for each time period, and performing a weighted average of the weekday and weekend results, it is possible to determine the minimum and maximum possible hours of non-zero ventilation in each season, and to compare these to the reported ventilation hours from questions 28-31. If the data were consistent, the ventilation hours from questions 28-31 would fall between the minimum and maximum calculated above, but in fact many responses fail in this regard, as discussed below.

In every season, many people reported in questions 28-31 more hours of ventilation than they accounted for in questions 10-25. The problem is not just a small miscalculation, such as people saying that they have 10 hours of ventilation but only accounting for 9 of them: in many cases, even multiplying the accounted-for hours by 1.5 does not fix the problem. Out of the 1515 survey respondents, the number with this type of impossible response is shown in the first two columns of Table 6.

**Table 6: Inconsistency of Ventilation Hours Reported:** > than Maximum

| **Number of surveys with inconsistent answers (out of 1515 surveys)** | **L+M+H hours > max. hours accounted for** | **L+M+H> 1.5 x max hours accounted for** | **Number who report 24 hours of L+M+H, but account for less than this** | **Number who report some L+M+H, but account for none at all** |
|---|---|---|---|---|
| Summer | 464 | 251 | 199 | 38 |
| Fall | 548 | 335 | 183 | 86 |
| Winter | 545 | 447 | 109 | 185 |
| Spring | 587 | 340 | 205 | 68 |

The two right-hand columns of Table 6 quantify two of the largest types of discrepancies that cause general ventilation hours to be larger than the maximum that should be possible based on time-of-day-specific reports: many people report 24 hours of ventilation beyond “no ventilation” but fail to account for that amount in the time-of-day-specific reports, and many people don’t account for any ventilation at all in the time-of-day-specific reports but do say that they have more than “no ventilation” for at least some period during the day. Except for winter, these two issues account for roughly half of the results in which the responses from questions 28-31 are higher than should be possible based on questions 10-25.

In addition to the type of inconsistency summarized in Table 6, many people had the opposite problem: the hours of low, medium, or high ventilation that they reported in questions 28-31 was smaller than the minimum possible numbers of hours with ventilation based on their responses to questions 10-31. Table 7 summarizes these impossible responses.

**Table 7: Inconsistency of Ventilation Reported:** < than Minimum

| Number of surveys with inconsistent answers (out of 1515 surveys) | Ventilation hours < minimum hours accounted for | Reported 24 hours with windows/doors open, but reported some hours of “no ventilation” | Reported some hours with windows/doors open, but reported 24 hours of “no ventilation” |
|---|---|---|---|
| Summer | 290 | 79 | 158 |
| Fall | 275 | 63 | 149 |
| Winter | 271 | 31 | 167 |
| Spring | 306 | 60 | 143 |

The two right-hand columns of Table 7 quantify the two largest types of discrepancies that cause general ventilation hours to be lower than the minimum that should be possible based on time-of-day-specific reports: many people report leaving some windows or doors open for 24 hours per day, but fail to credit themselves with 24 hours with more than “no ventilation”, and many people report 24 hours of “no ventilation” but say in the time-of-day-specific reports that they do have at least some hours with some windows or doors open.

The two tables above summarize two different types of inconsistencies: those in which reported time-of-day-specific ventilation behavior implies more ventilation than the no/low/medium/high-ventilation hours reported in questions 28-31, and those in which it implies less.

The number of surveys that report inconsistent results is quite large. As might be expected, these surveys differ in systematic ways from the surveys that report consistent results on the various ventilation questions. On average, they tend to report more hours of ventilation in questions 28-31 than do the consistent surveys, while reporting substantially fewer hours of ventilation in questions 10-25. (However, some surveys report the opposite problem as discussed above).

One type of inconsistency is straightforward to handle: We assume that if the time-of-day-specific reports say that a house has windows or doors open for at least a given amount of time, then the house probably does have at least “low” ventilation for that amount of time. Therefore we added hours of “low ventilation” to questions 28-31 as needed to bring the ventilation hours up to the minimum number that is consistent with the time-of-day-specific reports.

A different approach is needed for the several hundred respondents who reported some hours with ventilation (in questions 28-31), but did not account for enough hours in their responses to questions 10-25, as shown in Table 6. For these cases, we used a modification of the Census Bureau's "hot deck" procedure (described in R.J.A. Little and D.B. Rubin, "Statistical Analysis with Missing Data" (1987, Wiley)). In our procedure, if a respondent (who we will call "the subject") gave time-of-day-specific information that was inconsistent with the reported level of ventilation, we did the following. (For purposes of this discussion, we assume that the problem was with data from the summer; the same procedure was used for other seasons as well):

- Select all of the surveys that gave similar responses (as defined below) to the subject's ventilation question (question 28A-D) *and* gave responses to questions 10-13 that were consistent with the ventilation question;

- Draw (at random) one of the surveys from the subsample defined in (1), and record their responses to all time periods (parts A through F) of questions 10-13;

- For each time period and for each room, average the hours reported by the subject with the hours recorded in (2). Compare the result to the reported number of hours. Take the maximum of these two numbers as the imputed number of hours of use for that room in that time period.

Responses were deemed to be "similar" to the subject, if:

- The total number of hours with some ventilation from the survey average (i.e. not "no ventilation") was within a factor of 2 of the subject's response; and

- The total number of hours with "medium" plus "high" ventilation from the survey average was within a factor of 2 of the subject's response; and

- The average number of weekday hours that the house was reported to be unoccupied from the survey average (questions 80A1-80C1) was within a factor of 2 of the subject's response; and

- The average number of weekend hours that the house was reported to be unoccupied from the survey average (questions 80A2-80C2) was within a factor of 2 of the subject's response.

In fewer than ten cases, applying these rules did not result in finding any "similar" responses; this happened, for example, with a few people who had given inconsistent answers to the ventilation questions and who reported that the house is occupied only a few hours per day during the week but is heavily occupied on weekends. In these cases, we dropped first the comparison with weekend hours, then with weekday hours, and finally both if necessary in order to obtain a survey that was deemed “similar” to the subject; dropping both conditions was necessary in only three cases.

Using the “hot deck” procedure described above imputes a new temporal behavior of ventilation, for each person who had accounted for many fewer hours of ventilation than they claimed in questions 28-31. The imputed behavior still does not always account for the full number of ventilation hours, but it is “less inconsistent.” The resulting ventilation metric, effective specific leakage area, (ESLA, described below) is a compromise between the ventilation implied by questions 10-25 alone and the ventilation reported in questions 28-31. Homes that reported inconsistent results in the two types of ventilation questions tended to report higher levels of ventilation on their time-independent questions, and lower hours of ventilation on the time-specific questions, than did people who gave consistent answers to both.
In principle, we could run the full procedure many times, to create many realizations of this randomized process. In practice we did not do so, because we used these realizations only to summarize large quantities of data in which the effects of the imputation largely cancel out: although each individual’s summarized ventilation behavior depends substantially on random aspects of the imputation procedure, the summary statistics of a large population do not.

Figure 2 shows, for each household, the maximum and minimum number of possible hours in the day with at least one window open. As the figure shows, for many households there is a substantial difference between the minimum and maximum number of possible hours. The imputation procedure generates window-open hours in the same range as those for respondents whose reported window use was consistent with their reported hours of medium and high ventilation.

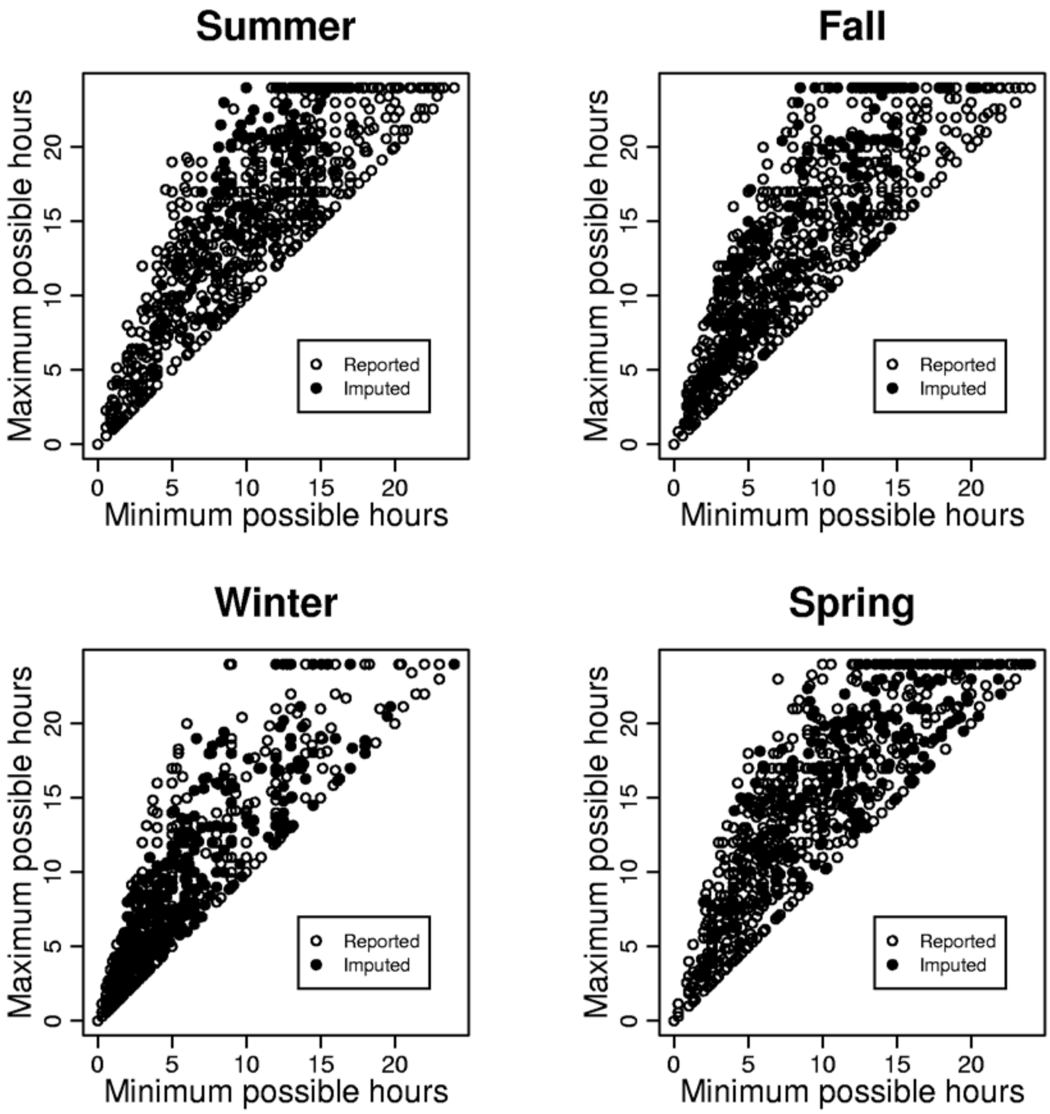


**Figure 2: Maximum Possible Hours of Ventilation Plotted Against the Minimum Reported.** Filled circles show post-imputation results for responses for which additional hours of ventilation were imputed in order to make their hourly reported ventilation less inconsistent with their overall self-assessment of ventilation.

To compare ventilation behavior among respondents and to roughly quantify ventilation effectiveness, we have converted the information in the questions about window opening (that is, questions 10-25, 28-31, 32, and 33) into a quantitative metric as described below.

A window opening has an Effective Leakage Area (ELA) associated with it; essentially this is just the area of the opening to the outdoors, potentially modified slightly by some geometric factors (e.g. for windows that tilt rather than sliding open). Title 24 uses a normalized ELA term, a dimensionless number, called Specific Leakage Area (SLA) to quantify envelope air leakage;

SLA is simply the leakage area divided by the floor area of the house, and then multiplied by 10,000 to bring the numbers into a convenient range. (Equivalently, it is the leakage area in square centimeters, divided by the floor are of the house in square meters). We estimate SLA from the survey data by using a linear combination of the number of hours of Low, Medium, and High ventilation, where the coefficients of Low and Medium ventilation scale with floor area and with the use of cross-ventilation and high-low ventilation.

In the survey instrument, Low and Medium ventilation are defined in terms of the absolute number of windows open and the amount by which they are opened, but High ventilation is defined in terms of either the absolute number ("several doors or windows open part way") *or* the fraction of windows open ("almost all windows or doors open a crack). The distinction is important because a given number of windows, open by a certain amount, will ventilate a small house more effectively than a large house. Thus, for Low and Medium ventilation the Specific Leakage Area scales inversely with floor area: "Low ventilation" or "Medium ventilation" as defined in the survey will ventilate a large house less effectively than a small house. In contrast opening "almost all windows" by a given amount will be about equally effective, in terms of promoting air changes per hour, whether the house is large or small, because the number of windows scales with the size of the house; therefore the SLA values for the high-ventilation condition do not scale with floor area.

Cross-ventilation (opening windows on opposite sides of the house) and high-low ventilation (opening windows on different stories, or at ground and ceiling level) substantially increase the ventilation provided, for a given number and area of open windows. If people indicated that they "frequently" use cross-ventilation, the SLA value for periods of Low and Medium ventilation was multiplied by 1.4, compared to providing the same number of open windows but never providing cross ventilation. If they "sometimes" use cross-ventilation, their SLA value for Low and Medium ventilation was multiplied by 1.2, and if they "rarely" use cross-ventilation, their SLA value was multiplied by 1.05. The same multipliers were used for people who "frequently," "sometimes," or "rarely" provide high-low ventilation. These numbers are rough estimates of the increased effectiveness of ventilation for these various conditions; in practice, there is no way to know exactly what people mean when they say they "frequently provide cross-ventilation." No multiplier was applied to periods of "High" ventilation because High ventilation was assumed to always include cross-ventilation and high-low ventilation.

In Appendix II, we have developed a method for using the questionnaire data to generate the Effective Specific Leakage Area (or ESLA) induced by the window opening behavior. ESLA is a dimensionless number that quantifies the effectiveness of ventilation by taking into account both the amount of ventilation provided, as determined by SLA, as well as the times during the day that it is provided. The temporal behavior makes a difference because, for example if windows are open six hours per day, the effect on indoor air quality is somewhat better if this is distributed as three hours in the morning and three hours at night than if the windows are open for six hours at night and then closed for 18 consecutive hours.

The maximum possible ESLA value of 40 (See appendix II for details.) is obtained with 24 hours of high ventilation. Figure 3 shows histograms of SLA in various seasons, including SLA values that were imputed; as discussed above, if respondents reported in questions 10-25 that they do have windows open for some amount of time during the day, but reported total ventilation hours less than that amount in questions 28-31, we credited them with enough low-ventilation hours to make up the difference. See Figure 3.

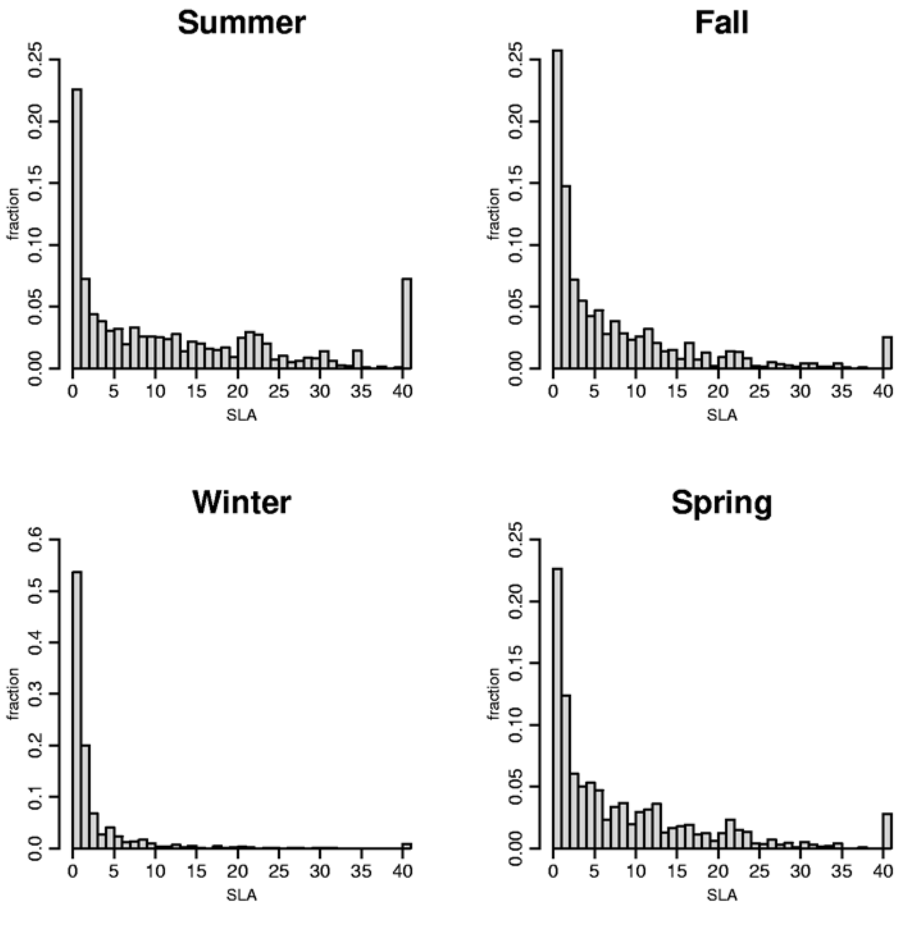


**Figure 3**: **Specific Leakage Area (SLA)**
Histograms (for the Statewide Probability Sample, adjusted for sampling weight) of Specific Leakage Area (SLA) in various seasons. SLA values at a bin boundary are tallied in the upper of the two bins. The y-axis scale is different for winter than for the other seasons.

The 25th, 50th, and 75th percentiles of Specific Leakage Area are:
Summer 0.72, 7.6, 20.0
Fall 0.47, 3.0, 9.8
Winter 0.16, 0.45, 1.7
Spring 0.61, 4.20, 11.8

As defined in Appendix II, there is a separate "ventilation efficiency" for weekend and weekday in each season, and these efficiencies effect the value of ESLA. We define the "seasonal ventilation efficiency" as ESLA/SLA in each season. Efficiencies are summarized in Table 8.

**Table 8: Ventilation Efficiency**

| **Ventilation efficiency** | **25th percentile** | **50th percentile (median)** | **75th percentile** |
|---|---|---|---|
| Summer | 0.54 | 0.76 | 0.98 |
| Fall | 0.33 | 0.65 | 0.90 |
| Winter | 0.01 | 0.24 | 0.59 |
| Spring | 0.38 | 0.66 | 0.94 |

Ventilation efficiency is generally low in winter because in many households the hours with ventilation are restricted to certain times of day, with all windows closed for most of the day: someone who reports only 2 or 3 hours of ventilation, in just one time period during the day, will have a very low efficiency; for instance, 2 hours of ventilation during the weekday, with no ventilation at any other time and with no cross-ventilation, leads to an efficiency under 0.01. However, the efficiency climbs rapidly with hours of ventilation (or, more correctly, as the number of un-ventilated hours decreases). Ventilation efficiencies are much higher in the other seasons.

The ventilation efficiency depends on the temporal behavior of the window-opening, and as discussed above there were many cases in which the reported temporal behavior was inconsistent with people's reported hours of low, medium, and high ventilation. Our imputation procedure credits people with more hours of ventilation than they actually reported in the temporally-detailed questions, but not necessarily enough to make their temporally-detailed results consistent with their reported hours of low, medium, and high ventilation. (As discussed above, people who reported inconsistent results were likely to report very high levels of ventilation on the time-independent ventilation questions, and rather low numbers of hours of ventilation on the time-dependent questions). There is simply no way to be sure about the efficiency, or, indeed, the number of hours of ventilation, for people who gave inconsistent answers.

A large number of window-open hours necessarily leads to a high ventilation efficiency. A small number of window-open hours leads to a low ventilation efficiency, since (in practice) a low number of window-open hours always leads to long periods of the day with no ventilation at all. Therefore the efficiency and the number of ventilation hours tend to vary together, and there is a high correlation between SLA (the Specific Leakage Area, which is just a weighted sum of low-, medium-, and high-ventilation hours) and ESLA: in every season, r-squared exceeds 0.9 in a linear model to predict ESLA from SLA. See Figure 4.

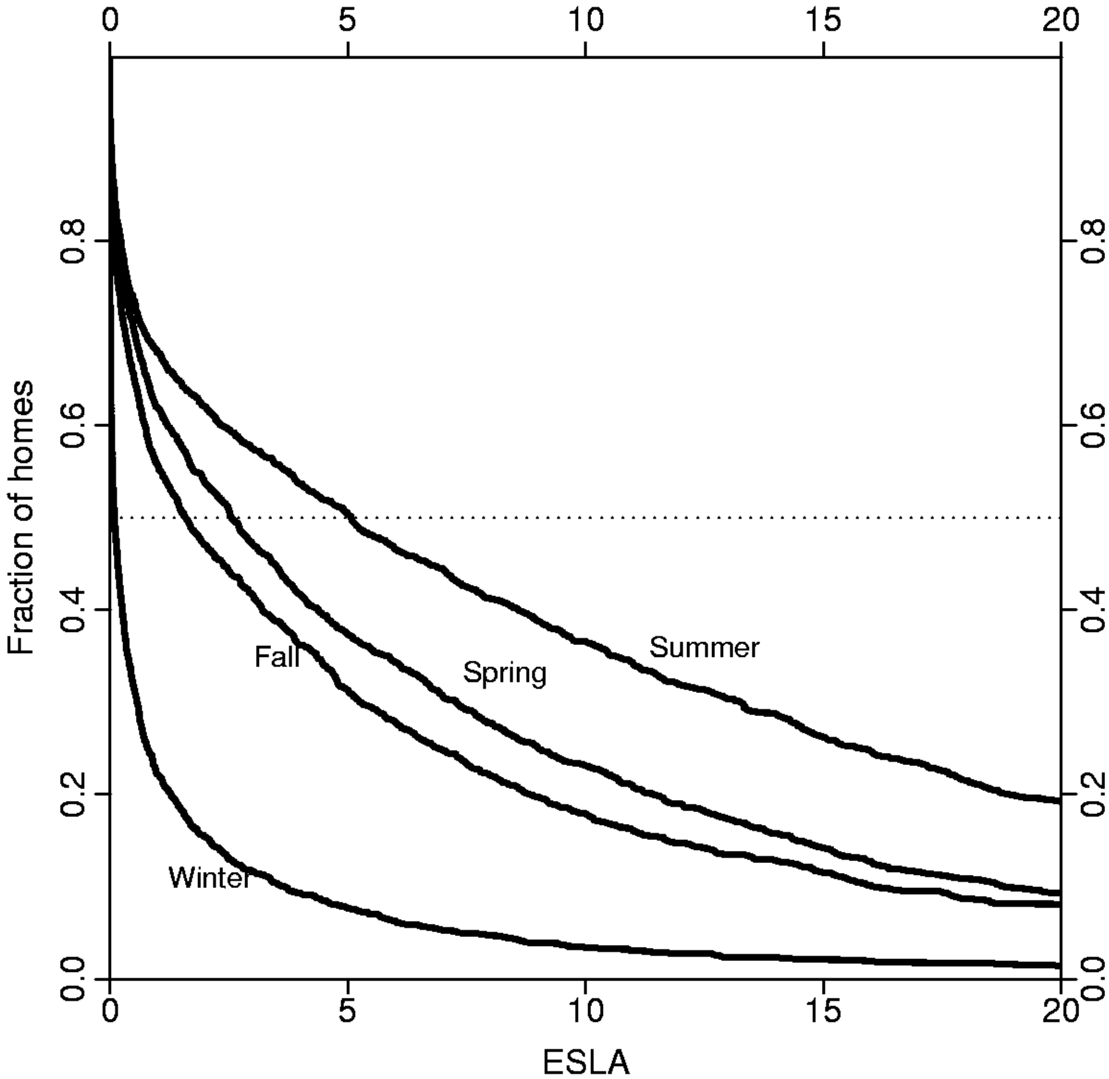


**Figure 4: Cumulative Probability Distribution for ESLA for the Statewide Probability Sample, by Season, (adjusted for sampling weights)**.
The vertical axis shows what fraction of homes meet or exceed the ESLA value on the horizontal axis. (This reverses the conventional way of presenting cumulative distribution functions). A dashed line helps identify the median.

To achieve 0.35 air changes per hour, the ESLA has to be between about 3.5 and 6.5 depending on the climate and season; higher values are needed in milder climates and seasons. See Appendix II for details. Physically the SLA from envelope air leakage and the ESLA from window opening can be added together.

As Figure 4 illustrates, although some houses receive adequate ventilation from opening of windows and doors, most houses do not get a significant contribution from window opening, and (unsurprisingly) this is particularly true in winter, when many people report no ventilation at all, and many others report only a few hours of low ventilation.

The ESLA estimate for any particular home is subject to inherent imprecision because the survey breaks ventilation into no/low/medium/high-ventilation categories, and each category encapsulates a substantial range of ventilation. Two houses could differ by a factor of more than 3 in specific leakage area and still correctly report that they receive “medium ventilation,” if one home is near the lower end of the “medium” definition while the other is near the upper end. We have tried to set the constants in the SLA and ESLA definitions so that the definitions are correct for the median house in each category; that is, so that half the people who report “medium” ventilation have higher SLA than we assume, and half lower. Based on experience and judgment, we believe that if people have correctly answered the ventilation questions in the survey, the estimated SLA and ESLA values for any individual house are unlikely to differ from the actual values by more than a factor of three. We also think that the bias in the definitions (when applied to the entire population of houses) is probably less than a factor of 1.5, if people have correctly answered their ventilation questions. However, people may well give answers to the ventilation questions that are in error by a factor of 1.5 or more, in terms of the durations that windows are open and the amount that they are open, so inaccuracy of people’s answers may be a substantial contributor to overall error.

We used the “simple bootstrap” method (Efron, B., 1981) to evaluate the uncertainty in the median ESLA for the Statewide Probability Sample in each season, cited below as the range that contains 68% of the bootstrap simulations. Of course this procedure only estimates the component of uncertainty that is due to stochastic variability. As discussed above, other sources of error are probably more important for this dataset.

| ESLA | Median | 68% confidence range for median |
|---|---|---|
| Summer | 5.1 | 4.8-5.2 |
| Fall | 1.6 | 1.4-1.8 |
| Winter | 0.09 | 0.08-0.10 |
| Spring | 2.6 | 2.4-2.8 |

Figure 5 shows the ESLA distribution for homes in the non-representative Builders’ Sample. The lines appear choppy because of small sample sizes: each home’s response forms the endpoint of a line segment.  Summer ELSA values seem to be generally lower than in the Statewide Probability Sample, but other results are similar to the Statewide Probability Sample.

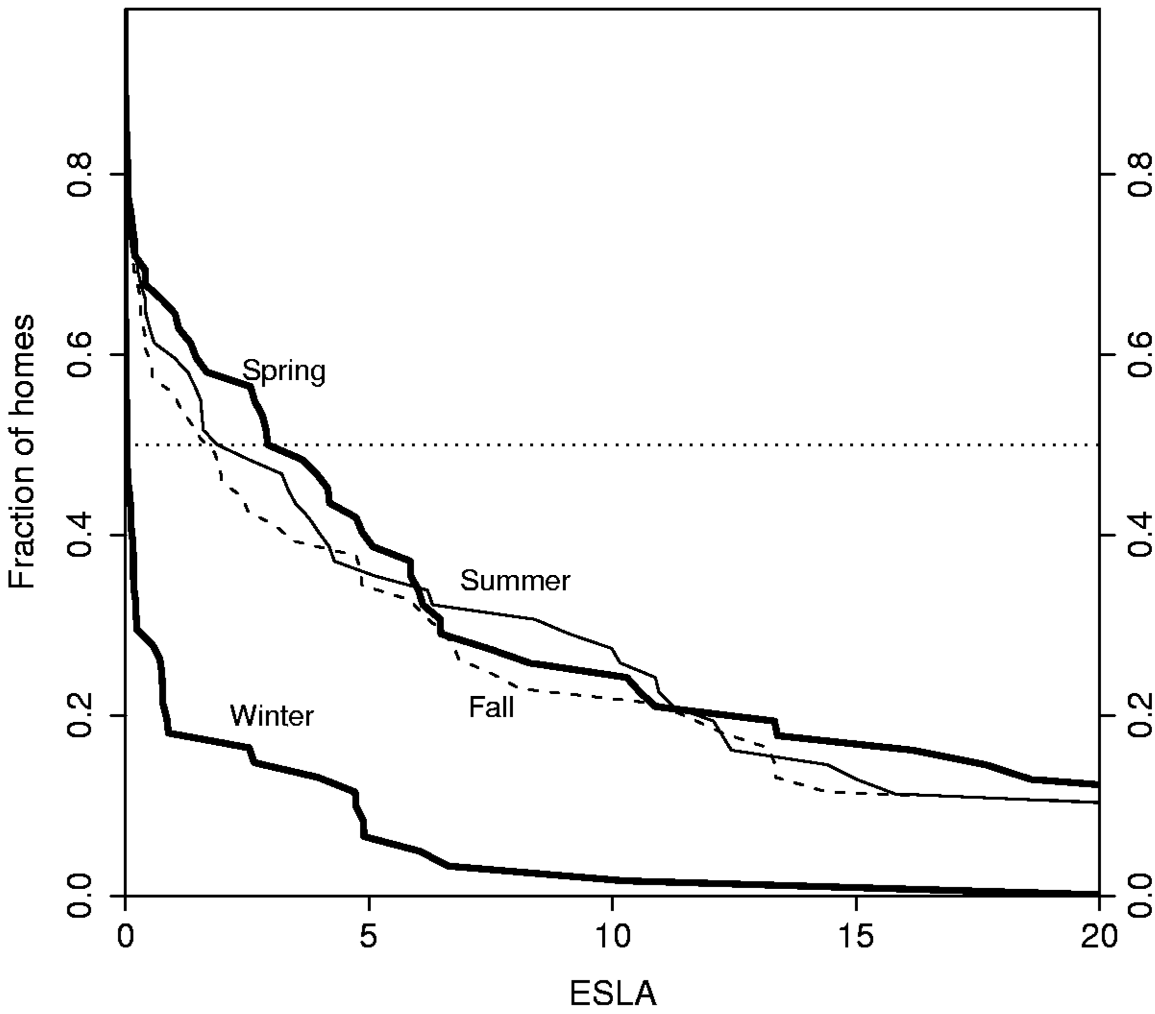


**Figure 5: Cumulative Probability Distribution for ESLA for the Builders' sample, by Season, (adjusted for sampling weights)**. The vertical axis shows what fraction of homes meet or exceed the ESLA value on the horizontal axis. (This reverses the conventional way of presenting cumulative distribution functions). A dashed line helps identify the median.

Uncertainties due to small sample sizes are substantial. Even so, errors due to inaccurate answers to the ventilation questions are probably larger than the uncertainties due to small-sample variation. We again used the "bootstrap" method to estimate the uncertainty in the median, cited below as the range that contains 68% of the bootstrap simulations.

| ESLA | Median, 68% confidence range | |
|---|---|---|
| Summer | 2.5 | 1.6-3.8 |
| Fall | 1.8 | 1.0-2.4 |
| Winter | 0.03 | 0.01-0.11 |
| Spring | 3.6 | 2.8-4.8 |

**Regional Variation in Ventilation:**

Figure 6 below, shows the ESLA distribution in each season, with a different curve for each of the three regions in the survey. People report slightly less ventilation (and thus lower ESLA) in Region 1, the Sacramento Delta area, than in either Southern California or the rest of the state. This effect is strongest in summer: The mean (median) summer ESLA in the Sacramento Delta, Southern California Coastal, and the rest of the state respectively are 7.9 (3.1), 10.2 (5.2), and 10.1(5.1). The mean summer ESLA in the Sacramento Delta is about two units lower than in the other parts of the state (p-value 0.02).

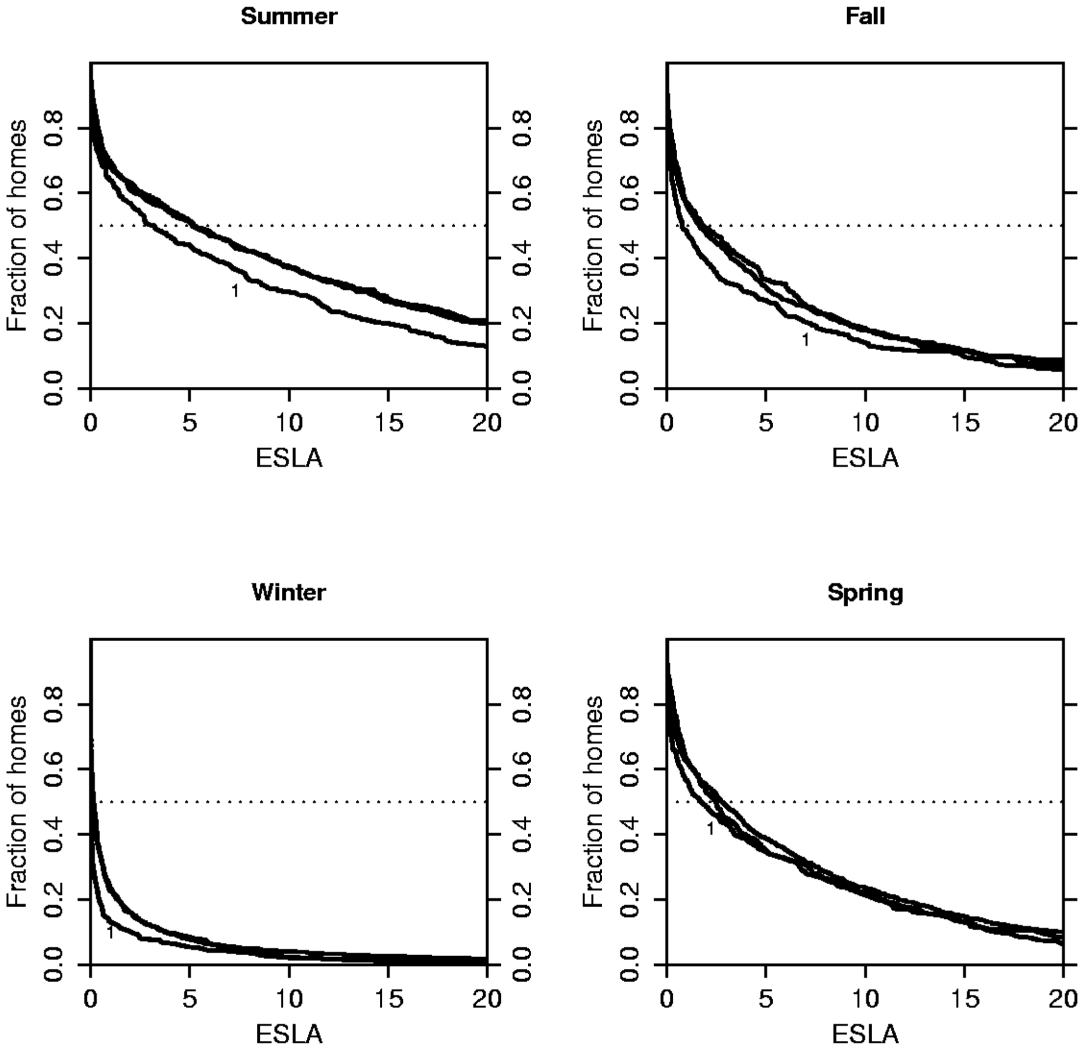


**Figure 6 (above): Cumulative probability distribution for ESLA for the Statewide Probability Sample, by Season and Region, (adjusted for sampling weights)**. The vertical axis shows what fraction of homes meet or exceeds the ESLA value on the horizontal axis. (This reverses the conventional way of presenting cumulative distribution functions). A dashed line helps identify the median. In each case, Region 1 (Sacramento Delta area, identified by the digit "1" on the plots) has slightly lower ESLA values than the other two regions; the other regions overlay each other almost perfectly on the plots.

Table 9 summarizes the distributions of estimated ESLA by region (i.e. the same information shown in Figure 6) and for the whole state (i.e. as shown in Figure 4). As indicated in Appendix II, an ESLA value in the range 3.5 to 6.5 is necessary (depending on season and climate) to provide 0.35 ACH. Even given the uncertainties in estimating the ESLA values, it is clear that in every season many households fail to achieve ESLA values as high as 3.

**Table 9: Statistical Distribution Of Estimated ESLA by Season, by Region and for the Entire State.**

| ESLA distribution by season and region | | Percentile | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 5 | 10 | 25 | 50 | 75 | 90 | 95 |
| | REGION | | | | | | | |
| Summer | Sacramento Delta | 0.0 | 0.0 | 0.3 | 3.2 | 11.6 | 21.5 | 31.4 |
| | Southern CA | 0.0 | 0.1 | 0.6 | 5.2 | 17.0 | 30.2 | 36.2 |
| | Rest of State | 0.0 | 0.0 | 0.3 | 5.1 | 16.1 | 28.6 | 39.6 |
| | State Total | 0.0 | 0.0 | 0.4 | 5.1 | 15.9 | 28.6 | 38.8 |
| | | | | | | | | |
| Fall | Sacramento Delta | 0.0 | 0.0 | 0.1 | 0.8 | 5.6 | 14.9 | 22.0 |
| | Southern CA | 0.0 | 0.0 | 0.3 | 1.9 | 7.4 | 16.2 | 21.5 |
| | Rest of State | 0.0 | 0.0 | 0.2 | 1.7 | 7.3 | 16.4 | 25.1 |
| | State Total | 0.0 | 0.0 | 0.2 | 1.6 | 7.1 | 16.1 | 23.5 |
| | | | | | | | | |
| Winter | Sacramento Delta | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 2.2 | 5.7 |
| | Southern CA | 0.0 | 0.0 | 0.0 | 0.2 | 0.9 | 3.7 | 6.9 |
| | Rest of State | 0.0 | 0.0 | 0.0 | 0.1 | 1.0 | 3.7 | 8.6 |
| | State Total | 0.0 | 0.0 | 0.0 | 0.1 | 0.8 | 3.6 | 7.5 |
| | | | | | | | | |
| Spring | Sacramento Delta | 0.0 | 0.0 | 0.2 | 1.7 | 8.1 | 16.6 | 24.3 |
| | Southern CA | 0.0 | 0.0 | 0.5 | 2.4 | 8.5 | 18.7 | 23.2 |
| | Rest of State | 0.0 | 0.0 | 0.3 | 2.8 | 9.2 | 20.3 | 25.6 |
| | State Total | 0.0 | 0.0 | 0.3 | 2.5 | 9.0 | 18.7 | 25.1 |

The fact that ESLA values in the Sacramento area are slightly lower than in the rest of the state is primarily due to fewer hours of medium and high ventilation, in all seasons. In summer, for example, the 25th percentile of hours of medium or high ventilation is 2.25 hours in the Sacramento area compared to 4 hours in the rest of the state, and the median is 10 hours in the Sacramento area compared to 12 hours in the rest of the state. Even in winter, when the median is 0 hours of medium or high ventilation in both Sacramento and the rest of the state, the 75th percentile is 1 hour in the Sacramento area compared to 4 hours in the rest of the state.

Except for Winter, the difference in ventilation behavior may be partly attributable to allergies. As we discuss in a later section, households that reported having members who are allergic to outdoor agents reported less ventilation than other households. In the Sacramento area 62% (+/- 4%) of households report having at least one household member who is allergic to an outdoor agent, compared to 48% (+/- 3%) in the rest of the state, a difference well outside the range of stochastic variability (p-value 0.002). However, this factor alone does not explain the difference in ventilation hours between Sacramento and the rest of the state: even households without a person who is allergic to outdoor agents get less ventilation in the Sacramento area than in the rest of the state.

Before the study, there was some expectation that households in the Sacramento area might provide more nighttime summer ventilation than households in the rest of the state, to cool the house, but there is no evidence that this is the case. For instance, the mean number of summer nighttime hours with at least one bedroom window open was 2.4 in the Sacramento area compared to 3.0 in the rest of the state. The median was 0 in both Sacramento and the rest of the state, that is 50% of the households do not have window opening in summer nighttime hours.

Although new houses in the Sacramento Delta area do tend to receive slightly less ventilation than houses in the rest of the state, it is not clear that the reason for this variation is attributable to differences in climate. Indeed, differences in climate seem to explain very little of the variation in ventilation behavior among houses, as we discuss next.

The California Energy Commission splits California into sixteen “Climate Zones” (CZ). We used the zip code from each survey home to match it to its climate zone. This yielded unambiguous results for 62% of the houses in the survey, but 38% of homes were in zip codes that include multiple climate zones. Usually the climates included in a single zip code are similar to each other. For cases in which the climate zone could not be determined unambiguously, we assigned the house to the lowest-numbered of the possible climate zones. (We also performed the following analyses using just the 62% of houses for which the climate zone could be determined, but that decreased the sample size without leading to substantially different results, those results are not discussed here). More than 90% of the surveyed homes in the Sacramento Delta area were assigned to climate zone 12, and almost all of the homes from the Southern California region were from climate zones 6, 7, and 9.

Figure 7 shows the cumulative distribution functions for summer hours of high ventilation, and medium or high ventilation, separately for twelve of California’s sixteen “climate zones,” for the statewide probability sample. (The other climate zones had too few samples to include). Each of the individual plots is analogous to Figure 1: the upper curve summarizes the statistical distribution of high-ventilation hours, and the lower curve summarizes the statistical distribution of high- or medium-ventilation hours. Four climate zones with very few houses (less than 35 per zone) are not shown; each of the ones shown has more than 70. (The number of houses in each climate zone is tabulated in Table 10.) As the similarity of the plots indicates, there is only modest apparent variation between climate zones, from the standpoint of how many summer hours of high and medium ventilation are provided.

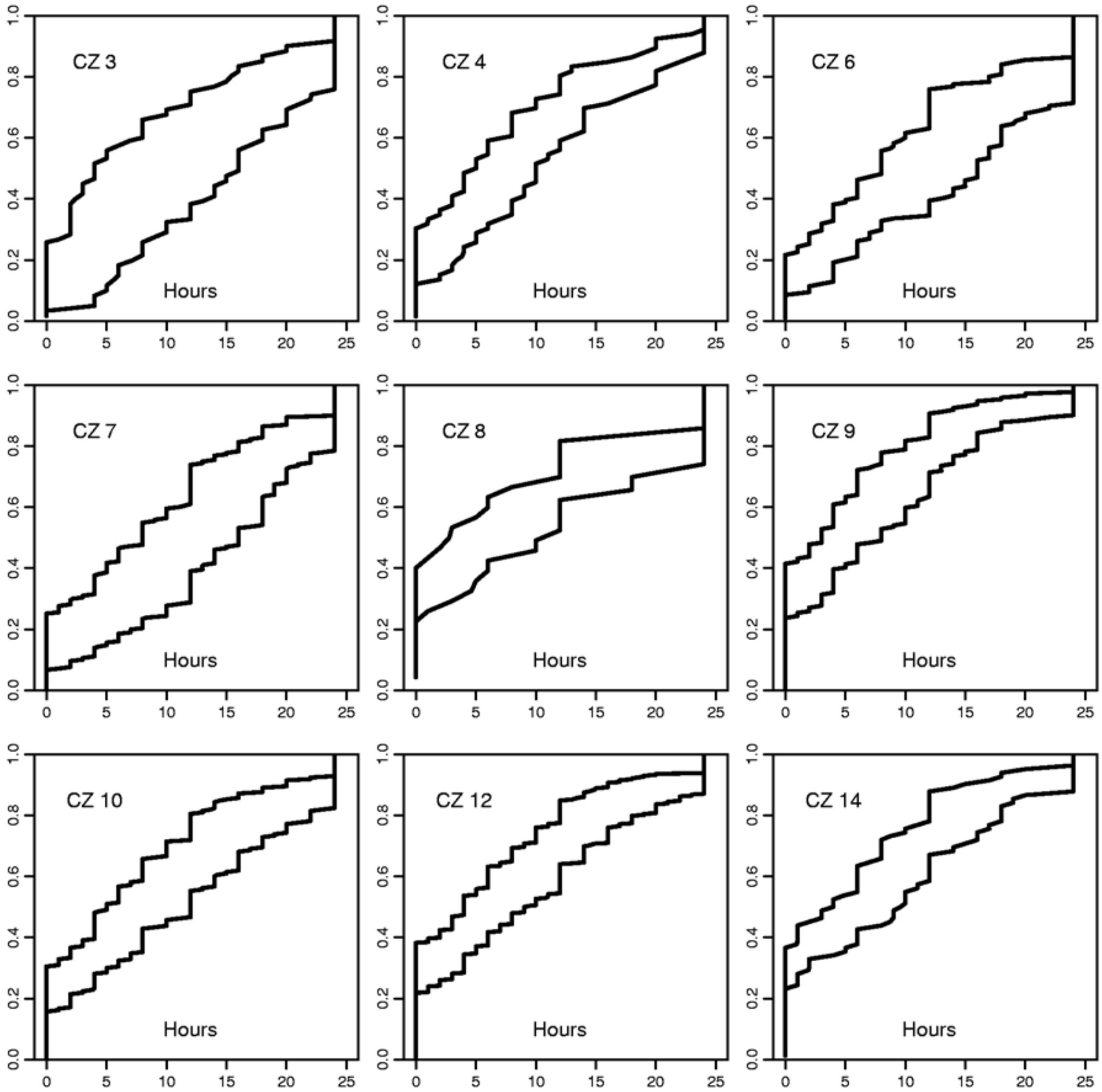


**Figure 7: Cumulative Distribution of High Ventilation and High-or-Medium Ventilation for Twelve of California's Sixteen Climate Zones.** Cumulative distribution of high ventilation (upper curve) and high-or-medium ventilation (lower curve), for twelve of California's sixteen climate zones. Y-axis shows fraction of homes that receive less than or equal to the number of hours of ventilation on the x-axis.

In addition to hours of medium or high ventilation as discussed above, we also examined the variation of ESLA among climate zones, for all seasons. We used climate zone indicator variables in a linear model to predict ESLA, including sampling weights.

Tables 10 through 13 summarize the estimated distributions of ESLA for all of the climate zones with more than 15 houses in the statewide probability sample. The ESLA values can be compared to the minimum ESLA values needed to provide 0.35 ACH, shown in Appendix II. Stochastic variability due to small sample sizes is large even for the more highly sampled climate zones. For example, the median estimated summer ESLA in Zone 6 is 6.9, but the 68% confidence interval estimated using the bootstrap method (Efron, 1981) ranges from 5.8-8.8.

There is modest variation in ESLA among climate zones. Analysis of variance (ANOVA) rejects the hypothesis that the mean summer ESLA in each climate zone is identical (p-value less than 0.0001). Linear regression of summer ESLA on climate zone indicator variables suggests that houses in climate zones 6 and 7 are somewhat better-ventilated than houses in other climate zones (by an average of 2.4 +/- 0.9 units in zone 6 and 3.9 +/- 0.7 in zone 7) and that houses in climate zones 9 and 15 are more poorly ventilated (by an average of –2.8 +/- 0.8 units in zone 9 and –8.8 +/- 2.5 in zone 15); p-values are less than 0.01 in all of these cases. However, this modest variation in ESLA among climate zones is almost completely swamped by the enormous variation within climate zones, so the r-squared value is only 0.04. In other words, variability among climate zones explains only about 4% of the overall variance in ESLA.

**Table 10**: **Distribution of Estimated Summer ESLA, by Climate Zone.**
Stochastic variability is substantial, especially for sparsely sampled climate zones.

| Summer ESLA by Climate Zone | | Percentile | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Climate Zone | Number of Houses | 5 | 10 | 25 | 50 | 75 | 90 | 95 |
| 2 | 24 | 0.0 | 0.0 | 3.8 | 10.2 | 17.8 | 24.9 | 40.0 |
| 3 | 68 | 0.0 | 0.1 | 1.5 | 5.2 | 18.0 | 32.0 | 40.0 |
| 4 | 74 | 0.0 | 0.0 | 0.4 | 4.6 | 13.4 | 31.7 | 39.5 |
| 6 | 144 | 0.1 | 0.2 | 0.6 | 6.9 | 20.8 | 33.1 | 40.0 |
| 7 | 211 | 0.0 | 0.2 | 1.5 | 10.5 | 21.4 | 33.8 | 40.0 |
| 8 | 30 | 0.0 | 0.0 | 0.2 | 4.5 | 14.9 | 39.8 | 40.0 |
| 9 | 199 | 0.0 | 0.0 | 0.3 | 2.9 | 9.5 | 19.7 | 25.5 |
| 10 | 236 | 0.0 | 0.0 | 0.3 | 4.9 | 16.6 | 26.5 | 38.6 |
| 11 | 20 | 0.0 | 0.0 | 3.0 | 7.4 | 8.4 | 10.2 | 10.2 |
| 12 | 320 | 0.0 | 0.0 | 0.3 | 3.3 | 13.6 | 24.8 | 36.3 |
| 14 | 96 | 0.0 | 0.0 | 0.0 | 3.0 | 11.4 | 21.5 | 28.6 |
| 15 | 19 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 1.3 | 1.5 |

**Table 11: Distribution of Estimated Fall ESLA, by Climate Zone**.
Stochastic variability is substantial, especially for sparsely sampled climate zones.

| Fall ESLA by Climate Zone | | Percentile | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Climate Zone | Number of Houses | 5 | 10 | 25 | 50 | 75 | 90 | 95 |
| 2 | 24 | 0.0 | 0.0 | 0.1 | 1.9 | 5.7 | 9.2 | 10.5 |
| 3 | 68 | 0.0 | 0.0 | 0.2 | 1.0 | 6.3 | 12.7 | 15.0 |
| 4 | 74 | 0.0 | 0.0 | 0.0 | 0.6 | 4.2 | 12.3 | 23.7 |
| 6 | 144 | 0.0 | 0.1 | 0.3 | 2.2 | 7.1 | 22.7 | 30.6 |
| 7 | 211 | 0.0 | 0.0 | 0.3 | 2.7 | 9.1 | 15.9 | 21.5 |
| 8 | 30 | 0.0 | 0.0 | 0.1 | 0.6 | 5.8 | 8.4 | 12.2 |
| 9 | 199 | 0.0 | 0.0 | 0.3 | 1.7 | 5.7 | 12.9 | 21.5 |
| 10 | 236 | 0.0 | 0.0 | 0.2 | 2.3 | 8.1 | 18.3 | 22.5 |
| 11 | 20 | 0.0 | 0.0 | 0.4 | 5.7 | 7.5 | 13.5 | 13.5 |
| 12 | 320 | 0.0 | 0.0 | 0.1 | 0.9 | 6.7 | 17.5 | 28.9 |
| 14 | 96 | 0.0 | 0.0 | 0.1 | 1.6 | 7.8 | 15.4 | 20.3 |
| 15 | 19 | 0.0 | 0.0 | 0.1 | 0.3 | 5.8 | 11.7 | 26.6 |

**Table 12: Distribution of Estimated Winter ESLA, by Climate Zone.**
Stochastic variability is substantial, especially for sparsely sampled climate zones.

| Winter ESLA by Climate Zone | | Percentile | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Climate Zone | Number of Houses | 5 | 10 | 25 | 50 | 75 | 90 | 95 |
| 2 | 24 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 3.5 | 3.6 |
| 3 | 68 | 0.0 | 0.0 | 0.0 | 0.1 | 0.9 | 2.4 | 7.3 |
| 4 | 74 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 2.3 | 4.8 |
| 6 | 144 | 0.0 | 0.0 | 0.0 | 0.2 | 1.1 | 5.1 | 19.9 |
| 7 | 211 | 0.0 | 0.0 | 0.0 | 0.2 | 1.1 | 3.4 | 6.9 |
| 8 | 30 | 0.0 | 0.0 | 0.0 | 0.2 | 0.9 | 1.7 | 4.6 |
| 9 | 199 | 0.0 | 0.0 | 0.0 | 0.1 | 0.8 | 4.4 | 8.7 |
| 10 | 236 | 0.0 | 0.0 | 0.0 | 0.2 | 1.1 | 3.7 | 7.0 |
| 11 | 20 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 8.8 | 8.8 |
| 12 | 320 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 2.0 | 6.1 |
| 14 | 96 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 4.4 | 7.9 |
| 15 | 19 | 0.0 | 0.0 | 0.0 | 0.1 | 1.4 | 4.0 | 12.8 |

**Table 13: Distribution of Estimated Spring ESLA, by Climate Zone**.
Stochastic variability is substantial, especially for sparsely sampled climate zones.

| Spring ESLA by Climate Zone | | Percentile | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Climate Zone | Number of Houses | 5 | 10 | 25 | 50 | 75 | 90 | 95 |
| 2 | 24 | 0.0 | 0.0 | 0.8 | 4.0 | 7.3 | 10.3 | 10.9 |
| 3 | 68 | 0.0 | 0.0 | 0.3 | 1.6 | 7.4 | 16.0 | 22.4 |
| 4 | 74 | 0.0 | 0.0 | 0.0 | 0.5 | 4.2 | 12.5 | 23.7 |
| 6 | 144 | 0.0 | 0.1 | 0.3 | 2.6 | 7.0 | 21.1 | 28.6 |
| 7 | 211 | 0.0 | 0.0 | 0.5 | 3.5 | 10.2 | 21.0 | 30.3 |
| 8 | 30 | 0.0 | 0.0 | 0.3 | 2.7 | 5.8 | 11.8 | 12.2 |
| 9 | 199 | 0.0 | 0.0 | 0.5 | 2.4 | 8.0 | 15.7 | 23.2 |
| 10 | 236 | 0.0 | 0.0 | 0.3 | 2.9 | 10.5 | 20.8 | 24.8 |
| 11 | 20 | 0.0 | 0.0 | 4.1 | 7.5 | 8.9 | 19.6 | 19.6 |
| 12 | 320 | 0.0 | 0.0 | 0.2 | 2.3 | 10.0 | 19.8 | 28.3 |
| 14 | 96 | 0.0 | 0.0 | 0.1 | 3.1 | 10.7 | 18.5 | 22.4 |
| 15 | 19 | 0.0 | 0.0 | 0.2 | 1.7 | 4.0 | 15.2 | 26.6 |

**Use of Mechanical Ventilation Systems:**

Mechanical, whole-house ventilation is mandated for new houses in noise abatement areas, but otherwise is not required. Nevertheless many such systems go into new California houses as part of voluntary programs or customer options. (For example, the *Engineered For Life p*rogram used by Building America has installed about 10,000 over 5 years.) For the Statewide Probability Sample, the fraction of people whose homes were built as part of energy efficiency programs can be seen in Question 9:

21% of respondents indicate that their home was built under a special energy-efficiency program,
33% say that it wasn't, and
44% aren't sure.

Of those who said that their home was built under such a program, the program was:

69% Energy Star
1% Building America,
4% Comfortwise,
9% SMUD Advantage Home,
5% SoCalGas Energy Advantage Home,
11% other or don't know.

Participating in these programs, however, does not always imply whole-house mechanical ventilation systems and lack of participation does not imply their absence.

**Reported Installations:**

Question 43A-D asks about the presence of whole-house mechanical ventilation systems.

**Excluding** the “builder sample”, which consists of homes known to have whole-house mechanical ventilation -According to the survey:

52% of the homes have a whole-house ventilation system; some people say they have more than type of one whole-house system.
31% of homes have “a whole-house ventilation system, such as the type … that brings outdoor air into the duct system of a central heating or air conditioning system...” (Question 43A). This question was poorly phrased: as written, it is asking about the presence of *any* whole-house ventilation system (of which a type that brings outdoor air into a duct system is an example), but it could also be interpreted as asking about a specific type of whole-house system. A subset of these, 4% of homes, have “Freshvent”, a specific version of this type of system.
28% have an exhaust fan *whole-house* ventilation system (Q43B),
5% have a heat-recovery whole-house ventilator (Q43C),
5% have some other type of whole-house ventilation system (Q43D).

However Question 43A was interpreted, the responses indicate a much higher penetration of whole-house mechanical systems than we believe to be the case. Outside of the specially selected builder sub-sample (which was not included in the results summarized above), we believe that the respondents had a difficult time interpreting the question and answering correctly.

Question 43N describes the reason they chose the system. The following table applies to respondents who were **not** in the “Builders’ sample.” One might infer that those who checked something other than “came with the house” might have made a conscious choice and may have an actual system. See Table 14 below.

**Table 14: Reason for Choosing System: Statewide Probability Sample**

| Why did you choose the system (percentage among those with a given system) | Whole-house ventilation, such as Freshvent | Exhaust Fan ventilation system | Heat-recovery ventilator | Other whole-house ventilation |
|---|---|---|---|---|
| Came with house | 28 | 73 | 87 | 77 |
| Household member has health condition | 0 | 1 | 2 | 2 |
| Wanted filtered outdoor air | 9 | 3 | 9 | 9 |
| Affordable cost | 1 | 2 | 4 | 11 |
| Good reliability | 1 | 3 | 9 | 7 |
| Reduced energy costs | 7 | 6 | 9 | 3 |
| Other | 4 | 2 | 3 | 1 |

**Use of Mechanical Ventilation Systems, Builders' Sample Only:**

The "Builders' sample" is a non-representative set of homes that are known to have a whole-house mechanical ventilation system or systems. Unfortunately not all homeowners in this sample know that they have such systems, or else did not understand that they were being asked about their system: out of the 67 homes in the Builders' sample, only 45 (67%) indicated that they have any kind of whole-house mechanical ventilation system. Out of these 45 homes, some indicated that they have two systems. Moreover, several people indicated that their home has three systems.

Out of the 45 people who know that they have a whole-house mechanical ventilation system:

(Q43E)
60% said the operation of the system was explained to them when they bought the house,
24% said it wasn't, and
16% didn't answer.

(Q43F)

60% said they understand how the system works,
24% said they don't, and
16% didn't answer.

(Q43G)
49% said they know how to operate it properly,
33% said they don't, and
18% didn't answer.

**System Usage:**

Question 43H-K addresses the perceived usage of a whole-house mechanical system. We believe that most people in the Statewide Probability Sample who said that they have a mechanical ventilation system do not actually have one, so we cannot use the Statewide Probability Sample to address this question. Instead, we look at the Builders' sample only. The following system usage is reported in Table 15:

**Table 15: Usage of Whole House Ventilation System: Builders' Sample**

| Whole-house ventilation system usage (percent of Builders' sample) | Continuous | Somewhat frequent | Infrequent | Never | No answer |
|---|---|---|---|---|---|
| Summer | 18 | 25 | 8 | 3 | 45 |
| Fall | 13 | 18 | 20 | 3 | 45 |
| Winter | 21 | 18 | 12 | 5 | 45 |
| Spring | 13 | 21 | 16 | 5 | 45 |

To within statistical error (one standard deviation, p-values greater than 0.3 in all seasons), there was no reported difference in overall IAQ satisfaction (Q48-51) between the homes in the Builders' sample that know they have mechanical ventilation systems and those that have such a system but don't know it. However, statistical power to address this question is rather poor.

Out of the 45 respondents in the Builders' sample who know that they have a mechanical ventilation system, 32 (68%) identified at least one thing that they like about the system. Some people like more than one thing. See Table 16.

**Table 16: Positive Characteristics of System**

| Characteristic | Pct (out of n=47) |
|---|---|
| Fresh Air | 47% |
| Quiet | 38% |
| Reduced odors | 22% |
| Reduced energy costs | 27% |
| Reduced allergies | 13% |
| Reduced concern about IAQ | 31% |
| Other | 7% |

Out of the 45 respondents in the Builders' sample who know that they have a mechanical ventilation system, 22 (49%) identified at least one thing that they dislike about the system---noisiness and draftiness were the major complaints. Some people dislike more than one thing about their system. See Table 17.

Some people report having more than one system, so the number of people who report having a system (N=45) is less than the sum of the reported numbers in each system type. Note that with n=45, one respondent is about 2% of the sample; with N=7, one respondent is 14% of the sample.

**Table 17: Reasons for Dissatisfaction: Builders' Sample**

| **Reasons for dissatisfaction Percent** | **Entire Sample N=45** | **Inlet system N=25** | **Exhaust fan N=29** | **Heat-recovery ventilator N=7** | **Other whole-house N=15** |
|---|---|---|---|---|---|
| Too noisy | 22% | 24% | 17% | 0% | 27% |
| Too drafty | 18% | 24% | 7% | 0% | 20% |
| Increases odors | 2% | 4% | 0% | 0% | 0% |
| Hard to operate | 11% | 16% | 7% | 0% | 7% |
| Hard to maintain | 4% | 4% | 3% | 0% | 0% |
| Too expensive | 9% | 16% | 10% | 0% | 13% |
| Too quiet | 2% | 4% | 3% | 14% | 0% |
| Not effective | 4% | 0% | 3% | 14% | 7% |
| Other | 2% | 0% | 3% | 14% | 7% |

Out of the 45 respondents in the Builders' sample who know that they have a mechanical ventilation system, 37 (79%) indicated why they have the system. Considering just this subset that indicated why they have a mechanical ventilation system:

36 respondents (97%) said it came with the house
2 respondents (5%) said they wanted filtered outdoor air; in one of these cases they also said the system came with the house.
1 respondent (3%) said they chose it for "affordable cost"
1 respondent (3%) said they chose it for "good reliability"
2 respondents (6%) said they chose it for "reduced energy costs"; one of these also said the system came with the house.

**Use of Cooling, Heating, and Ventilating Systems:** Statewide Probability Sample

Question 34 asked about the number of hours of use of the following systems, by season: Central Air Conditioning, Room Air Conditioning, Whole House Fan, Central or Room Dehumidifier, Central Gas Heating, Central Electric or Heat-pump Heating, Gas Wall Heater, Electric Wall Heater, Wood stove or gas or wood fireplace with tight doors, Fireplace without tight-fitting doors, Freestanding combustion heater, Freestanding electric heater, Central or room humidifier, Central HEPA or electrostatic filter, and Smartvent or other ventilative cooling system.

To summarize the use of these systems, an overall "average use" is not appropriate: that measure would make no distinction between a situation in which half the houses use their system for 0 hours and half for 24 hours, and a situation in which all of the houses use their system for 12 hours. Instead, in Table 18 we summarize the 10th, 50th, and 90th percentile of reported use, for homes that have a system. (If a respondent reported 0 average hours of use in every season, or if they left the answer blank, we assume they did not have the type of system in question).

For instance, from the second row of the table we see that 7% of homes report having room air conditioning. Looking at the "Summer" column we see that out of those homes, in summer, 10% use the system for 2 hours per day or less, 50% use the system for 6 hours or less per day, and 90% use it for 18 hours per day or less.

**Table 18: Use of Cooling, Heating, and Ventilating Systems: Statewide Probability Sample**

| 10th, 50th, and 90th percentile of hours of reported use, among homes that have the system | Frac. of homes that have a system | Summer | Fall | Winter | Spring |
|---|---|---|---|---|---|
| Central Air Conditioning | 75% | 2, 8, 24 | 0, 0, 6 | 0, 0, 0 | 0, 0, 6 |
| Room Air Conditioning | 7% | 2, 6, 18 | 0, 0, 6 | 0, 0, 3 | 0, 0, 8 |
| Whole House Fan | 23% | 1, 6, 19 | 0, 0, 8 | 0, 0, 3 | 0, 1, 10 |
| Central or Room Dehumidifier | 3% | 0, 1, 24 | 0, 0, 20 | 0, 2, 10 | 0, 1, 10 |
| Central Gas Heating | 84% | 0, 0, 0 | 0, 1, 6 | 2, 7, 20 | 0, 0, 4 |
| Central Electric or Heat-Pump Heating | 6% | 0, 0, 0 | 0, 0, 6 | 1, 8, 20 | 0, 0, 6 |
| Gas Wall Heater | 3% | 0, 1, 24 | 0, 3, 24 | 0, 6, 24 | 0, 2, 24 |
| Electric Wall Heater | 2% | 0, 0, 0 | 0, 0, 6 | 0, 3, 12 | 0, 0, 6 |
| Wood stove or gas or electric stove with tight-fitting doors | 30% | 0, 0, 0 | 0, 0, 3 | 1, 2, 6 | 0, 0, 2 |
| Fireplace without tight-fitting doors | 13% | 0, 0, 0 | 0, 0, 2 | 1, 2, 5 | 0, 0, 2 |

| | | | | | |
|---|---|---|---|---|---|
| Freestanding combusting heater, not vented | 1% | 0, 0, 2 | 0, 0, 6 | 0, 2, 8 | 0, 0, 4 |
| Freestanding electric heater | 13% | 0, 0, 0 | 0, 0, 3 | 1, 2, 8 | 0, 0, 1 |
| Central or room humidifier | 6% | 0, 0, 12 | 0, 0, 10 | 0, 5, 12 | 0, 0, 8 |
| Central HEPA or electrostatic filter | 6% | 1, 16, 24 | 0, 8, 24 | 0, 12, 24 | 0, 10, 24 |
| Smartvent or other ventilative cooling | 3% | 0, 4, 24 | 0, 2, 24 | 0, 0, 24 | 0, 2, 24 |

Question 41 asked whether people use their central heating or air conditioning fan to circulate air, even when no heating or cooling is going on. Results did not vary substantially among the three strata. Results also did not differ substantially between the Statewide Probability Sample and the Builders' sample.

Statewide Probability Sample /Builder Sample

7% / 3% Frequently
16% / 18% Sometimes
25% / 31% Rarely
46% / 42% Never
3% / 5% Not applicable
2% / 2% No answer

**Use of Bath Fans:**

Questions 67, 69 and 70 ask related questions about why people do or do not use their bathroom fan.

Question 67 asked how often people use their bathroom fan.
27% always use it
16% frequently use it
19% sometimes use it
17% rarely use it
13% never use it
6% said there is no fan.

Reported fan usage was much higher in the Sacramento Delta area than elsewhere, with 40% (rather than 70%) indicating that they "always" use the fan (p-value < 0.001). Responses of Sacramento Delta residents to other bathroom fan usage questions were similar to those from the rest of the state, so the reason for the discrepancy in fan usage is not clear.

Question 69: Respondents may indicate more than one reason for using the fan.

65% to remove moisture
7% to provide noise
74% to remove odors
7% comes on automatically when light comes on
1% Other

Question 70:

49% of respondents sometimes fail to use the fan even when the bathroom is steamy or has an unpleasant odor. Of this 49%, the reasons not to use the fan are (respondents may indicate more than one reason):

43% window is open
60% don't think of it
27% the fan is too noisy
12% don't think it helps
14% don't want to use the energy
1% fan doesn't work
6% fan causes a draft

For some people their bathroom fan may be their whole-house ventilation fan and for some it may not be, but they think it is.

**Use of Kitchen Fans:**

Question 67 (discussed above) addresses how often bathroom ventilation fans are run. Questions 65-66 look at similar numbers for the kitchen

Question 65: When using the *stovetop*,

28% of respondents always use the exhaust fan or range hood (if present),
32% only use it when odor or humidity seems to be an issue,
26% "sometimes" use it,
11% rarely use it, and
2% never use it.

Among the homes that use the stovetop exhaust fan or range hood more than "rarely": in 12% the fan exhausts back into the room and in 4% the respondent doesn't know. In the other 82% of the homes that use the fan more often than "rarely", the fan vents to the outdoors.

Question 66: When cooking with the *oven*,
15% always use the exhaust fan or range hood,
12% only use it when odor or humidity seems to be an issue,
15% "sometimes" use it,

21% rarely use it, and
35% never use it.

In question 64 we found that only 35% of homes definitely have an oven that vents directly to the outdoors, 34% do not, and 30% don't know. Reasonably, we might expect that people whose oven vents to the indoors would use the stovetop exhaust fan to provide needed ventilation, but this is not the case: people who should use stovetop ventilation the most in conjunction with their oven – those whose oven vents to the indoors – use it the least. (See Table 19.) It is not clear to us, however, that most people know whether their oven vents to the outdoors.

**Table 19: Types of Oven Vents**

| **Percent of homes with the given type of oven vent that use the *stovetop* fan with the specified frequency in conjunction with the oven** | **Oven vents to the outdoors** | **Oven vents to indoors** | **Don't Know** |
|---|---|---|---|
| Always use fan when cooking with oven | 29% | 8% | 7% |
| Only when odor/humidity is a problem | 15% | 13% | 8% |
| Sometimes | 18% | 16% | 12% |
| Rarely | 18% | 21% | 24% |
| Never | 20% | 41% | 48% |

## Overall Use of the Kitchen Fan:

Cooking time using the stove or oven (Question 59) is summarized as follows:

On both weekdays and weekends: 10% of households cook less than 1 hour, 50% cook less than 2 hours, and 90% cook less than 4 hours.

To determine the overall use of the kitchen fan requires making assumptions about the relative amount of time spent cooking with the stovetop, the oven, or both, as well as assumptions about what respondents mean when they say, for example, that they ``sometimes'' use the fan when they cook with the oven. We made the following assumptions:

In questions 65 and 66, which ask about the use of the fan, “always” means 98% of the time, “sometimes” means 40% of the time, “rarely” means 10% of the time, “only when odor/humidity seems to be a problem” means 30% of the time when referring to the stove and 15% of the time when using the oven, and “never” means never.

Using those assumptions, the Statewide Probability Sample has average daily fan usage as follows:

10% of homes use it less than 10 minutes per day
25% of homes use it less than 20 minutes per day
50% of homes use it less than 40 minutes per day
75% of homes use it less than 75 minutes per day (1:15 per day)
90% of homes use it less than 145 minutes per day (2:25 per day)

To examine the sensitivity to our assumptions about oven usage versus stove usage, and quantitative interpretation of the reported frequency of use, we repeated the analysis with the following changes. We reversed the proportions of stove and oven use; assumed “always” means 90% of the time; assumed “sometimes” means 20 percent of the time; and assumed “only when odor/humidity seems to be a problem” means 20% of the time for both oven and stove usage. The result is approximately a 30% to 50% reduction in estimated fan use for each quartile (for instance, the estimated median drops to 21 minutes per day rather than 40 minutes per day).

### 3.2 Determine Occupant Perceptions of and Satisfaction with IAQ in Their Homes:

#### Indoor Air Acceptability:

The purpose of ventilation and hence ventilation standards is to provide acceptable indoor air quality. Acceptable IAQ includes characteristics that can be directly sensed by the occupants as well as health and safety aspects that may not be apparent. ASHRAE defines it as follows:

> ***Acceptable indoor air quality****: air toward which a substantial majority of occupants express no dissatisfaction with respect to odor and sensory irritation and in which there are not likely to be contaminants at concentrations that are known to pose a health risk.*

We cannot directly determine acceptable IAQ from the survey, but we can set an upper limit on it by looking at the respondents’ responses when asked directly and indirectly.

**Perceived Indoor Air Acceptability**: Questions 48-51 specifically ask about how acceptable occupants find the indoor air. Results (adjusted for sampling weights) are shown separately for the representative random samples in each region and for the non-representative "builder samples". See Tables 20A and Table 20B.

**Table 20A: Acceptability of IAQ by Region and Season: Statewide Probability Sample**

| **Acceptability (Percent, adjusted by sampling wt.) Sacramento Area, Southern California Coast, Rest of State, Total** | **Very acceptable** | **Somewhat acceptable** | **Barely acceptable** | **Not acceptable** | **NA** |
|---|---|---|---|---|---|
| Summer | 56,62,64,**62** | 39,35,32,**33** | 3,2,2,**2** | 1,0,1,**1** | 1,2,1,**1** |
| Fall | 71,72,73,**73** | 27,25,24,**24** | 1,2,1,**2** | 1,1,0,**0** | 1,2,1,**1** |
| Winter | 60,63,67,**65** | 35,34,28,**31** | 2,2,2,**2** | 1,0,1,**1** | 1,2,1,**1** |
| Spring | 72,75,74,**74** | 24,23,23,**23** | 2,0,1,**1** | 1,0,0,**0** | 1,2,1,**1** |

**Table 20B: Acceptability of IAQ by Region and Season: Builders' Sample**

| **Acceptability (Percent, adjusted by sampling wt.) Sacramento Area, Southern California Coast, Rest of State, Total** | **Very acceptable** | **Somewhat acceptable** | **Barely acceptable** | **Not acceptable** | **NA** |
|---|---|---|---|---|---|
| Summer | 63,53,69,**63** | 37,47,21,**33** | 0,0,7,**3** | 0,0,0,**0** | 0,0,3,**2** |
| Fall | 74,79,72,**75** | 26,21,24,**24** | 0,0,0,**0** | 0,0,0,**0** | 0,0,3,**2** |
| Winter | 63,68,69,**67** | 37,32,21,**28** | 0,0,7,**3** | 0,0,0,**0** | 0,0,3,**2** |
| Spring | 68,74,69,**70** | 32,26,28,**28** | 0,0,0,**0** | 0,0,0,**0** | 0,0,3,**2** |

Uncertainties in the percentages are indicated in the following table (Table 21), which can also be used for other summaries of the complete sample in each region.

To see how to use the table, consider this example: suppose that in every region, 30% of the people find their winter indoor air quality "somewhat acceptable." In this case, the percentage of returned surveys that report the winter air quality to be "somewhat acceptable" would be expected to be 30 +/- 2.6 in the Sacramento Delta region, 30 +/- 2.8 in the Southern California Coastal region, and so on, where the reported uncertainty is one standard error (which implies that the value would fall within the indicated bounds 68% of the time). The uncertainties for the "total representative" sample take into account the variable sampling weights among the three areas, under the assumption that the true percentage is approximately the same in all areas. (We will give separate uncertainty estimates if there are analyses in which this assumption is substantially violated).

**Table 21: Uncertainties in the Reported Percentage of IAQ**

| **Uncertainty in reported percentage (1 standard error)** | **Actual Percent in Population** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Sample** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** |
| Sacramento Delta Region Statewide Probability Sample (N=308) | 1.7 | 2.3 | 2.6 | 2.8 | 2.8 | 2.8 | 2.6 | 2.3 | 1.7 |
| Southern CA Coast Statewide Probability Sample (N=275) | 1.8 | 2.4 | 2.8 | 3.0 | 3.0 | 3.0 | 2.8 | 2.4 | 1.8 |
| Rest of State Statewide Probability Sample (N=865) | 1.0 | 1.4 | 1.6 | 1.7 | 1.7 | 1.7 | 1.6 | 1.4 | 1.0 |
| Total Statewide Probability Sample (N=1448, weighted) | 1.6 | 2.1 | 2.4 | 2.5 | 2.6 | 2.5 | 2.4 | 2.1 | 1.6 |
| Sacramento Delta or Southern CA Coast Builders' sample (N=19) | 6.9 | 9.2 | 10 | 11 | 11 | 11 | 10 | 9.2 | 6.9 |
| Rest of State Builders' sample (N=29) | 5.6 | 7.4 | 8.5 | 9.1 | 9.3 | 9.1 | 8.5 | 7.4 | 5.6 |
| Total Builders' Sample | 3.7 | 4.9 | 5.6 | 6.0 | 6.1 | 6.0 | 5.6 | 4.9 | 3.7 |

The vast majority of people report a high degree of acceptability with their indoor air quality. With more than 95% of respondents reporting that their air quality is somewhat or very acceptable, there is little statistical power to determine what characteristics of a house (or of occupant behavior) are associated with unacceptable or barely acceptable air quality.

There is little inter-regional variation in reported satisfaction. In the Statewide Probability Sample, slightly fewer people in the Sacramento Delta region than in the other areas report that air quality is "very" acceptable in both summer and winter: IAQ was judged "very acceptable" in 57% +/- 4% of homes in the

Sacramento area, 62%+/-3% in the Southern California Coast area, and 64%+/-2% of homes in the rest of the state. The difference between the Sacramento area and the rest of the state is small and of borderline statistical significance (p-value 0.06).

**IAQ and Thermal Comfort Problems:**

Although a large fraction reported satisfaction with the indoor air, they were separately asked whether they had experienced any conditions that might indicate that the IAQ was not, in fact, acceptable. Questions 45-47 asked about specific comfort, odor and moisture problems that the occupants might have experienced.

Question 45, summarized in Table 22A and 22B characterizes each region separately (Sacramento area, Southern California, and Rest Of State) as well as the state totals; uncertainties in the percentages are shown in Table 21 above. Most of the reported problems relate to thermal comfort, with approximately half of respondents indicating that the house is sometimes too hot in summer and/or too cold in winter. Since most of the homes have air conditioning and all homes have heating, it's not clear whether these complaints indicate that people are setting their thermostats to a level that is not quite sufficient to keep them comfortable (perhaps to save energy), whether the systems are sometimes overloaded by extreme weather, or something else.

The Statewide Probability Sample shows very little variation between the three strata, perhaps surprisingly given the climate differences between them.

The data are mildly suggestive of possibly fewer problems occurring in the builder sample, especially with regard to the complaint that air is sometimes "too stagnant" but to a lesser degree in several other categories as well. To quantify the statistical significance of this apparent effect would require a complicated statistical model that takes into account the correlations between responses (e.g. if some people tend to be "complainers" compared to others, then there will be correlation in responses between and within cells of the table, and these correlations will need to be modeled in detail). Considering the builder sample is not statistically representative of mechanically ventilated homes in the first place, this effort is probably not worthwhile.

There were more reported problems than might be expected from the questions about the perceived indoor air acceptability: even though many people reported that the air is sometimes too dry, stagnant, or dusty, very few said their IAQ was unacceptable or barely acceptable. This suggests that people expect and are willing to accept a certain amount of moisture and discomfort and do not consider these to be unacceptable. In addition, no description of the elements that constitute acceptable or unacceptable "air quality" was provided to respondents.

Therefore, apparent inconsistencies between a general assessment of air quality and the more detailed evaluation of various conditions within the home (too hot, too cold, too stagnant, etc.) were probably not considered by some respondents when answering the acceptability questions.

**Table 22A: Problems Noticed in IAQ and Thermal Comfort: Statewide Probability Sample**

| **Problem noticed (Q45)** (Percent, adjusted by sampling weight) Sacramento Delta Area, Southern California Coast, Rest of State, **Total** | **Summer** | **Fall** | **Winter** | **Spring** |
|---|---|---|---|---|
| Sometimes too hot | 51,55,40,**51** | 1,5,2,**3** | 0,2,1,**1** | 1,3,2,**2** |
| Sometimes too cold | 0,0,0,**0** | 3,6,4,**4** | 47,49,46,**47** | 1,4,1,**2** |
| Sometimes too dry | 8,7,12,**10** | 3,7,5,**6** | 8,15,12,**12** | 2,4,3,**3** |
| Sometimes too humid | 4,6,5,**5** | 2,0,1,**1** | 3,2,1,**1** | 2,1,1,**1** |
| Sometimes too drafty | 3,3,2,**2** | 8,6,11,**6** | 11,10,10,**10** | 3,5,3,**3** |
| Sometimes too stagnant | 15,14,15,**15** | 4,5,5,**5** | 8,8,10,**10** | 5,6,4,**5** |
| Sometimes too dusty | 25,24,24,**25** | 17,21,17,**18** | 14,16,13,**14** | 17,19,16,**17** |

**Table 22B: Problems Noticed in IAQ and Thermal Comfort: Builders' sample**

| **Problem noticed (Q45)** (Percent, adjusted by sampling weight) Sacramento Delta Area, Southern California Coast, Rest of State, **Total** | **Summer** | **Fall** | **Winter** | **Spring** |
|---|---|---|---|---|
| Sometimes too hot | 32,53,38,**40** | 5,0,3,**3** | 5,0,7,**5** | 5,0,0,**2** |
| Sometimes too cold | 0,0,0,**0** | 5,0,3,**3** | 26,42,41,**37** | 5,0,7,**5** |
| Sometimes too dry | 0,5,14,**8** | 0,0,3,**2** | 11,11,14,**12** | 0,0,0,**0** |
| Sometimes too humid | 0,0,3,**2** | 0,0,0,**0** | 0,0,3,**2** | 0,0,3,**2** |
| Sometimes too drafty | 5,0,0,**2** | 5,0,3,**3** | 5,5,17,**10** | 5,0,7,**5** |
| Sometimes too stagnant | 5,5,7,**6** | 0,0,3,**2** | 0,5,3,**3** | 0,5,0,**2** |
| Sometimes too dusty | 21,11,21,**18** | 16,11,14,**13** | 5,5,10,**8** | 16,5,10,**10** |

Many people who expressed dissatisfaction with one aspect of their comfort or IAQ also expressed dissatisfaction with others. For example, more than 85% of homes that have a problem with stagnant air in summer also have air that is sometimes too hot.

Reported thermal comfort problems were far higher in summer and winter than in other seasons. Adjusted for sampling weight, 60% of households report at least one IAQ problem or thermal comfort problems in summer, 29% in fall, 58% in winter, and 24% in spring.

Questions 46 and 47 show very little variation among the three Regions of the state, so we summarize just the overall data from the Statewide Probability

Sample (weighted to account for the different sampling weights), in Tables 23 and 24. Some people report bathroom mold or mildew, but few people report problems in other areas. Plumbing leaks and poor site drainage are fairly common complaints.

**Table 23: Percent of Homes that Report Occasional Mold or Mildew.**

| **Occasional mold or mildew, Q46 (Percent of homes)** | **Summer** | **Fall** | **Winter** | **Spring** |
|---|---|---|---|---|
| Bathroom | 5 | 5 | 7 | 4 |
| Basement/crawl space | 0 | 0 | 0 | 0 |
| Walls or ceilings | 0 | 1 | 1 | 0 |
| Carpets | 0 | 0 | 1 | 0 |
| Closets | 1 | 1 | 1 | 1 |

**Table 24: Conditions Experienced**

| **Condition experienced, Q47** | **Percent of homes** |
|---|---|
| Condensation on windows/surfaces | 4 |
| Roof leaks | 4 |
| Plumbing leaks | 13 |
| Wall or window leaks | 8 |
| Flooding | 2 |
| Poor site drainage | 10 |
| Bothersome carpet odors | 2 |
| Bothersome cabinetry odors | 1 |
| Other unpleasant odors | 3 |
| Other moisture problems | 6 |

## 3.3 Determine the Relationship Among Ventilation Practices, Perceived IAQ, and House and Household Characteristics:

### Relationship Between Hours at Home and Ventilation:

To investigate the relationship between ventilation and hours that the home is unoccupied, we restricted our analysis to the respondents who gave completely consistent answers on the ventilation questions (questions 10-25 and 28-31). We did this to avoid the possibility that our imputation procedure could create, or obscure, a relationship between ventilation and hours that the home is unoccupied. This is a particular worry because the number of hours that the home is unoccupied was one of the variables used in the imputation procedure.

Many people indicated that worries about security are a major reason for closing windows (to be discussed more fully in Objective 4). As such, we would expect that homes that are usually occupied might be better ventilated than are homes that are frequently unoccupied. This does appear to be the case, although the effect is rather mild. We divided surveys into three groups of roughly the same number of homes: those in which the home is empty on weekdays more than 8 hours per day, from 2-8 hours per day, and less than 2 hours per day.

In all seasons, homes that are empty for more than 8 hours per day tend to report less ventilation than other homes: in summer the median ESLA is about 20% lower in less-occupied homes than in the others, and in winter the median ESLA is about half the median ESLA in the other homes.

The variation in ESLA between homes that are and aren't empty for more than 8 hours per day is a tiny fraction of the variation among homes in any given category of hours unoccupied. A linear regression of ESLA on reported hours that the home is empty has an r-squared of less than 0.01, and a coefficient of "unoccupied hours" that is not statistically significant at the p=0.5, 0.10, or even 0.20 level.

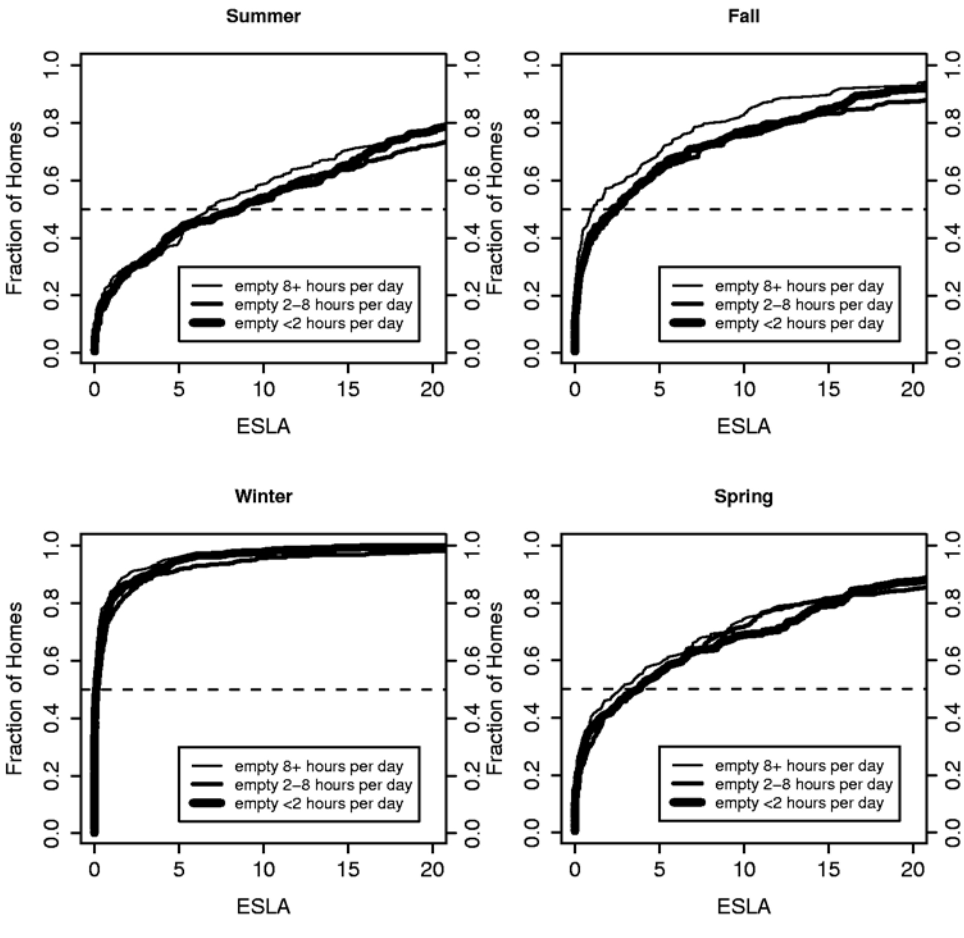


**Figure 8: Relationship of Hours at Home and Ventilation**

The same picture is obtained by looking at the reported hours of ventilation, from questions 28-31: in the fall-the season with the biggest difference – the median reported hours with no ventilation is 14 for homes that are unoccupied for more than eight hours per day, and is 12 for homes that are unoccupied for eight or fewer hours per day. There is no difference in the median between homes that were unoccupied 2-8 hours per day and homes that were unoccupied less than 2 hours per day.

**Relationship Between Ventilation and Household Health Characteristics:**

Questions 52—58 asked about the number of people in each household who have asthma, allergies, and other breathing problems, as well as the number of adults and children and the number of adult and child smokers. From the Statewide Probability Sample, 59% reported that at least one household member has at least one of the health problems; 62% reported that at least one household member has at least one of the health problems and/or smokes.

We performed linear regressions of seasonal ESLA on indicator variables for the presence in the household of: at least one smoker, at least one asthmatic, at least one person with allergies to indoor agents, at least one person with allergies to outdoor agents, at least one person with allergies to other airborne agents, or at least one person with another breathing or lung problem. We also used indicator variables for small households (3 people or less) and large households (6 people or more). We tried these indicator variables in various combinations. In all cases we also included indicator variables for region. We also performed logistic regressions of the probability that ESLA is very low (less than 1) on these indicator variables. In no case was ESLA, or the probability of a low ESLA, predicted with substantial goodness-of-fit. (All r-squared values were less than 0.1).

Only in summer was there some evidence of a relationship between ESLA and some of the health problems. Table 25 shows estimated coefficients, standard errors, and p-values for the coefficients of indicator variables, as they entered the model in various combinations. Each row presents estimates a model that includes all of the variables with entries on that row, in addition to regional indicator variables. (Coefficients for the regional variables are not shown). For instance, the first row represents a model in which only an asthma indicator variable is used. As the table shows, presence of an asthmatic in the household is associated with a change in summer ESLA: households with asthmatics report an ESLA value about 1.5 higher than other households, with or without controlling for other health issues. Regional coefficients, not shown, were stable near –2 +/- 1 (p-value 0.04) for the Sacramento area and 0.3 +/- 0.7 (p-value 0.7) for the Southern California region. The “rest of state” coefficient is 0.0 by definition. The stability of the coefficients across the models shows that co-linearity of household parameters is not a concern. There is little indication that conditions other than asthma influence ventilation behavior substantially.

The coefficient of asthma is not statistically significantly different from zero in either fall or winter, but is again positive (coefficient estimate in the “full model” that includes all of the health issues is 1.7 +/- 0.6, p-value 0.01) in spring, so there is some evidence that asthmatics do indeed get 1.5 to 2 units higher ESLA than others.

We also performed several of the regressions using total hours of reported ventilation as the dependent variable, including the "full model" that used all of the health indicator variables. None of the coefficients were reliably "statistically significant," and r-squared values were negligible.

**Table 25: Coefficient Estimates that Describe the Effect on ESLA of Presence of Different Health Issues.** Each row summarizes the coefficients from a different linear model; coefficients indicate the increase in ESLA associated with the presence of a person in the household with the given characteristic. Region effects (for Sacramento region and Southern California region) are included in each model, but those coefficients are not shown in the table. P-values are shown in parentheses.

| Asthma | Smoker | Allergic to Outdoor agent | Allergic to Indoor agent | Allergic to Other or Unknown | Other Lung Problem |
|---|---|---|---|---|---|
| 1.6 +/- 0.8 (p=0.04) | | | | | |
| | -0.8 +/- 1.1 (0.5) | | | | |
| | | 0.1 +/- 0.6 (0.9) | | | |
| | | | 0.9 +/- 0.7 (0.2) | | |
| | | | | 0.5 +/- 0.8 | |
| 1.5 +/- 0.8 (0.06) | | -0.7 +/- 0.7 (0.2) | 0.9 +/- 0.8 (0.3) | | |
| 1.5 +/- 0.8 (0.06) | -0.8 +/- 1.1 (0.5) | -0.8 +/- 0.8 (0.3) | 0.8 +/- 0.8 (0.3) | 0.3+/- 0.8 (0.8) | |
| 1.8 +/- 0.8 (0.03) | -0.6 +/- 1.1 (0.6) | -0.8 +/- 0.8 (0.3) | 0.9 +/- 0.8 (0.3) | 0.4 +/- 0.8 (0.5) | -1.9 +/- 1.1 (0.1) |

## Relationship Between Ventilation and Indoor Sources:

Question 78 asked about the presence of indoor sources of air pollution: candles or incense, paints or solvents, pesticides, deodorizers, and potpourri. We created indicator variables for the presence of each of these and, as with the health issues, we performed linear regressions of ESLA on these source variables, in various combinations. None of the models produced an r-squared over 0.01. Over all of the seasons and all of the models, only two variables were statistically significant: paint users in winter and candle users in spring reported higher values of ESLA**.** We suspect this to be a statistical accident: checking 5 sources in each of 4 seasons generates 20 comparisons, so on average we would expect to find one "statistically significant" positive result (at the 5% level) even if the variables are random. The lack of persistence over the various seasons – indeed, even the signs of the coefficient estimates change – suggests that there is not in fact a substantial relationship between these sources and ventilation levels.

Question 59 asked about cooking. We created two indicator variables: one that identifies households that cook 7 to 18 hours per week, and one that indicates households that cook 18 or more hours per week. We again included regional indicator variables. R-squared values were quite low in every season, ranging from 0.02 to 0.03. However, the coefficient estimates were substantial and statistically significant. The coefficient estimates (and p-values) describing the effect on ESLA of cooking 7 to 18 hours per week are:

Summer 1.4 +/- 1.4 (p-value 0.3)
Fall 1.1 +/- 1.4 (0.4)
Winter 1.8 +/- 1.4 (0.2)
Spring 2.7 +/- 1.4 (0.05)

For households that cook 18 or more hours per week, estimates are:

Summer 3.3 +/- 1.4 (p-value 0.02)
Fall 3.6 +/- 1.4 (0.02)
Winter 4.2 +/- 1.5 (0.004)
Spring 5.3 +/- 1.4 (0.0001).

Thus people who cook a lot uniformly report higher levels of ventilation (as quantified by estimated ESLA) than do people who cook less frequently. However, there is still a great deal of variation among people with a given cooking behavior, and there are not many people who households that cook more than 18 hours per week, so the explanatory power of the "cooking" variables is low, as noted above.

**Relationship Between Perceived Indoor Air Quality and Comfort**:

For the Statewide Probability Sample, we performed a linear regression, for which the dependent variable was an indicator variable for whether a home's IAQ was judged "very acceptable," using several explanatory variables. As explanatory variables, we tried:

- Seasonal ESLA; or
- Indicator variables for high ESLA (>15) and low ESLA (< 1); or

- Number hours of low, medium, or high ventilation (from question 28 or 30);or
- Number of hours of high ventilation.

We also included indicator variables for region of the state. In all cases, coefficients of the ventilation variables were negligible, and r-squared values were less than 0.01. All models based on ESLA estimated a coefficient for Region 1 near –0.07 +/- 0.035 in both seasons, with a p-value below 0.05, but no other coefficient approached "statistical significance."

Ventilation behavior varies enormously among the seasons, yet people's perceptions of indoor air quality hardly vary at all: 83% of respondents gave the same answer for both summer and winter IAQ acceptability (with most of them rating it "very acceptable" in both cases). This suggests that any given person (or household) is very insensitive to ventilation, when it comes to assessing air quality. So it is not surprising that the relationship between overall IAQ acceptability (as assessed through questions 48-51) and ESLA, SLA, or hours with ventilation, is very weak.

We also created an index based on the individual IAQ issues in Question 45: we simply counted the number of problems that people reported in each season. We tried models that did or did not include the "sometimes too hot" or "sometimes too cold" variables. These are comfort rather than IAQ variables, so we did not include them in the results discussed below.

There was fairly high correlation (r=0.60) between the number of reported problems in summer and in winter. Figure 9 plots the number of problems summer versus the number in winter for each home in the survey (including the Builders' Sample); random "jitter" has been added in both the x- and y-directions to separate the points.

Figure 9 below shows the number of specific IAQ problems in summer (excluding "too hot") versus number in winter (excluding "too cold"), for the entire survey. Horizontal and vertical "jitter" have been added to separate the points.

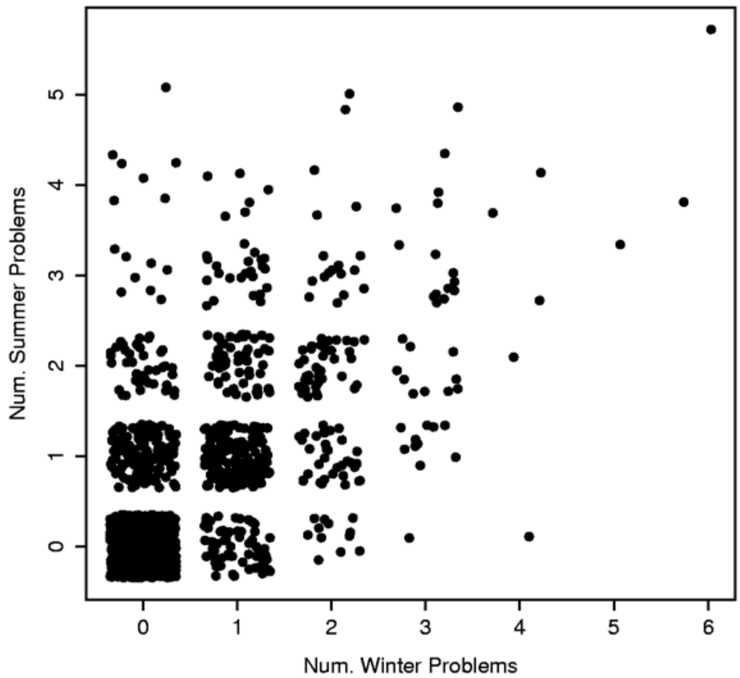


**Figure 9: Specific IAQ Problems in Winter and Summer**

We performed a linear regression with the "problem index" in a given season as the dependent variable, and with the various explanatory variables listed above. None of the models yielded an r-squared value greater than 0.02. The coefficient of ESLA was "statistically significant," however. Table 26 gives the coefficient estimates for the model based on the summer data for the Statewide Probability Sample, using indicator variables for high and low ESLA (this model provided a very better model fit than did a model that includes ESLA as a continuous variable). Controlling for region, people with low ESLA reported about 0.2 fewer problems than those with medium or high, on average. The regression summarized in Table 26 had an r-squared of 0.005.

**Table 26: Linear Model Estimates of the Number of Reported Specific IAQ Problems During the Summer**, other than "too hot"

| Variable | Coefficient | Std. Error | t value | P-value |
|---|---|---|---|---|
| (Intercept) | 0.69 | 0.04 | 15.5 | <0.0001 |
| High ESLA | –0.01 | 0.06 | –0.18 | 0.85 |
| Low ESLA | –0.18 | 0.06 | –3.05 | 0.002 |
| Region1 | 0.00 | 0.08 | 0.02 | 0.99 |
| Region2 | 0.02 | 0.06 | 0.37 | 0.71 |

The situation in winter is quite similar: low ESLA was associated with a reduction of about 0.2 in the reported number of specific IAQ problems, after controlling for region. The regression had an r-squared of 0.006. Coefficients are summarized in Table 27.

**Table 27: Linear Model Estimates of the Number of Reported Specific IAQ Problems During the Winter**, other than “too cold”

| Variable | Coefficient | Std. Error | t value | P-value |
|---|---|---|---|---|
| (Intercept) | 0.56 | 0.05 | 11.8 | <0.0001 |
| High ESLA | –0.11 | 0.15 | –0.7 | 0.4 |
| Low ESLA | –0.18 | 0.05 | –3.3 | 0.001 |
| Region1 | 0.06 | 0.07 | 0.09 | 0.4 |
| Region2 | 0.07 | 0.05 | 1.3 | 0.2 |

Overall, the results are mildly suggestive of the possibility that people who experience fewer specific IAQ problems feel less of a need to try to ventilate in order to avoid the problems. However, there are many other possibilities, including interactions with other variables not included in the models, difference in ventilation behavior or reporting of ventilation behavior between people who do or don’t tend to notice IAQ problems if they exist.

**Relationship Between Ventilation and Perceived Indoor Air Quality:**

As discussed in a previous section, very few people felt that their indoor air quality (IAQ) is unacceptable or only barely acceptable. However, a substantial number of people did express the feeling that their IAQ is only “somewhat acceptable” rather than “very acceptable,” particularly in summer and winter. There is some evidence that some people are more likely to be less than completely satisfied than are other people, either because they are more sensitive to their environment or for reasons of temperament. For example, people who rated their IAQ less than “very acceptable” in winter were very likely to rate it less than “very acceptable” in summer as well. Considering all of the respondents (un-adjusted for sampling weights), 55% said IAQ is “very acceptable” in both summer and winter, 28% said it is less than “very acceptable” in both summer in winter, and only 18% said it is “very acceptable” in one of these seasons but not the other. Some of these respondents might live in houses that have problems that lead to poor IAQ in both seasons. Others may simply be more sensitive to IAQ issues than are other people or may simply be less inclined to agree that something is “very acceptable.” Available data do not allow us to distinguish between these cases, or at least not very well.

Question 45 asked whether there is a “significant period” in each season when a given problem was noticed (house too hot, too cold, too dry, etc.). We investigate the relationship between the specific air quality issues in Question 45 and the general acceptability of air quality by season as reported in Questions 48-51. We begin by creating a binary “indicator variable” based on acceptability of indoor air quality as reported in Questions 48-51: for a given season, the variable takes a value of 1 for surveys that reported that IAQ in that season is “very acceptable,” and a value of 0 for any other response. We wish to predict the value of this variable, using as predictive variables the responses to the specific IAQ questions such as whether the air in the house is too humid, too stagnant, etc.

It would be convenient to fit a model in which each particular IAQ problem is associated with a fixed reduction in expected satisfaction: "Start by assuming a 75% chance that the IAQ is 'very acceptable', and subtract 15 percentage points if the air is too stagnant, subtract 12 percentage points if the air is too dry…" A statistically correct way of fitting such a model is discussed below, but we start with an approximation. We can approximate such a model simply by performing a linear regression of the acceptability indicator variable on indicator variables for the specific IAQ problems. If we do this, we get coefficient estimates for several variables that are negative (indicating lower IAQ acceptability if these problems are present) and both practically and statistically significant (see Table 28.) However, the specific IAQ complaints do little to explain the variation in peoples' responses to the general IAQ question: the value of r-squared is only 0.11 for this model.

**Table 28: Summer IAQ Acceptability, Linear Model Parameters**

| Variable | Coefficient | Std.Error | t-value | P-value |
|---|---|---|---|---|
| (Intercept) | 0.77 | 0.02 | 42.063 | <0.0001 |
| Too hot | -0.11 | 0.03 | -4.212 | <0.0001 |
| Too dry | -0.15 | 0.04 | -3.532 | <0.001 |
| Too stagnant | -0.18 | 0.04 | -5.052 | <0.0001 |
| Too dusty | -0.18 | 0.03 | -6.186 | <0.0001 |
| Region 1 | -0.07 | 0.03 | -2.373 | 0.011 |

There is a slight problem with using ordinary linear regression to analyze data such as these. The issue is both theoretical and practical. The problem is that in most cases the reduction in the response is not linear in the independent variables. If stagnant air leads to an 18-point reduction in the probability that IAQ is judged "very acceptable", and dusty air does as well, then air that is both stagnant *and* dusty may not lead to a 36-point reduction in satisfaction, but to some reduction between 15 and 30 points. (In fact, assuming a linear model for the percentage can lead to a predicted probability less than 0 in some cases, though not in the model summarized above.)

To address this issue, we use logistic regression, which is a statistical method for investigating the relationship between a binary response and a predictive variable or variables. Logistic regression fits a model that assumes that:

$$\log[p/(1-p)] = b0 + b1*x1 + b2*x2 + \dots$$

where p is the probability that IAQ is judged "very acceptable", b0…bn are regression coefficients, and x1, x2, … are explanatory variables. In this case, the explanatory variables are indicator variables (0=no, 1=yes) for the presence of specific IAQ problems from Question 45.

**Table 29: Summer IAQ Acceptability, Logistic Model Parameters**

| Variable | Coefficient | Std. Error | z-value | Pr(>\|z\|) |
|---|---|---|---|---|
| (Intercept) | 1.21 | 0.09 | 12.9 | <0.0001 |
| Too hot | -0.49 | 0.12 | -4.2 | <0.0001 |
| Too dry | -0.67 | 0.20 | -3.4 | 0.001 |
| Too stagnant | -0.80 | 0.17 | -4.8 | <0.0001 |
| Too dusty | -0.79 | 0.13 | -6.0 | <0.0001 |
| Region 1 | -0.32 | 0.13 | -2.4 | 0.002 |

Table 29 summarizes logistic model parameters for a model that predicts whether IAQ is judged “very acceptable,” depending on the responses to various complaints about individual IAQ problems.

We tried several models using various sets of variables based on Question 45, as well as indicator variables for the Region of the state, and to indicate whether the home was in the Builders’ Sample. Table 30 shows the results for the summer season, for a model that includes just the variables that had substantial effects on the probability that IAQ would be judged “very acceptable.”

To use the coefficient estimates to predict whether the IAQ is likely to be rated “very acceptable,” calculate the probability from

Probability “very acceptable” = exp(s)/(1+exp(s))

where s is the sum of the appropriate coefficients, and the exponent is to the base e. For instance, the model predicts that if a home has air that is “too dry” and “too dusty” for a significant portion of the summer, then s = 1.21 – 0.67 – 0.79 = -0.25, and the resulting probability is 43%.

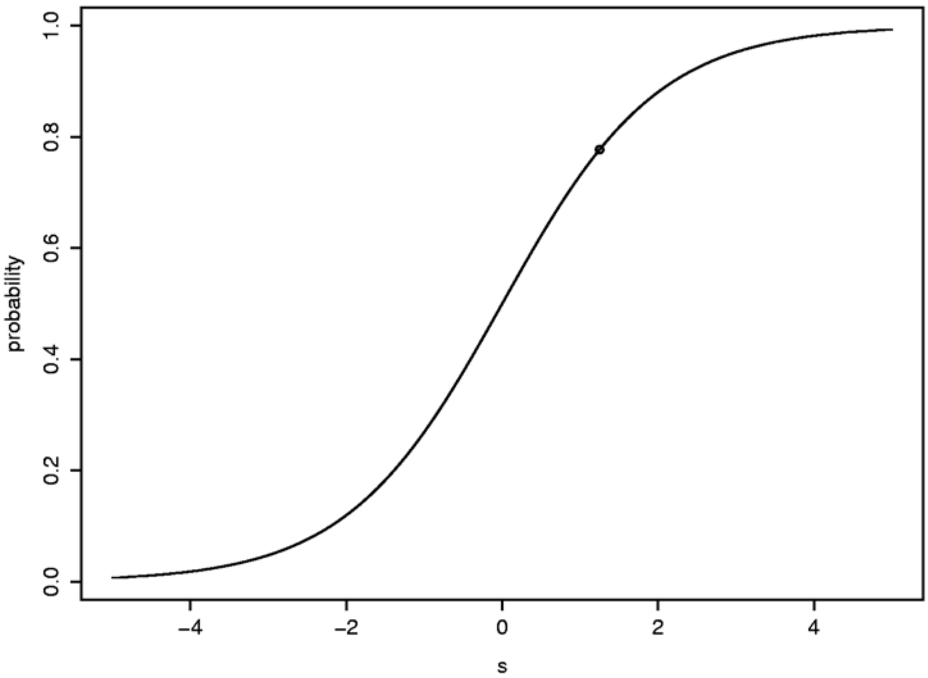


**Figure 10: Plot of the Predicted Probability of Indicating that IAQ is "Very Acceptable" as a function of s.** The function is exp(s)/(1+exp(s)). The point corresponding to a response with no specific IAQ complaints is indicated with a dot.

Figure 10 above can be used to convert between s and probability. A dot marks the intercept term: s=1.21 implies a probability of 0.77 that the IAQ will be judged "very acceptable." Specific IAQ problems lead to lower values of s (along the x-axis) and thus lower values of the probability. As it happens, only the most extreme responses in our data – those that reported almost every possible IAQ problem and are also in Region 1 – have predicted probabilities less than 0.2. Since the probability is fairly linear in s (with a slope near 0.25) from about s=-2 to s=+2, it turns out the linear model discussed above should not be problematic; indeed, multiplying the coefficients from the logistic regression by 0.25 gives values rather close to the coefficients of the linear model.

To investigate how well the model actually predicts responses, the predicted probability that the IAQ would be judged "very acceptable" was calculated for each respondent, using the logistic regression results. Respondents were grouped into bins based on expected probability, and their actual response was noted. Table 30 summarizes the results. The last column, "predicted fraction 'very acceptable'," is the mean predicted probability for the responses in the bin. As the table shows, the model performs quite well in the sense that even in the lowest-probability bins, in which respondents indicated that they have most or all of the individual IAQ problems, the fraction that report "very acceptable" IAQ is correctly predicted.

**Table 30: Summer IAQ Acceptability, Characteristics of the Predictions.**

| Predicted probability of "very acceptable" | Number "very acceptable" | Number in bin | Fraction "very acceptable" | Predicted fraction "very acceptable" |
|---|---|---|---|---|
| 0.1-0.2 | 7 | 37 | 0.19 | 0.16 |
| 0.2-0.3 | 19 | 64 | 0.30 | 0.28 |
| 0.3-0.4 | 17 | 46 | 0.37 | 0.32 |
| 0.4-0.5 | 105 | 242 | 0.43 | 0.46 |
| 0.5-0.6 | 81 | 146 | 0.55 | 0.56 |
| 0.6-0.7 | 250 | 377 | 0.66 | 0.66 |
| 0.7-0.8 | 458 | 603 | 0.76 | 0.76 |

This table compares the predicted response about whether IAQ is "very acceptable" to the actual response. The probability that IAQ will be judged "very acceptable" is predicted for each house, and houses are put into "bins" that span a given range of acceptability. The predicted number of "very acceptable" responses in each bin is compared with the observed number. For instance, from the first row of the table, the model predicts that 37 houses have a probability in the range 0.1-0.2 of finding their IAQ to be "very acceptable"; if the model were perfect, 16% of those houses would in fact judge their IAQ to be very acceptable. The observed fraction was 19%.

The logistic model fits well and the coefficients estimates are highly statistically significant: people who report certain specific IAQ problems, and especially people who report many such problems, are much more likely to report that their general IAQ is less than "very satisfactory." However, the specific IAQ problems explain very little of the variation in response to the general IAQ question: if we were to guess "very acceptable" for everyone whose predicted probability from the model is greater than 0.5, and "less than 'very acceptable'" for everyone else, we would correctly guess the response for 68% of the respondents. This is only a little better than the 62% who we would correctly guess if we simply guessed "very acceptable" for everyone. And, as noted above, the linear model generates an r-squared of only 0.11. Some people report no specific IAQ problem but still say they have IAQ that is less than "very acceptable," while others report one or more specific problems but still judge their overall IAQ to be "very acceptable."

The situation in winter is much the same: some specific IAQ complaints are highly statistically significant in their effect on the probability that IAQ will be judged "very acceptable," but very little of the overall variability in acceptability is attributable to those complaints: r-squared of the linear model is only 0.07. As before, people in the Sacramento Delta area were somewhat more likely to report that IAQ was less than "very acceptable" than were people elsewhere in the state. Table 31 presents linear model coefficient estimates, and Table 32 presents logistic model estimates for winter.

**Table 31: Winter IAQ Acceptability,** Linear Model Parameters, "very acceptable"

| | Estimate | Std.Error | t-value | P-value |
|---|---|---|---|---|
| (Intercept) | 0.72 | 0.01 | 48.8 | < 0.0001 |
| Too dry | -0.26 | 0.06 | -4.7 | <0.0001 |
| Too dusty | -0.23 | 0.03 | -7.0 | <0.0001 |
| Too drafty | -0.13 | 0.05 | -2.4 | 0.02 |
| Region 1 | -0.06 | 0.03 | -2.2 | 0.03 |

Table 31 summarizes the coefficient estimates from a linear model that predicts whether winter IAQ is judged "very acceptable," depending on the presence of various individual IAQ problems.

**Table 32: Winter IAQ Acceptability,** Logistic Model Parameters, "very acceptable"

| | Estimate | Std.Error | z-value | Pr(>\|z\|) |
|---|---|---|---|---|
| (Intercept) | 0.95 | 0.07 | 13.4 | <0.0001 |
| Too dry | -1.14 | 0.26 | -4.5 | <0.0001 |
| Too dusty | -0.97 | 0.14 | -6.7 | <0.0001 |
| Too drafty | -0.56 | 0.24 | -2.3 | 0.02 |
| Region 1 | -0.28 | 0.13 | -2.1 | 0.03 |

Table 32 summarizes the coefficient estimates from a logistic model that predicts whether winter IAQ is judged "very acceptable," depending on the presence of various individual IAQ problems.

We did not look in detail at spring and fall IAQ acceptability data, because very few people reported any specific IAQ problems in those seasons.

Overall, it seems that some people do take specific IAQ complaints into account when assessing overall indoor air quality, but most people do not, or at least not at a level of precision that can be determined through this survey: many people report that IAQ is less than "very acceptable" even though they report none of the specific IAQ problems, and many people report that IAQ is "very acceptable" even though they report one or more specific problems.

**Mold:**

Presence of mold can indicate a problem with indoor air quality (too much humidity); it can also cause perceived air quality problems due to allergies and irritation. Out of the 1515 respondents, 162 indicated that they have noticed mold in at least one place, in at least one season; 65 of these respondents said they have mold in every season. Most people who reported mold said it occurs in the bathroom, with closets and carpets about a factor of six lower, and a handful of reported problems in basement/crawlspace or walls/ceilings. The scarcity of reported problems in basement or crawlspace may not indicate very much other than the facts that most new California homes do not have basements and many people may not have been into their crawlspace.

Most people who reported mold in one season also reported it in one or more other seasons. About 40% of the people who reported mold in one season reported it in all seasons.

For both summer and winter, we created an indicator variable to indicate whether the respondent had noticed mold in one or more locations in their house. We also created separate indicator variables for exactly one location, and for more than one location.

People who noticed summer mold in at least one location were less likely to report that their summer IAQ was “very acceptable.” The coefficients of the variables were nearly unchanged in a model that included the mold indicator variable; the mold indicator variable has a coefficient estimate of –0.48 +/- 0.23 in the logistic model (p-value 0.04), corresponding to a coefficient of about –0.1 in the linear model; that is, a 10% decrease in the probability of rating their IAQ “very acceptable.”

People who noticed winter mold were also less likely to report that their winter IAQ was “very acceptable.” This affect was extremely strong for the small number of respondents who reported mold in more than one location in their home; indeed, this effect is so strong that a linear model as discussed above cannot be used to predict IAQ acceptability for this group, because it would predict negative probability of finding IAQ “very acceptable” if they also reported other specific IAQ problems in addition to mold. Out of the 20 homes that reported mold in more than one place in winter, only 3 reported that IAQ is “very acceptable.” The coefficients for the variables other than mold in the logistic model for winter, shown in Table 33, are nearly unchanged when the mold variables are added to the model. In the logistic model, the coefficient associated with noticing mold in exactly one location in the house is –0.37 +/- 0.21 (p-value 0.08), and the coefficient associated with noticing mold in multiple locations is –2.29 +/- 0.64 (p-value 0.0003).

**Relationship between ventilation, ethnicity, house and household size, and income:**

Since the summer season had the greatest amount of ventilation and the greatest variability in ventilation, we considered the summer ESLA values when searching for variables that explain or predict the amount of ventilation.

In each Region, homes over one story in height were substantially better ventilated (in terms of ESLA) than were single-story homes. The estimated effect was almost the same size in all regions: in Regions 1, 2, and 3 respectively, the estimated effect on ESLA that is associated with a higher-than-one-story home was 2.1 +/- 1.2, 2.4 +/- 2.2, and 2.8 +/- 0.9 units. The r-squared values in all regions are only around 0.01, however. It is possible that the reason taller homes are better-ventilated is partially due to people being more willing to leave upstairs windows open while the house is unoccupied if they live in a multi-story house. We checked to see if, instead, the effect could be a proxy for household size – larger households tend to occupy larger houses -- but this does not seem to be the case: the relationship between household size and ventilation is weaker in all regions than is the relationship between taller houses and ventilation.

We created indicator variables for the largest ethnic groups in the survey (reported in Question 83): blacks, Hispanics, Asians, and whites, and regressed ESLA on these indicator variables. In every region, no relationship between ethnicity and ESLA approached statistical significance, and r-squared values were all very close to zero. The same null result was found when we used “hours of medium or high summer ventilation” as the dependent variable, rather than ESLA.

We created indicator variables for the income categories reported in Question 82. (More than 93% of respondents indicated their income category.) These categories are: under \$35K, \$35K-\$49,999, \$50K-\$74,999, \$75K-\$99,999, \$100K-\$149,999, and \$150K or over. We used these indicator variables in a linear regression to predict summer ESLA in each region, using households in the \$100K-\$149,999 range as a baseline. Only in the Sacramento Delta area was there a statistically significant relationship between income and ESLA: the lowest-income category had an estimated coefficient of 5.0 +/- 2.5 (p=0.025), indicating that homes in the lowest income category get substantially more ventilation than homes of other income levels. However, this relationship was not observed in any of the other regions and may be a statistical artifact or accident; however, given that it is very hot in the Sacramento inland area in the summer, more than in the Southern California Coastal region or in the Rest of the State in the summer, and given that air conditioning is very expensive, it may be a real result. A linear regression including the entire state, weighted to account for sampling weights, found no significant relationship between ESLA and income, whether or not regional indicator variables were also included.

It is possible in principle that income, ethnicity, household size, and house size could have significant predictive value in combination even though they do not have significant individual effects. To check this, we tried both CART (Breiman et al., 1984) and multivariate linear regression, using all of the income, ethnicity, and home and household size indicator variables as predictive variables. No significant relationship was found, and r-squared values were negligible.

## 3.4 Determine the Barriers that Prevent or Inhibit the Use of Windows, Doors, and Mechanical Ventilation Systems.

**Reasons for Closing Windows**:

Respondents were asked about how important various reasons were for why they closed their windows in Question 27. Regional estimates are tabulated in Table 33A (for the representative statewide sample) and 33B (for the Builders' sample); uncertainties are quantified in Table 21. Variability among areas of the state is small, for most of the reasons for closing windows. Excluding wood smoke, pollen, and insects all seem to be slightly more important reasons for window-closing in the Sacramento Region than in the rest of the state.

**Table 33A: Reasons for Closing Windows: Statewide Probability Sample**

| How important is this reason to close windows (percent of houses) Sacramento Area, Southern California Coast, Rest of State, **Total** | **Very** | **Somewhat** | **Slightly** | **Not at all** | **Never close for this reason** |
|---|---|---|---|---|---|
| Nobody home | 93,84,84,**85** | 4,11,10,**9** | 2,3,3,**3** | 0,1,1,**1** | 1,1,2,**2** |
| Maintain comfortable temperature | 74,68,66,**68** | 21,24,26,**24** | 3,6,6,**5** | 1,0,2,**1** | 1,1,1,**1** |
| Reduce pollutants or odors from outdoors | 43,37,34,**36** | 21,23,19,**20** | 15,15,21,**19** | 9,14,13,**12** | 11,11,14,**12** |
| Too windy/drafty | 44,46,44,**45** | 28,26,29,**28** | 21,19,18,**19** | 3,5,5,**4** | 4,4,4,**4** |
| Keep out noise | 40,41,38,**39** | 24,25,23,**24** | 22,21,19,**20** | 7,7,10,**9** | 7,6,10,**8** |
| Keep pets in/out | 23,19,22,**22** | 6,6,10,**8** | 6,8,5,**6** | 6,4,8,**7** | 59,63,55,**57** |
| Save energy | 68,61,59,**61** | 21,21,22,**22** | 6,12,10,**9** | 2,4,3,**3** | 3,3,6,**5** |
| Keep out rain/snow | 73,68,66,**68** | 12,12,14,**13** | 7,12,11,**10** | 2,4,3,**3** | 7,4,6,**6** |
| Keep out woodsmoke | 30,21,21,**23** | 5,6,5,**6** | 8,6,7,**7** | 10,12,11,**11** | 48,55,55,**54** |
| Keep out dust | 47,37,41,**42** | 23,25,23,**24** | 16,15,16,**16** | 6,8,7,**7** | 9,15,13,**12** |
| Keep out pollen/allergens | 45,31,35,**35** | 22,18,17,**18** | 15,17,18,**17** | 5,13,11,**10** | 12,21,19,**19** |
| Keep out insects | 62,52,49,**52** | 15,20,18,**18** | 8,9,14,**12** | 5,7,7,**7** | 9,12,12,**12** |
| Privacy from neighbors | 38,26,27,**29** | 25,26,21,**23** | 16,24,22,**21** | 8,10,14,**12** | 12,15,16,**15** |
| Security/safety | 85,83,78,**80** | 8,10,14,**12** | 4,4,4,**4** | 1,1,1,**1** | 2,2,2,**2** |
| Hard to open/close | 3,2,4,**4** | 6,5,4,**5** | 7,8,6,**7** | 19,19,17,**18** | 65,66,68,**67** |

Table 33A gives the percent of houses in each region, and in the state, that say that various reasons for closing windows to have a given level of importance.

**Table 33B**: **Reasons for Closing Windows: Builders' Sample**

| How important is this reason to close windows (percent of houses) Sacramento Area, Southern California Coast, Rest of State, **Total** | **Very** | **Somewhat** | **Slightly** | **Not at all** | **Never close for this reason** |
|---|---|---|---|---|---|
| Nobody home | 92,74,86,**84** | 0,16,3,**7** | 0,0,3,**2** | 0,10,0,**3** | 8,0,7,**5** |
| Maintain comfortable temperature | 86,47,69,**66** | 14,42,21,**26** | 0,5,0,**2** | 0,5,3,**3** | 0,0,7,**3** |
| Reduce pollutants or odors from outdoors | 40,44,28,**36** | 13,22,24,**21** | 13,11,14,**13** | 7,11,7,**8** | 27,11,28,**23** |
| Too windy/drafty | 27,53,38,**40** | 27,32,38,**33** | 20,16,21,**19** | 13,0,0,**3** | 13,0,3,**5** |
| Keep out noise | 13,42,38,**33** | 27,32,34,**32** | 27,21,14,**19** | 7,5,7,**6** | 27,0,7,**10** |
| Keep pets in/out | 11,26,28,**23** | 11,16,10,**12** | 0,5,0,**2** | 0,5,10,**6** | 78,47,52,**58** |
| Save energy | 67,58,69,**65** | 20,5,17,**14** | 0,21,0,**6** | 7,10,3,**6** | 7,5,10,**8** |
| Keep out rain/snow | 53,53,66,**59** | 13,21,3,**11** | 7,21,14,**14** | 0,5,7,**5** | 27,0,10,**11** |
| Keep out woodsmoke | 20,16,28,**22** | 0,16,10,**10** | 13,5,0,**5** | 13,10,7,**10** | 53,53,55,**54** |
| Keep out dust | 29,53,52,**47** | 29,16,21,**21** | 29,21,10,**18** | 7,10,0,**5** | 7,0,17,**10** |
| Keep out pollen/allergens | 20,32,34,**30** | 33,10,28,**24** | 27,16,14,**18** | 0,26,0,**8** | 20,16,24,**21** |
| Keep out insects | 53,42,55,**51** | 27,21,21,**22** | 7,16,3,**8** | 0,5,0,**2** | 13,16,21,**18** |
| Privacy from neighbors | 21,26,21,**23** | 21,32,28,**27** | 43,21,17,**24** | 7,5,14,**10** | 7,16,21,**16** |
| Security/safety | 56,68,69,**66** | 25,16,14,**17** | 6,10,10,**9** | 6,0,0,**2** | 6,5,7,**6** |
| Hard to open/close | 0,16,0,**5** | 14,5,7,**8** | 0,5,14,8 | 21,37,18,**25** | 64,37,61,**54** |

Table 33B gives the percent of houses in the non-representative "Builders' Sample" in each region, and in the state, that say that various reasons for closing windows to have a given level of importance.

People seemed to feel stronger about their reasons for closing windows than for opening them. Safety and security concerns were very strong, as people did not want to leave windows open when they were not home and in some cases even when they were home. Protecting the conditioned environment was also a strong reason to close windows. Keeping pollutants out (dust, insects, pollen, weather) was also quite important, but keeping animals and wood-smoke out was not usually very important.

**Importance of Reasons to Open or Close Windows:**

We created indicator variables for each reason to open or close windows: for each household, the variable took the value 1 if the indicated reason was "very" or "somewhat" important, and a value of 0 otherwise. We then used stepwise regression based on the Akaike Information Criterion (Venables, W. N. and Ripley, B. D. (2002) *Modern Applied Statistics with S.* New York: Springer (4th ed)) to select the subset of predictive variables that best predicts ESLA. Stepwise regression is an automated procedure that is helpful for producing candidate models for detailed consideration. The variables that were identified by stepwise regression were: windows are opened to cool the house, windows are opened to warm the house, windows are open to air out the house during cleaning, windows are opened to remove odors, windows are opened to provide a draft for cooking appliances or fireplace, windows are opened to save energy, windows are opened to allow pet access, windows are closed because “nobody at home”, windows are closed to maintain a comfortable temperature, windows are closed if it is too windy, windows are closed to keep out noise, windows are closed to keep out rain, and windows are closed to keep out pollen.

We started with the set of variables identified by stepwise regression, and then eliminated some and included others based on statistical or engineering judgment. For instance, a variable that indicates that “removing odors” was an important reason for opening windows was identified by stepwise regression as being mildly predictive of ESLA. However, its coefficient estimate is slightly negative (indicating slightly lower ventilation in houses that open windows for this reason than in other houses) and well short of statistical significance (p-value 0.3), so we excluded this variable. Additionally, several reasons to close windows were found to be *positively* correlated with summer ESLA, whereas we might expect that if something is a reason to *close* windows, it should be associated with *lower* levels of ventilation. (A likely possibility is that if someone said that something is a reason to close windows, it means that they are likely to have had windows open in the first place.) In retrospect, it might have been better to ask why people don’t provide more ventilation than they currently do, rather than to ask separately about reasons to open windows and reasons to close them.

We searched for a set of reasons to open or close windows that made sense if interpreted causally (i.e. the signs of the coefficients were in the right direction) and whose coefficients were at or near statistical significance (i.e. p-values below 0.1) We also included regional indicator variables even though they fall short of statistical significance. The resulting model is summarized in Table 34. The table shows the coefficient estimates from a linear model to predict summer ESLA from variables that indicate if a particular factor is a very or somewhat important reason to open or close windows. The r-squared value for this model is 0.08.

**Table 34: Predicting Summer ESLA**

| | **Estimate** | **Std. Error** | **t-value** | **P-value** |
|---|---|---|---|---|
| (Intercept) | 9.5 | 1.2 | 7.8 | <0.0001 |
| Open to cool the house | 5.2 | 0.8 | 6.3 | <0.0001 |
| Open to warm the house | 1.6 | 0.7 | 2.2 | 0.03 |
| Open to save energy | 2.0 | 0.7 | 2.9 | 0.004 |
| Open to allow pet access | 2.2 | 0.9 | 2.6 | 0.01 |
| Close because nobody home | -4.3 | 1.2 | -3.5 | <0.001 |
| Close to keep out pollen | -3.1 | 0.7 | -4.5 | <0.0001 |
| Region 1 | -1.4 | 0.9 | -1.5 | 0.14 |
| Region 2 | -0.2 | 0.7 | -0.2 | 0.79 |

Table 34 shows coefficient estimates from a linear model that predicts summer ESLA from whether the occupants say that certain reasons for opening or closing windows are very or somewhat important. For instance, from the second row we see that households that say that cooling the house is an important reason to open windows have an ESLA value 5.2 units higher, on average, than houses for which cooling the house is not an important reason to open windows.

A relationship between summer ESLA and opening windows to *warm* the house seems counterintuitive. However, the questions about reasons to open and close windows are not season-specific; the people who say that they open windows to warm the house presumably mean that they do so during times of year when the interior of the house is undesirably cool while the outside air is warmer. This might include summer mornings in some areas, or might include seasons other than summer. In any case, the tendency to open windows to warm the house may be associated with a general willingness to open windows more often when appropriate, leading to a positive coefficient.

We fit the same regression as described in Table 34, but excluding the “open to warm the house” variable. The “open to cool the house” coefficient estimate increased by 0.2; none of the other coefficients changed by more than 0.1. The r-squared value and p-values were nearly unchanged.

Providing comfort (and maintaining comfortable temperatures without using energy) seem to be the most important reasons that people open windows, or at least are the best predictors (among reasons to open windows) of increased ventilation. People who close windows because nobody is home or to keep out pollen tend to have reduced ventilation.

Note that this model is *not* a time-series of analysis of the reasons that any given household opens or closes windows. Instead, it simply finds that households that said that these factors are important are likely to get higher or lower summer ventilation than are other households.

### 3.5 Variation of Ventilation Behavior Among Houses:

We fit many different linear models and tree models to attempt to explain the variability in ESLA or in the number of hours with medium or high ventilation. We included indicator variables for smokers, asthmatics, etc., as well as indicator variables for reasons for opening and closing windows. We also included interaction terms, such as an interaction between the number of hours that the house is unoccupied and an indicator for whether security is an important reason for closing windows. We also included region indicator variables, number of household members, ethnicity indicators, and hours spent cooking. Even when many variables were included, we were unable to find a model that explains more than 25% of the variability in ESLA among houses; i.e. more than 75% of the variance remained unexplained. This modeling exercise did not reveal any relationships that are not already discussed above, and coefficients found in these models are difficult to interpret because of the interactions between variables, so we do not report them here. In summary, ventilation behavior varies greatly among households, especially in seasons other than winter, and much of that variation cannot be predicted based on factors investigated by the survey instrument.

## 4. Conclusions & Recommendations

### Summary:

In setting building energy design standards, the Commission assumes a certain level of outdoor air ventilation from occupant use of windows and mechanical devices. However, because houses built within the last few years are designed to be very airtight in order to conserve energy, concerns were raised that the occupant use of windows, doors, and mechanical ventilation devices may not provide adequate ventilation with outdoor air, and may contribute to unacceptable indoor air quality.

Information was needed by the Commission on household ventilation practices of occupants. A mail survey was used to collect information on occupants' use of windows and mechanical ventilation equipment in 1515 new homes in California, and on occupant perceptions of and satisfaction with indoor air quality and ventilation conditions. The survey questionnaire was developed, pre-tested, and sent to households in all regions of California. The results were analyzed to meet the following objectives: (1) Determine how occupants used windows, doors, and mechanical ventilation; (2) Determine occupant perceptions of and satisfaction with IAQ in their homes; (3) Determine the relationship among ventilation practices, perceived IAQ, and house and household characteristics; and (4) Determine barriers that prevent or inhibit the use of windows, doors, and mechanical ventilation systems.

Information was also needed concerning some specific pollutant sources that are sometimes problematic or can contribute to indoor pollutant levels, such as new carpets, paint, cabinetry, and heating and cooking appliances. Such key information was needed by ARB for assessment of Californians' exposures to indoor and outdoor air pollutants in new homes. Under HSC Section 39660.5, ARB is required to assess Californians' exposures to toxic air contaminants.

## Conclusions:

**Objective 1:** To determine how occupants used windows, doors, and mechanical ventilation:

- Many occupants do not get substantial ventilation through window opening. Survey data suggest that windows provide much less than 0.35 ACH for most homes in winter, and less than 0.35 ACH in about half of homes in fall and spring.

- Local exhaust fans are under-utilized. Kitchen and bathroom ventilation fans tend to be used based on perception of moisture or odors, rather than being used routinely. Nearly 50% of respondents indicate that they sometimes fail to use the bathroom fan even when conditions clearly call for it, most often because they "don't think of it."

- People are not familiar enough with mechanical ventilation systems to meaningfully respond to mail survey questions about them.

**Objective 2**: To determine occupant perceptions of and satisfaction with IAQ in their homes:

- Occupants generally perceive their IAQ to be satisfactory, even though some of them report problems that might be expected to bother them.

- Few occupants report problems with mold at more than one location in their house, but those who do are almost all less than completely satisfied with the IAQ in their house.

**Objective 3**: To determine the relationship among ventilation practices, perceived IAQ, and house and household characteristics:

- There is no evidence that households with significant indoor pollutant sources (such as candles, pesticides, etc.) get more ventilation than others. The exception is cooking: households where people cook at home for many hours per week tend to get substantially more ventilation than do other households.

- There is no evidence that health issues motivate ventilation behavior, except that households containing asthmatics appear to get more ventilation than other households.

**Objective 4**: Determine barriers that prevent or inhibit the use of windows, doors, and mechanical ventilation systems.

- Security and energy saving are the two main reasons people close their windows or keep them closed.

**Recommendations**:

- Because so many of the questions were clearly misinterpreted or too difficult to answer correctly, field measurements of ventilation-related performance should be made to determine how it relates to reported behavior. Some studies are being initiated for a subset of these houses.

- A clear definition of IAQ is needed for people to have a clear sense of what variables make up air quality. Temperature may be viewed as separate from other issues such as stagnant or dusty air.

- Respondents had a very difficult time understanding the mechanical ventilation questions. A clear list of industry systems might greatly improve respondent comprehension.

- The study was not designed to focus on thermal comfort issues, but reported window behavior suggests that additional studies on warm-weather behavior should be initiated because results indicate that people are using windows for ventilative cooling.

**Benefits to California**:

This was the first large survey to obtain information on occupant ventilation practices in new California homes. The data from this study are immediately useful by the California Energy Commission to guide the development of future building energy design standards that protect indoor air quality and comfort in California homes, and by the California Air Resources Board to improve exposure assessments of indoor and outdoor air pollutants. Additionally, the data may be used to help design a future field study that will measure pollutant concentrations and other parameters in new California homes.

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## APPENDIX I: Summary of Window and Door Usage by Season and Weekend/Weekday

These tables show the percentage of homes with windows open less than the specified number of hours during the period specified. For example, from the first table (Hours during weekdays 6PM-6PM), the first row shows that 40% of homes had kitchen windows open 0 hours in summer; 49% had kitchen windows open 1 hour or less; 61% had windows open 2 hours or less; and so on. These tables summarize the raw data, excluding people who did not answer the questions (questions 10-25) about the temporal details of their ventilation behavior. Specifically, the results in these tables have not been modified to impute additional hours in order to make them less inconsistent with reported total hours of ventilation as reported in questions 28-31. All respondents indicated an integer number of hours, so percentiles can be determined from these tables without interpolation. For instance, from Table I-1 we see that 49% of houses report less than or equal to 1 hour of summer kitchen ventilation, and 61% report less than or equal to 2 hours. Therefore all of the percentiles from 49% to 61%, including the median (50%), are exactly 2 hours.

A small fraction of people (less than 2% in each case) indicated a number of hours greater than the total number of hours in the time period in question. We did not exclude those respondents. If those respondents intended to indicate that the window is open for the entire time period, then changing the final entry in each column to 100% will correctly handle the problem. For instance, in the second table (Weekday evenings 6PM-11PM), about 1% of respondents indicated (impossibly) that they leave their kitchen windows open for *more* than 5 hours during this time period in summer; if these people leave their windows open for the full 5 hours during that time slot, then changing the last entry in that row to 100 (from 99) will give the correct result.

**Table I-1: Percent Of Homes With Windows Open Less Than Or Equal To A Given Number Of Hours On Weekday Days, By Season And Room:**

| Percent of Homes with windows open less than (or equal to) the given number of hours | Room | Hours During Weekday Days (6AM-6PM) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Summer | Kitchen | 40 | 49 | 61 | 68 | 73 | 77 | 83 | 84 | 88 | 89 | 92 | 92 | 100 |
| | Bedrooms | 40 | 47 | 58 | 64 | 70 | 73 | 78 | 79 | 83 | 84 | 86 | 87 | 100 |
| | Bath/laundry/ utility | 56 | 61 | 68 | 70 | 73 | 75 | 78 | 79 | 81 | 81 | 83 | 83 | 100 |
| | Other | 58 | 64 | 72 | 77 | 82 | 84 | 87 | 88 | 91 | 91 | 93 | 93 | 100 |
| Fall | Kitchen | 39 | 50 | 63 | 71 | 78 | 82 | 87 | 88 | 92 | 92 | 94 | 95 | 100 |
| | Bedrooms | 42 | 51 | 64 | 69 | 75 | 79 | 83 | 84 | 88 | 88 | 91 | 91 | 100 |
| | Bath/laundry/ utility | 58 | 65 | 71 | 74 | 78 | 80 | 82 | 83 | 86 | 87 | 88 | 88 | 100 |
| | Other | 61 | 69 | 78 | 81 | 85 | 88 | 91 | 92 | 94 | 94 | 95 | 95 | 100 |
| Winter | Kitchen | 52 | 71 | 85 | 90 | 93 | 95 | 96 | 97 | 98 | 98 | 99 | 100 | 100 |
| | Bedrooms | 57 | 73 | 85 | 89 | 92 | 93 | 95 | 95 | 96 | 97 | 97 | 100 | 100 |
| | Bath/laundry/ utility | 64 | 75 | 82 | 85 | 88 | 89 | 90 | 90 | 92 | 92 | 93 | 93 | 100 |
| | Other | 75 | 85 | 93 | 94 | 96 | 97 | 98 | 99 | 99 | 100 | 100 | 100 | 100 |
| Spring | Kitchen | 37 | 45 | 60 | 69 | 76 | 80 | 86 | 87 | 92 | 92 | 94 | 95 | 100 |
| | Bedrooms | 38 | 46 | 60 | 68 | 75 | 78 | 84 | 85 | 88 | 89 | 91 | 91 | 100 |
| | Bath/laundry/ utility | 58 | 64 | 71 | 74 | 78 | 80 | 82 | 83 | 87 | 87 | 88 | 88 | 100 |
| | Other | 59 | 66 | 75 | 80 | 85 | 87 | 91 | 91 | 94 | 94 | 95 | 95 | 100 |

**Table I-2: Percent Of Homes With Windows Open Less Than Or Equal To A Given Number Of Hours On Weekday Days, By Season And Room:**

| Percent of Homes with windows open less than (or equal to) the given number of hours | Room | Hours During Weekday Evenings (6PM-11PM) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 |
| Summer | Kitchen | 36 | 44 | 65 | 77 | 87 | 99 |
| | Bedrooms | 30 | 37 | 53 | 64 | 73 | 98 |
| | Bath/laundry/util | 57 | 62 | 70 | 74 | 78 | 99 |
| | Other | 53 | 59 | 72 | 82 | 88 | 99 |
| Fall | Kitchen | 42 | 57 | 74 | 85 | 91 | 100 |
| | Bedrooms | 41 | 52 | 68 | 79 | 84 | 99 |
| | Bath/laundry/util | 63 | 70 | 79 | 82 | 85 | 99 |
| | Other | 62 | 71 | 82 | 89 | 92 | 99 |
| Winter | Kitchen | 69 | 86 | 95 | 97 | 98 | 100 |
| | Bedrooms | 70 | 84 | 91 | 94 | 95 | 100 |
| | Bath/laundry/util | 74 | 84 | 89 | 91 | 92 | 100 |
| | Other | 83 | 92 | 97 | 98 | 98 | 100 |
| Spring | Kitchen | 39 | 53 | 73 | 84 | 90 | 99 |
| | Bedrooms | 37 | 49 | 66 | 78 | 84 | 99 |
| | Bath/laundry/util | 62 | 69 | 78 | 82 | 85 | 99 |
| | Other | 62 | 70 | 80 | 88 | 92 | 99 |

***Table I-3: Percent of homes with windows open less than or equal to a given number of hours on weekday evenings, by season and room.***

| Percent of Homes with windows open less than (or equal to) the given number of hours | Room | **Hours During Weekday Nights (11PM-6AM)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Summer | Kitchen | 83 | 85 | 87 | 87 | 88 | 89 | 91 | 100 |
| | Bedrooms | 49 | 52 | 55 | 57 | 60 | 63 | 67 | 98 |
| | Bath/laundry/util | 68 | 70 | 72 | 73 | 74 | 76 | 78 | 99 |
| | Other | 80 | 83 | 86 | 88 | 89 | 90 | 91 | 100 |
| Fall | Kitchen | 87 | 90 | 92 | 93 | 94 | 95 | 96 | 100 |
| | Bedrooms | 66 | 70 | 74 | 77 | 79 | 81 | 84 | 99 |
| | Bath/laundry/util | 78 | 81 | 83 | 84 | 85 | 87 | 88 | 99 |
| | Other | 86 | 88 | 91 | 92 | 93 | 94 | 95 | 100 |
| Winter | Kitchen | 95 | 96 | 98 | 98 | 99 | 99 | 99 | 100 |
| | Bedrooms | 86 | 90 | 92 | 92 | 93 | 94 | 94 | 100 |
| | Bath/laundry/util | 86 | 90 | 92 | 92 | 92 | 93 | 93 | 100 |
| | Other | 94 | 97 | 98 | 98 | 99 | 99 | 99 | 100 |
| Spring | Kitchen | 86 | 90 | 92 | 93 | 94 | 95 | 96 | 100 |
| | Bedrooms | 66 | 71 | 75 | 77 | 80 | 82 | 84 | 100 |
| | Bath/laundry/util | 77 | 80 | 83 | 84 | 85 | 87 | 88 | 100 |
| | Other | 86 | 89 | 91 | 92 | 93 | 94 | 95 | 100 |

***Table I-4: Percent of homes with windows open less than or equal to a given number of hours on weekend days, by season and room.***

| Percent of Homes with windows open less than (or equal to) the given number of hours | Room | **Hours During Weekend Days (6AM-6PM)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Summer | Kitchen | 30 | 35 | 46 | 54 | 63 | 67 | 76 | 77 | 85 | 86 | 90 | 90 | 100 |
| | Bedrooms | 30 | 35 | 47 | 54 | 61 | 64 | 71 | 72 | 79 | 80 | 83 | 100 | 100 |
| | Bath/laundry/util | 51 | 56 | 63 | 65 | 70 | 72 | 75 | 76 | 79 | 79 | 82 | 82 | 100 |
| | Other | 50 | 56 | 65 | 69 | 76 | 79 | 83 | 84 | 89 | 89 | 92 | 92 | 100 |
| Fall | Kitchen | 28 | 37 | 49 | 58 | 68 | 74 | 82 | 83 | 89 | 90 | 93 | 94 | 100 |
| | Bedrooms | 33 | 41 | 53 | 61 | 69 | 74 | 79 | 80 | 85 | 86 | 89 | 89 | 100 |
| | Bath/laundry/util | 53 | 61 | 67 | 70 | 75 | 78 | 80 | 81 | 85 | 85 | 87 | 87 | 100 |
| | Other | 54 | 60 | 69 | 75 | 80 | 83 | 88 | 88 | 92 | 92 | 94 | 94 | 100 |
| Winter | Kitchen | 37 | 56 | 77 | 84 | 91 | 92 | 94 | 95 | 97 | 98 | 98 | 98 | 100 |
| | Bedrooms | 46 | 64 | 78 | 84 | 90 | 91 | 94 | 94 | 96 | 96 | 96 | 97 | 100 |
| | Bath/laundry/util | 58 | 71 | 79 | 83 | 86 | 88 | 89 | 90 | 92 | 92 | 93 | 94 | 100 |
| | Other | 67 | 79 | 89 | 92 | 94 | 96 | 97 | 98 | 98 | 99 | 99 | 99 | 100 |
| Spring | Kitchen | 26 | 33 | 47 | 56 | 67 | 72 | 80 | 82 | 88 | 89 | 93 | 93 | 100 |
| | Bedrooms | 29 | 37 | 49 | 58 | 66 | 72 | 79 | 80 | 85 | 86 | 89 | 89 | 100 |
| | Bath/laundry/util | 52 | 59 | 66 | 70 | 75 | 78 | 80 | 81 | 85 | 85 | 87 | 87 | 100 |
| | Other | 51 | 58 | 68 | 73 | 80 | 82 | 88 | 88 | 92 | 93 | 94 | 94 | 100 |

**Table I-5: Percent of homes with windows open less than or equal to a given number of hours on weekend evenings, by season and room.**

| Percent of Homes with windows open less than (or equal to) the given number of hours | Room | **Hours During Weekend Evenings (6PM-11PM)** | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 |
| Summer | Kitchen | 34 | 42 | 60 | 73 | 83 | 99 |
| | Bedrooms | 29 | 35 | 50 | 62 | 71 | 97 |
| | Bath/laundry/util | 56 | 61 | 69 | 73 | 77 | 98 |
| | Other | 52 | 58 | 71 | 80 | 87 | 99 |
| Fall | Kitchen | 41 | 54 | 72 | 83 | 90 | 99 |
| | Bedrooms | 40 | 51 | 66 | 77 | 83 | 99 |
| | Bath/laundry/util | 63 | 70 | 78 | 82 | 85 | 99 |
| | Other | 61 | 70 | 80 | 88 | 91 | 99 |
| Winter | Kitchen | 68 | 84 | 94 | 96 | 98 | 100 |
| | Bedrooms | 69 | 81 | 90 | 94 | 95 | 100 |
| | Bath/laundry/util | 75 | 83 | 88 | 91 | 92 | 100 |
| | Other | 82 | 91 | 96 | 97 | 98 | 100 |
| Spring | Kitchen | 39 | 51 | 70 | 82 | 90 | 99 |
| | Bedrooms | 36 | 46 | 64 | 75 | 83 | 98 |
| | Bath/laundry/util | 62 | 68 | 76 | 80 | 84 | 99 |
| | Other | 60 | 69 | 79 | 86 | 91 | 99 |

***Table I-6: Percent of homes with windows open less than or equal to a given number of hours on weekend nights, by season and room.***

| Percent of Homes with windows open less than (or equal to) the given number of hours | Room | **Hours During Weekend Nights (11PM-6AM)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Summer | Kitchen | 81 | 84 | 86 | 87 | 88 | 89 | 91 | 100 |
| | Bedrooms | 48 | 51 | 55 | 57 | 59 | 63 | 67 | 98 |
| | Bath/laundry/util | 68 | 70 | 72 | 73 | 74 | 76 | 78 | 99 |
| | Other | 80 | 82 | 85 | 87 | 88 | 89 | 90 | 99 |
| Fall | Kitchen | 86 | 89 | 92 | 93 | 94 | 95 | 96 | 100 |
| | Bedrooms | 66 | 70 | 73 | 76 | 79 | 81 | 83 | 99 |
| | Bath/laundry/util | 79 | 81 | 83 | 84 | 85 | 86 | 87 | 100 |
| | Other | 86 | 88 | 90 | 91 | 93 | 94 | 94 | 100 |
| Winter | Kitchen | 94 | 96 | 98 | 98 | 98 | 99 | 99 | 100 |
| | Bedrooms | 85 | 89 | 91 | 92 | 93 | 93 | 94 | 99 |
| | Bath/laundry/util | 88 | 91 | 92 | 92 | 92 | 93 | 94 | 100 |
| | Other | 94 | 97 | 98 | 98 | 98 | 99 | 99 | 100 |
| Spring | Kitchen | 86 | 89 | 91 | 93 | 93 | 94 | 95 | 100 |
| | Bedrooms | 66 | 70 | 74 | 76 | 79 | 81 | 84 | 99 |
| | Bath/laundry/util | 77 | 80 | 82 | 83 | 84 | 86 | 87 | 100 |
| | Other | 86 | 88 | 91 | 91 | 92 | 93 | 94 | 100 |

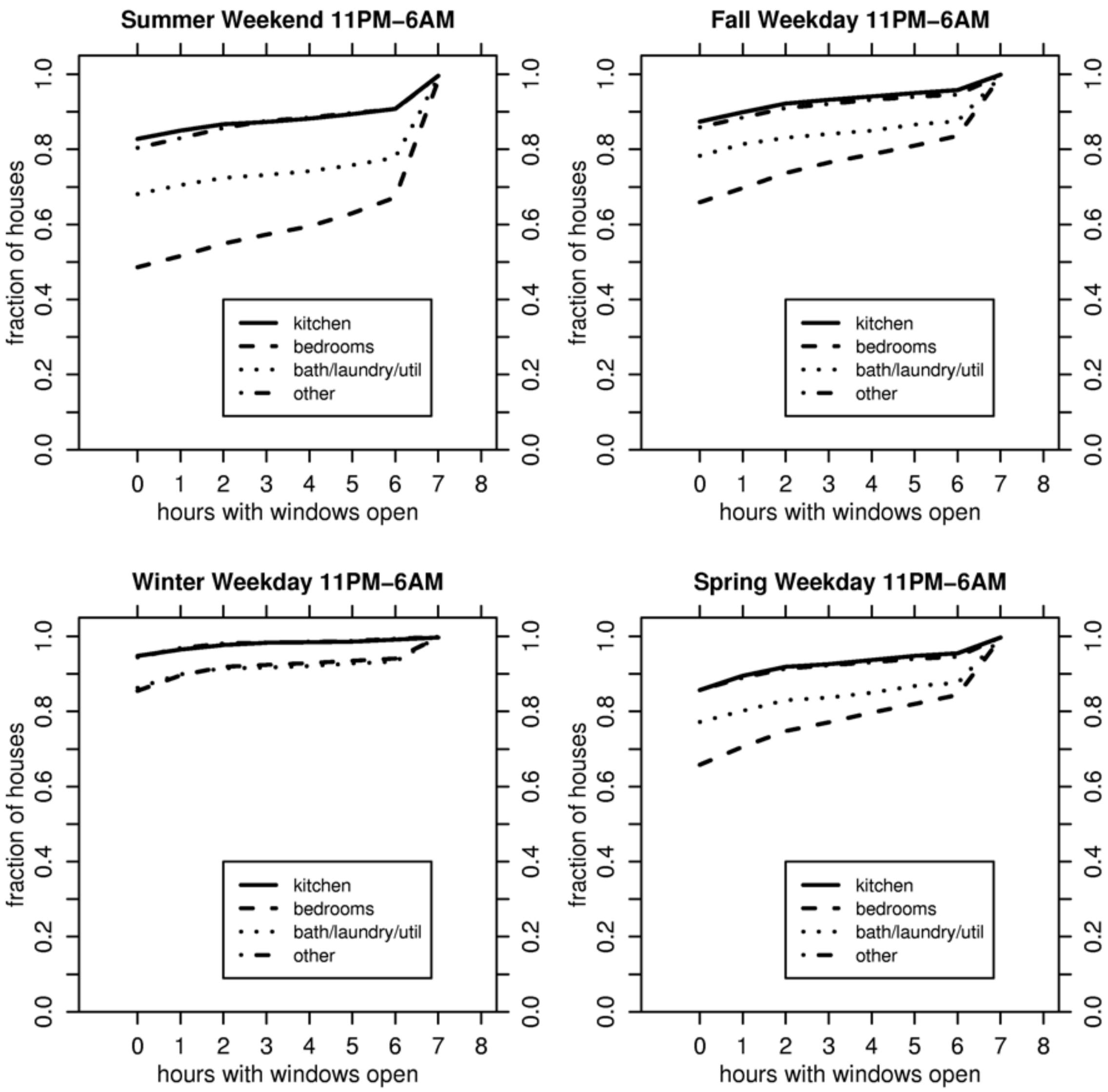



**Figure I-1:** Cumulative distribution functions for the number of hours windows are open in various rooms, on weekdays from 11PM-6AM. For a given number of hours on the x axis, the curves show the fraction of homes in which windows are open for a number of hours less than or equal to that number of hours.

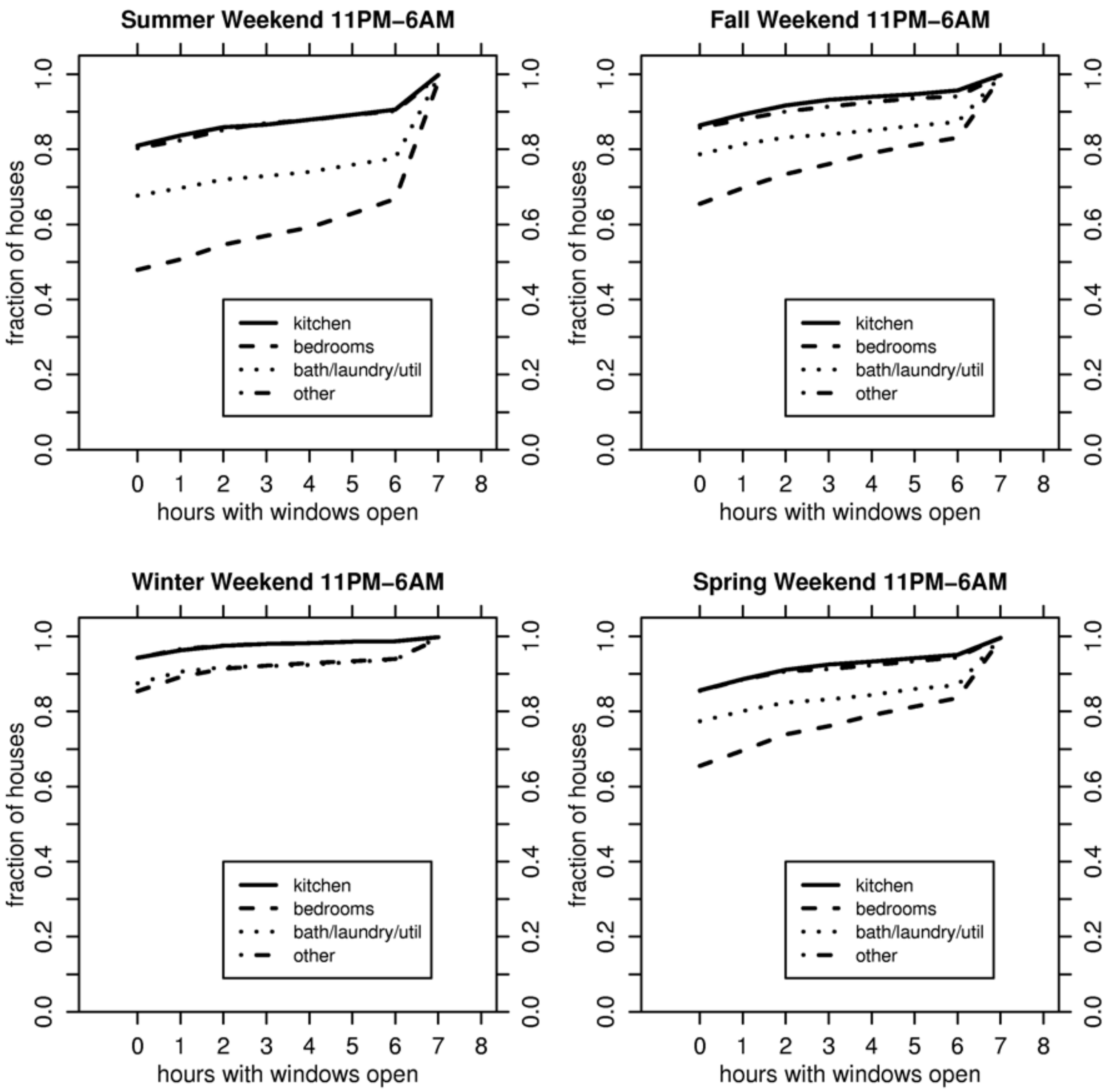



**Figure I-2:** Cumulative distribution functions for the number of hours windows are open in various rooms, on weekends from 11PM-6AM. For a given number of hours on the x axis, the curves show the fraction of homes in which windows are open for a number of hours less than or equal to that number of hours.

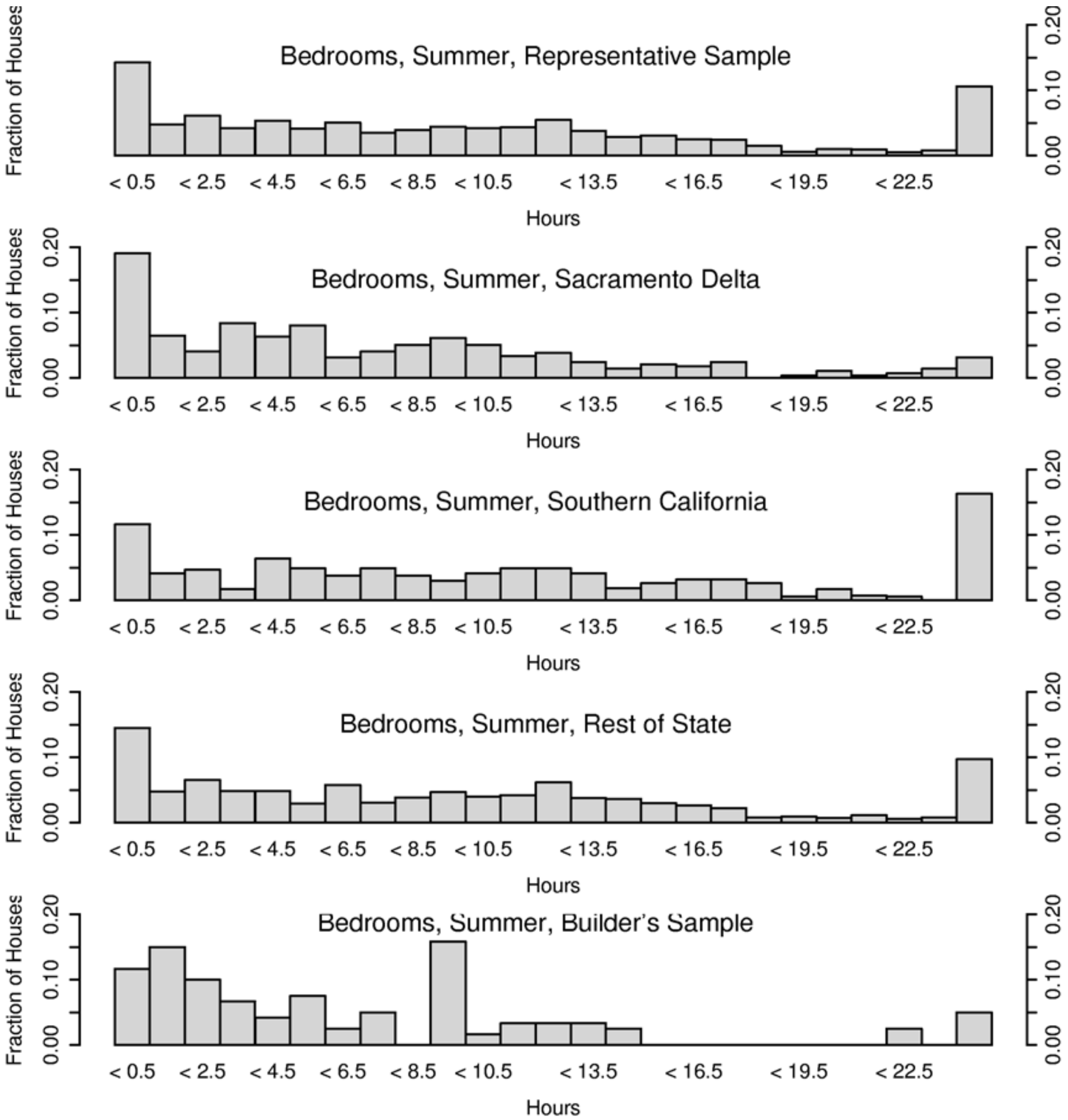



**Figure I-3:** Histogram showing fraction of homes that report specific hours of window opening in summer, for each survey stratum.

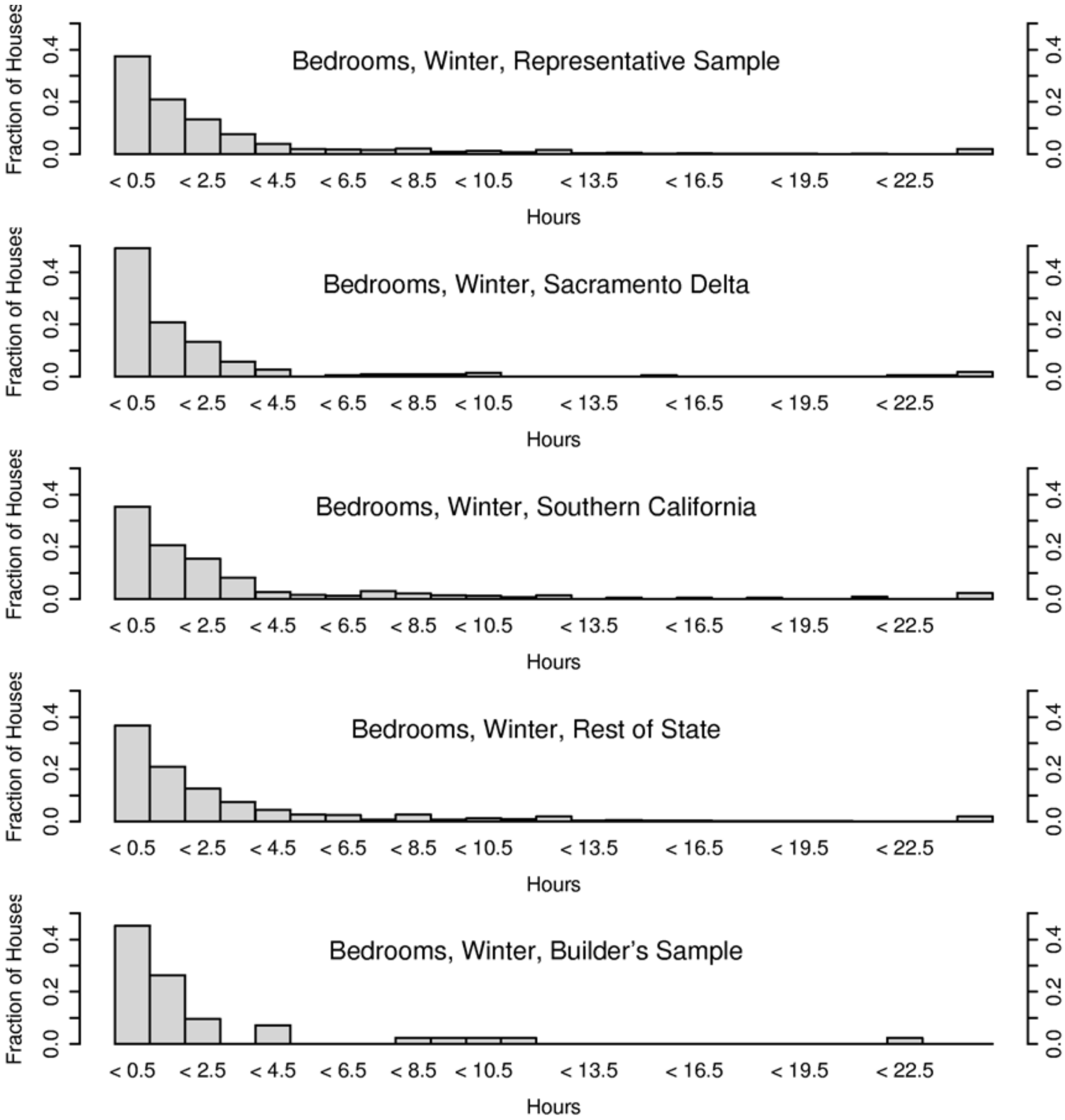



**Figure I-4:** Histogram showing fraction of homes that report specific hours of window opening in winter, for each survey stratum.

From the time-specific data on periods of time with windows open in various rooms, it is possible to determine the minimum and maximum possible number of hours in each time slot during which windows are open. For instance, if someone reports that on average a bedroom window is open for 3 hours on a weekday evening, and that a bathroom window is open for 2 hours, this could represent as little 3 hours during which at least one window is open (if both windows are open at the same time) or as many as 5 hours (if the windows are open at different times). Table I-7A through I-7D summarize the minimum possible numbers of hours with windows open, by time slot and season, for each sampling region. Tables 1-8A through I-8D summarize the maximum possible number of hours with windows open, by time slot and season, for each sampling region. These tables do not have direct bearing on estimating ventilation effectiveness because they do not include the amount by which the windows are open: windows open a crack are counted the same as windows open wide. See the discussion of Effective Specific Leakage Area, or ESLA, in the body of the report, for an investigation of ventilation effectiveness.

***Table I-7A: Statistical distribution of the minimum possible number of hours with at least one window open in Summer, by region and weekend/weekday.***

| Hours with at least one window open, in Fall | | Percent of Houses | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 5% | 10% | 25% | 50% | 75% | 90% | 95% |
| Sacramento Delta Area | Weekend | 0 | 0 | 3 | 9 | 13 | 20 | 24 |
| | Weekday | 0 | 0 | 4 | 10 | 15 | 21 | 24 |
| | | | | | | | | |
| Southern California Coast | Weekend | 1 | 3 | 7 | 13 | 24 | 24 | 24 |
| | Weekday | 1 | 3 | 8 | 14 | 24 | 24 | 24 |
| | | | | | | | | |
| Rest of State | Weekend | 0 | 1 | 4 | 11 | 16 | 24 | 24 |
| | Weekday | 0 | 1 | 6 | 12 | 18 | 24 | 24 |

***Table I-7B: Statistical distribution of the minimum possible number of hours with at least one window open in Fall, by region and weekend/weekday.***

| Hours with at least one window open, in Fall | | Percent of Houses | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 5% | 10% | 25% | 50% | 75% | 90% | 95% |
| Sacramento Delta Area | Weekend | 0 | 0 | 1 | 5 | 11 | 18 | 24 |
| | Weekday | 0 | 0 | 2 | 6 | 12 | 19 | 24 |
| | | | | | | | | |
| Southern California Coast | Weekend | 0 | 1 | 4 | 9 | 16 | 24 | 24 |
| | Weekday | 0 | 1 | 6 | 10 | 19 | 24 | 24 |
| | | | | | | | | |
| Rest of State | Weekend | 0 | 0 | 2 | 6 | 13 | 24 | 24 |
| | Weekday | 0 | 0 | 3 | 8 | 14 | 24 | 24 |

***Table I-7C: Statistical distribution of the minimum possible number of hours with at least one window open in Winter, by region and weekend/weekday.***

| Hours with at least one window open, in Fall | | Percent of Houses | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 5% | 10% | 25% | 50% | 75% | 90% | 95% |
| Sacramento Delta Area | Weekend | 0 | 0 | 0 | 0 | 2 | 8 | 12 |
| | Weekday | 0 | 0 | 0 | 0 | 3 | 8 | 13 |
| | | | | | | | | |
| Southern California Coast | Weekend | 0 | 0 | 0 | 2 | 6 | 18 | 24 |
| | Weekday | 0 | 0 | 0 | 2 | 7 | 18 | 24 |
| | | | | | | | | |
| Rest of State | Weekend | 0 | 0 | 0 | 2 | 5 | 12 | 17 |
| | Weekday | 0 | 0 | 0 | 2 | 6 | 12 | 18 |

**Table I-7D: Statistical distribution of the minimum possible number of hours with at least one window open in Spring, by region and weekend/weekday.**

| Hours with at least one window open, in Fall | | Percent of Houses | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 5% | 10% | 25% | 50% | 75% | 90% | 95% |
| Sacramento Delta Area | Weekend | 0 | 0 | 2 | 7 | 12 | 18 | 24 |
| | Weekday | 0 | 0 | 3 | 7 | 13 | 20 | 24 |
| | | | | | | | | |
| Southern California Coast | Weekend | 0 | 1 | 4 | 10 | 18 | 24 | 24 |
| | Weekday | 0 | 2 | 6 | 11 | 20 | 24 | 24 |
| | | | | | | | | |
| Rest of State | Weekend | 0 | 0 | 3 | 8 | 15 | 24 | 24 |
| | Weekday | 0 | 1 | 4 | 9 | 16 | 24 | 24 |

***Table I-8A: Statistical distribution of the maximum possible number of hours with at least one window open in Summer, by region and weekend/weekday.***

| Hours with at least one window open, in Fall | | Percent of Houses | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 5% | 10% | 25% | 50% | 75% | 90% | 95% |
| Sacramento Delta Area | Weekend | 0 | 0 | 5 | 12 | 20 | 24 | 24 |
| | Weekday | 0 | 0 | 7 | 16 | 22 | 24 | 24 |
| | | | | | | | | |
| Southern California Coast | Weekend | 1 | 5 | 12 | 17 | 24 | 24 | 24 |
| | Weekday | 2 | 5 | 13 | 20 | 24 | 24 | 24 |
| | | | | | | | | |
| Rest of State | Weekend | 0 | 1 | 8 | 16 | 24 | 24 | 24 |
| | Weekday | 0 | 2 | 10 | 17 | 24 | 24 | 24 |

**Table I-8B: Statistical distribution of the maximum possible number of hours with at least one window open in Fall, by region and weekend/weekday.**

| Hours with at least one window open, in Fall | | Percent of Houses | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 5% | 10% | 25% | 50% | 75% | 90% | 95% |
| Sacramento Delta Area | Weekend | 0 | 0 | 2 | 9 | 17 | 24 | 24 |
| | Weekday | 0 | 0 | 3 | 11 | 18 | 24 | 24 |
| | | | | | | | | |
| Southern California Coast | Weekend | 0 | 1 | 8 | 14 | 23 | 24 | 24 |
| | Weekday | 0 | 2 | 11 | 17 | 24 | 24 | 24 |
| | | | | | | | | |
| Rest of State | Weekend | 0 | 0 | 5 | 12 | 20 | 24 | 24 |
| | Weekday | 0 | 0 | 6 | 14 | 22 | 24 | 24 |

***Table I-8C: Statistical distribution of the maximum possible number of hours with at least one window open in Winter, by region and weekend/weekday.***

| Hours with at least one window open, in Winter | | Percent of Houses | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 5% | 10% | 25% | 50% | 75% | 90% | 95% |
| Sacramento Delta Area | Weekend | 0 | 0 | 0 | 0 | 4 | 12 | 19 |
| | Weekday | 0 | 0 | 0 | 0 | 6 | 14 | 19 |
| | | | | | | | | |
| Southern California Coast | Weekend | 0 | 0 | 0 | 4 | 12 | 24 | 24 |
| | Weekday | 0 | 0 | 0 | 5 | 12 | 24 | 24 |
| | | | | | | | | |
| Rest of State | Weekend | 0 | 0 | 0 | 3 | 9 | 17 | 24 |
| | Weekday | 0 | 0 | 0 | 4 | 11 | 18 | 24 |

**Table I-8D: Statistical distribution of the maximum possible number of hours with at least one window open in Spring, by region and weekend/weekday.**

| Hours with at least one window open, in Fall | | Percent of Houses | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 5% | 10% | 25% | 50% | 75% | 90% | 95% |
| Sacramento Delta Area | Weekend | 0 | 0 | 4 | 12 | 18 | 24 | 24 |
| | Weekday | 0 | 0 | 6 | 13 | 20 | 24 | 24 |
| | | | | | | | | |
| Southern California Coast | Weekend | 0 | 2 | 9 | 16 | 24 | 24 | 24 |
| | Weekday | 0 | 3 | 11 | 17 | 24 | 24 | 24 |
| | | | | | | | | |
| Rest of State | Weekend | 0 | 0 | 6 | 13 | 23 | 24 | 24 |
| | Weekday | 0 | 1 | 8 | 16 | 24 | 24 | 24 |

## APPENDIX II: EFFECTIVE SPECIFIC LEAKAGE AREA

The purpose of this appendix is to calculate the effective specific leakage area (ESLA) resulting from window opening behavior. The ESLA will serve as a derived parameter that can be compared to envelope air leakage and the used to estimate a contribution towards meeting minimum ventilation requirements

Specific Leakage Area (SLA) is related to Effective Leakage Area (ELA) as follows:

$$SLA \equiv 10,000 \cdot \frac{ELA}{FloorArea}$$

Where the ELA and floor area are measured in the same units. (NOTE: The 10,000 above is part of the definition and is dimensionless,; it will not change. The numbers in the equation below have units and also may change as we work the problem.)

For our purposes the equation becomes as follows with floor area coming from Question 4 (i.e in sq. ft).

$$SLA_{season} = \frac{1}{24}\left(\frac{2000 \cdot LOW_{season} + 10,000 \cdot MED_{season}}{FloorArea \big/ \sqrt{n_{x1}}} + 40 \cdot HIGH_{season}\right)$$

Where *LOW*, *MED*, and *HIGH* are the numbers of hours entered in questions 28-31; and where $n_{x1}$ =1 plus
If Q32=1 add 1 to $n_{x1}$; if Q32=2 add .5; if Q32=3 add 0.1
If Q33=1 add 1 to $n_{x1}$; if Q33=2 add .5; if Q33=3 add 0.1
The coefficients in the above equation are our best estimates of what people mean when they respond to the LOW, MED, HIGH queries of Q28-31. Specifically,

- LOW: We assume 1-2 windows of 2'-4' width open 1 inch with a discharge coefficient of 0.3-0.6. This leads to a range of possible values, but we choose 0.2 sq. ft. of ELA as being a representative number
- MED: We assume 1-2 windows open 4-12 inches with a discharge coefficient of 0.4-0.6. We choose a representative value of 1 sq. ft. which is also equivalent to five times LOW
- HIGH[1]: In this case we are assuming that the number of windows open will scale with the size of the house. A house typically has between 5-15% openable area (as a function of floor area). Here we assume that almost all of it is open at 1-5% of maximum with a discharge coefficient of 0.5-0.6. We choose an SLA of

[1] This level is "high" from the point of view of indoor air quality purposes, but it is not high from the point of view of ventilative cooling purposes. A common assumption is that one needs 5-10 ACH for ventilative cooling which would require a 3-5 times larger window opening than is required to meet our high level for IAQ. Thus the number of "high" hours is biased high if one wished to interpret them for ventilative cooling.

40 as the representative value in this range. (For a cross-ventilated 1700 sq. ft. house HIGH is roughly 4 times MED, but can go higher.)

It may be interesting to see this variable on its own, but it must be convolved with the Q10-25 to find out how much it really matters.

First we need to find the total number of average Number-of-Open-Windows -in-a-season. We will generate this from the raw data starting from questions 10-25. We convert that data in those tables into hours-Windows-are-Open-by-Room-Season-and-Time, or *WORST* for short:

$$NOW_{season} = \frac{1}{24} \sum_{room,time} \left[ \frac{5}{7} \cdot WORST_{season,room,time,\mathrm{WEEKDAY}} + \frac{2}{7} \cdot WORST_{season,room,time,\mathrm{WEEKEND}} \right]$$

Which means that the average window opening has an SLA (i.e. a Specific SLA) of

$$SSLA_{season} = \frac{SLA_{season}}{NOW_{season}}$$

Which tells us how much each person opens their average window(s).

## Temporal Ventilation Effectiveness

Before we can compare this to a steady SLA such as envelope leakage we need to estimate the efficiency of the reported window opening pattern. There are some intermediate calculations to get us there.

$$X1_{season,room,time,dayofweek} = \left(1 - \frac{WORST_{season,room,time,dayofweek}}{HOP_{time}}\right)^{n_{x1}}$$

(which is the effective fraction of time each room does not supply ventilation)
Where $HOP_{time}$ is the number-of-Hours-Open-Possible for each time slot (i.e. 5, 7, or 12)

$$X2_{season,time,dayofweek} = X1_{season,\mathrm{ALLOTHER},time,dayofweek} \cdot X1_{season,\mathrm{BEDROOM},time,dayofweek} \cdot \frac{(X1_{season,\mathrm{BATHROOM},time,dayofweek} + X1_{season,\mathrm{KITCHEN},time,dayofweek})}{2}$$

(which is the effective fraction of time the house is not ventilated)

So the efficiency in each time period becomes the following:

$$ESP_{season,time,dayofweek} = (1 - X2^2_{season,time,dayofweek})^{\frac{HOP_{time}}{6}}$$

We then average the efficiency over each time slot to take into account the seasonal temporal ventilation efficiency:

$$ESP_{season} = \sum_{time} \left( \frac{5}{168} HOP_{time} \cdot ESP_{season,time,WEEDAY} + \frac{2}{168} HOP_{time} \cdot ESP_{season,time,WEEKEND} \right)$$

**ESLA**
We can now define the Effective SLA f for each season

$$ESLA_{season} = SSLA_{season} \cdot ESP_{season} \cdot \sum_{room,time} \left( \frac{5}{7} WORST_{season,room,time,WEEKDAY} + \frac{2}{7} WORST_{season,room,time,WEEKEND} \right)$$

The Fractional-Standard-Deviation is

$$FSD_{season} = \frac{1}{ESLA_{season}} \cdot \sqrt{\sum_{time} \frac{1}{24} \begin{bmatrix} \frac{5}{7} \cdot \left( ESLA_{season,time,\mathrm{WEEKDAY}} - ESLA_{season} \right)^2 + \\ \frac{2}{7} \cdot \left( ESLA_{season,time,\mathrm{WEEKEND}} - ESLA_{season} \right)^2 \end{bmatrix}}$$

The ESLA for windows (combined with infiltration) needs to be compared to that necessary to meet ventilation standards such as that below:

| Minimum ESLA necessary to meet 0.35 ACH | | | | |
|---|---|---|---|---|
| | Spring | Summer | Fall | Winter |
| CZ1 | 3.99 | 4.84 | 4.83 | 4.05 |
| CZ2 | 5.23 | 5.83 | 5.72 | 4.55 |
| CZ3 | 3.85 | 4.23 | 4.69 | 3.95 |
| CZ4 | 4.74 | 5.57 | 5.37 | 4.30 |
| CZ5 | 4.30 | 4.81 | 4.91 | 4.51 |
| CZ6 | 4.42 | 5.44 | 5.39 | 4.64 |
| CZ7 | 4.60 | 5.39 | 5.49 | 4.68 |
| CZ8 | 5.40 | 6.47 | 6.19 | 5.09 |
| CZ9 | 5.42 | 5.63 | 5.87 | 5.16 |
| CZ10 | 5.41 | 7.15 | 6.47 | 5.29 |
| CZ11 | 4.47 | 4.98 | 4.54 | 3.50 |
| CZ12 | 4.47 | 4.61 | 4.95 | 3.80 |
| CZ13 | 4.86 | 5.75 | 5.56 | 4.26 |
| CZ14 | 4.68 | 5.36 | 5.15 | 4.20 |
| CZ15 | 5.14 | 4.61 | 5.89 | 5.07 |
| CZ16 | 3.87 | 5.36 | 4.01 | 3.34 |

# CALIFORNIA VENTILATION PRACTICES AND Indoor Air Quality Study

# QUESTIONNAIRE

**Here's how to fill out the Survey:**

- Please try to answer each question.
- Most questions can be answered by checking a box or writing a number or a few words on a line.
- Never check more than one box, except when it says **Check all that apply.**
- Sometimes we ask you to skip one or more questions. An arrow will tell you what question to answer next, like this:

  1 ○ YES

  2 ○ NO ⟶ **GO TO Q42**

- If none of the boxes is just right for you, please check the one that fits you the best. Feel free to add a note of explanation.
- If you need help with the survey, call Jackie Hayes collect at 0-510-643-2226.
- Consult with other household members as needed to answer the questions.

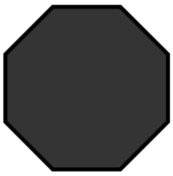
After you complete the survey, please mail it back to us in the enclosed envelope. No stamps are needed. Thank you for your prompt help.

Is the house at this address a **detached** single family house built in 2002 or 2003? By "detached" we mean no shared walls with another house.

○ Yes ○ No

B Have you lived in this home since at least JANUARY 2004?

○ Yes ○ No



- IF YOU ANSWERED "NO" TO QUESTION A OR B ABOVE, DO NOT COMPLETE THE REST OF THE SURVEY. INSTEAD, JUST RETURN THIS SURVEY AND KEEP THE ENCLOSED PEN AS OUR GIFT FOR YOU.

- IF YOU ANSWERED "YES" TO QUESTIONS A AND B ABOVE, PLEASE CONTINUE WITH THE REST OF THE SURVEY QUESTIONS. WHEN YOU MAIL BACK YOUR COMPLETED QUESTIONNAIRE, WE WILL SEND YOU $30.

**1.** What is today's date?

_______ _______ _______
Month Day Year

## GENERAL HOUSE CHARACTERISTICS

**2.** Are you or any other adult in your household the owner of this home?

1○ Yes 2○ No

**3.** When did you move into this house?

_______ _______
Month Year

**4.** How large is your house, rounded to the nearest 100 square feet?

#__________ square feet

**5.** How many stories are at or above ground?

[1] ○ 1

[2] ○ 1.5

[3] ○ 2

[4] ○ 2.5

[5] ○ 3 or more

**6.** Would you describe the foundation of the house as **primarily** being a …

[1] ○ concrete slab-on-grade (first floor rests on a concrete slab),

[2] ○ crawlspace, or

[3] ○ basement, or

[4] ○ Other (DESCRIBE: For example, combinations of the types above)?

______________________________________

**7.** How many bedrooms are in your house?

#__________ bedrooms

**8.** How many bathrooms including half-baths?
(For example: 2.5)

#__________ bathrooms

**9.** A. Was your home built under a special energy efficiency program offered by the utility company or builder?

[1] ○ Yes

[2] ○ No → **GO TO Q10, PAGE 2**

[3] ○ Don't know → **GO TO Q10, PAGE 2**

B. **IF YES:** Which program was that?

[1] ○ Energy Star

[2] ○ Building America

[3] ○ Health House

4 ○ Comfortwise

5 ○ SMUD Advantage Home

6 ○ SoCalGas Energy Advantage Home

7 ○ Other (SPECIFY: ____________________)

## WINDOWS

The next series of questions will ask you about how long you ventilate your house with outdoor air across the year as home heating and cooling needs change. For the purposes of this survey, we need to define seasons by their general weather patterns, rather than by months. Please use the following definitions of seasons, relative to your region:

- **Summer:** when heating is not needed, but air conditioning may be needed
- **Fall:** when little heating or cooling is needed
- **Winter:** when cooling is not needed, but substantial heating is needed
- **Spring:** when little heating or cooling is needed

For each question in this section, enter the **average number of hours per period per day** that any window, door, or skylight is open more than one inch, for the time frames indicated. If there are no windows, doors, or skylights in that room or they are never opened, enter zero.

In **summer**, what is the **average number of hours per period per day** that any windows, doors, or skylights are open more than 1 inch in the following rooms?

| | WEEKDAYS | | | WEEKENDS | | |
|---|---|---|---|---|---|---|
| | Daytime 6 AM to 6 PM **(up to 12 hours)** | Evening 6 PM to 11 PM **(up to 5 hours)** | Nighttime 11 PM to 6 AM **(up to 7 hours)** | Daytime 6 AM to 6 PM **(up to 12 hours)** | Evening 6 PM to 11 PM **(up to 5 hours)** | Nighttime 11 PM to 6 AM **(up to 7 hours)** |
| **10.** Kitchen area | _______ | _______ | _______ | _______ | _______ | _______ |
| **11.** Any of the bedrooms | _______ | _______ | _______ | _______ | _______ | _______ |
| **12.** Any of the bathrooms, laundry room, utility room | _______ | _______ | _______ | _______ | _______ | _______ |
| **13.** All other rooms | _______ | _______ | _______ | _______ | _______ | _______ |

In **fall**, what is the **average number of hours per period per day** that any windows, doors, or skylights are open more than 1 inch in the following rooms?

| | WEEKDAYS | | | WEEKENDS | | |
|---|---|---|---|---|---|---|
| | Daytime 6 AM to 6 PM **(up to 12 hours)** | Evening 6 PM to 11 PM **(up to 5 hours)** | Nighttime 11 PM to 6 AM **(up to 7 hours)** | Daytime 6 AM to 6 PM **(up to 12 hours)** | Evening 6 PM to 11 PM **(up to 5 hours)** | Nighttime 11 PM to 6 AM **(up to 7 hours)** |
| **14.** Kitchen area | _______ | _______ | _______ | _______ | _______ | _______ |
| **15.** Any of the bedrooms | _______ | _______ | _______ | _______ | _______ | _______ |
| **16.** Any of the bathrooms, laundry room, utility room | _______ | _______ | _______ | _______ | _______ | _______ |
| **17.** All other rooms | _______ | _______ | _______ | _______ | _______ | _______ |

In **winter**, what is the **average number of hours per period per day** that any windows, doors, or skylights are open more than 1 inch in the following rooms?

| | WEEKDAYS | | | | WEEKENDS | | |
|---|---|---|---|---|---|---|---|
| | Daytime 6 AM to 6 PM **(up to 12 hours)** | Evening 6 PM to 11 PM **(up to 5 hours)** | Nighttime 11 PM to 6 AM **(up to 7 hours)** | | Daytime 6 AM to 6 PM **(up to 12 hours)** | Evening 6 PM to 11 PM **(up to 5 hours)** | Nighttime 11 PM to 6 AM **(up to 7 hours)** |
| **18.** Kitchen area | _______ | _______ | _______ | | _______ | _______ | _______ |
| **19.** Any of the bedrooms | _______ | _______ | _______ | | _______ | _______ | _______ |
| **20.** Any of the bathrooms, laundry room, utility room | _______ | _______ | _______ | | _______ | _______ | _______ |
| **21.** All other rooms | _______ | _______ | _______ | | _______ | _______ | _______ |

In **spring**, what is the **average number of hours per period per day** that any windows, doors, or skylights are open more than 1 inch in the following rooms?

| | WEEKDAYS | | | | WEEKENDS | | |
|---|---|---|---|---|---|---|---|
| | Daytime 6 AM to 6 PM **(up to 12 hours)** | Evening 6 PM to 11 PM **(up to 5 hours)** | Nighttime 11 PM to 6 AM **(up to 7 hours)** | | Daytime 6 AM to 6 PM **(up to 12 hours)** | Evening 6 PM to 11 PM **(up to 5 hours)** | Nighttime 11 PM to 6 AM **(up to 7 hours)** |
| **22.** Kitchen area | _______ | _______ | _______ | | _______ | _______ | _______ |
| **23.** Any of the bedrooms | _______ | _______ | _______ | | _______ | _______ | _______ |
| **24.** Any of the bathrooms, laundry room, utility room | _______ | _______ | _______ | | _______ | _______ | _______ |
| **25.** All other rooms | _______ | _______ | _______ | | _______ | _______ | _______ |

**26.** How important are each of the following reasons why you and members of your household typically **open** windows, doors, or skylights to the outdoors? (CHECK ALL THAT TYPICALLY APPLY. DO NOT INCLUDE WHEN YOU OPEN THEM FOR A MINUTE OR TWO, OR TO ENTER OR EXIT YOUR HOME. IF YOU NEVER OPEN WINDOWS, DOORS, OR SKYLIGHTS FOR THAT REASON, PLEASE CHECK THE BOX FOR "NEVER OPEN FOR THIS REASON.")

| | Very Important | Somewhat Important | Slightly Important | Not at all Important | Never open for this reason |
|---|---|---|---|---|---|
| A. To cool the house ...................... | 1 ○ | 2 ○ | 3 ○ | 4 ○ | 5 ○ |
| B. To warm the house .................... | ○ | ○ | ○ | ○ | ○ |
| C. To provide air movement .......... | ○ | ○ | ○ | ○ | ○ |
| D. To remove odors........................ | ○ | ○ | ○ | ○ | ○ |
| E. To remove moisture................... | ○ | ○ | ○ | ○ | ○ |
| F. To air out during house cleaning | ○ | ○ | ○ | ○ | ○ |
| G. To remove smoke, such as from cigarettes, fireplace, woodstove, etc. (SPECIFY TYPES: ____) .... | ○ | ○ | ○ | ○ | ○ |
| H. To provide draft for fireplace, wooc stove, cooking appliance or exhaust fan.............................................. | ○ | ○ | ○ | ○ | ○ |
| I. To save energy........................... | ○ | ○ | ○ | ○ | ○ |
| J. To allow pets frequent or easy access......................................... | ○ | ○ | ○ | ○ | ○ |
| K. Other: (SPECIFY: ___________ ____________________________) | ○ | ○ | ○ | ○ | |

**27.** How important are each of the following reasons why you and members of your household typically **close** windows, doors, or skylights? (CHECK ALL THAT <u>TYPICALLY</u> APPLY. IF YOU <u>NEVER</u> CLOSE WINDOWS, DOORS, OR SKYLIGHTS FOR THAT REASON, PLEASE CHECK THE BOX FOR "NEVER CLOSE FOR THIS REASON")

| | Very Important | Somewhat Important | Slightly Important | Not at all Important | Never close for this reason |
|---|---|---|---|---|---|
| A. Nobody at home | 1 ○ | 2 ○ | 3 ○ | 4 ○ | 5 ○ |
| B. Maintain comfortable indoor temperature | ○ | ○ | ○ | ○ | ○ |
| C. Reduce pollutants or odors from outdoors | ○ | ○ | ○ | ○ | ○ |
| D. Too windy or drafty | ○ | ○ | ○ | ○ | ○ |
| E. Keep out noise | ○ | ○ | ○ | ○ | ○ |
| F. Keep pets in or out | ○ | ○ | ○ | ○ | ○ |
| G. Save energy | ○ | ○ | ○ | ○ | ○ |
| H. Keep out rain or snow | ○ | ○ | ○ | ○ | ○ |
| I. Keep out woodsmoke | ○ | ○ | ○ | ○ | ○ |
| J. Keep out dust | ○ | ○ | ○ | ○ | ○ |
| K. Keep out pollen or other allergens | ○ | ○ | ○ | ○ | ○ |
| L. Keep out insects | ○ | ○ | ○ | ○ | ○ |
| M. Privacy from neighbors | ○ | ○ | ○ | ○ | ○ |
| N. Security or safety | ○ | ○ | ○ | ○ | ○ |

| | | | | | |
|---|---|---|---|---|---|
| O. Hard to open or close windows........ | ○ | ○ | ○ | ○ | ○ |
| P. Other: (SPECIFY: ____________ ____________________________) | ○ | ○ | ○ | ○ | |

In each "season" in the past year, how many hours out of the 24 hours in a day—on average—did your house have no ventilation, or low, medium or high ventilation, as defined below?

**No ventilation:** All windows and doors closed.

**Low:** One or two windows or doors open just a crack (up to 1 inch).

**Medium:** Several windows or doors open at least a crack, or one or two windows open part-way (at least several inches).

**High:** Some windows or doors fully open, or several windows or doors open part-way, or almost all windows or doors open at least a crack.

(**NOTE:** The number of hours for no ventilation, low, medium, and high **SHOULD TOTAL 24** for each season)

| | No vent-ilation | Low | Medium | High | Total hours per day |
|---|---|---|---|---|---|
| **28.** Summer.. | _____ + | _____ + | _____ + | _____ | = 24 |
| **29.** Fall ......... | _____ + | _____ + | _____ + | _____ | = 24 |
| **30.** Winter .... | _____ + | _____ + | _____ + | _____ | = 24 |
| **31.** Spring..... | _____ + | _____ + | _____ + | _____ | = 24 |

**32.** How often, if ever, do you provide for cross-ventilation by opening windows on opposite sides of your house?

- 1 ○ Frequently
- 2 ○ Sometimes
- 3 ○ Rarely
- 4 ○ Never
- 5 ○ Not Applicable

**33.** When you open windows, doors, or skylights, how often, if ever, do you provide for high and low venting (for example, by opening ground floor and ceiling level windows, or by opening windows on different stories?)

- 1 ○ Frequently
- 2 ○ Sometimes
- 3 ○ Rarely
- 4 ○ Never
- 5 ○ Not Applicable

## COOLING, HEATING, AND VENTILATING SYSTEMS

**34.** For each season, how many hours of the 24 hours per day are the following heating or cooling devices used on an average day. If you do not have a specific piece of equipment, enter zeros for all seasons:

| | Summer | Fall | Winter | Spring |
|---|---|---|---|---|
| ○ Central Air Conditioning ......... | ______ | ______ | ______ | ______ |
| ○ Room Air Conditioning ......... | ______ | ______ | ______ | ______ |
| ○ Whole House Fan | ______ | ______ | ______ | ______ |
| ○ Central or Room Dehumidifier......... | ______ | ______ | ______ | ______ |
| ○ Central Gas Heating.................. | ______ | ______ | ______ | ______ |
| ○ Central Electric or Heat-pump heating.................. | ______ | ______ | ______ | ______ |
| ○ Gas Wall Heater.... | ______ | ______ | ______ | ______ |
| ○ Electric Wall Heater.................... | ______ | ______ | ______ | ______ |
| ○ Wood stove or gas or wood fireplace with tight-fitting doors .. | ______ | ______ | ______ | ______ |
| ○ Other Fireplace without tight-fitting doors........... | ______ | ______ | ______ | ______ |
| ○ Freestanding combustion heater (such as gas, kerosene) not vented to the outdoors ................ | ______ | ______ | ______ | ______ |
| ○ Freestanding electric heater........ | ______ | ______ | ______ | ______ |
| ○ Central or room humidifier ............. | ______ | ______ | ______ | ______ |
| ○ Central HEPA or electrostatic filter .. | ______ | ______ | ______ | ______ |
| ○ "SmartVent" or other similar ventilative cooling system ...... | ______ | ______ | ______ | ______ |
| ○ Other (SPECIFY: _______________) | ______ | ______ | ______ | ______ |

**35.** Where is your central heater located? (NOTE: This is the unit, or the part of the unit, that circulates heated or cooled air within your house.)

[1] ○ Attic

[2] ○ Crawlspace

[3] ○ Garage

[4] ○ Other space inside the house (SPECIFY: ____________________________)

[5] ○ Other space outside the house (SPECIFY: ____________________________)

[6] ○ House does not have central heater.

[7] ○ Don't know

**36.** Where is the particle air filter for your heater or central system located?

[1] ○ Ceiling register

[2] ○ In the central unit

[3] ○ Other (SPECIFY: ________________________)

[4] ○ Don't know

[5] ○ Don't have one

**37.** What kind of filter is it?

[1] ○ Traditional inexpensive fiberglass

[2] ○ Medium efficiency pleated filter (usually removes 40-70% of particles)

[3] ○ High efficiency pleated filter (usually removes 95% or more of particles)

[4] ○ Electrostatic filter (you wash it instead of replacing)

[5] ○ Electronic filter (usually built in, you wash it instead of replacing)

[6] ○ Other (SPECIFY: ________________________)

[7] ○ Not sure

[8] ○ Don't have one

**38.** How often, if ever, do you replace or clean the filter?

1 ○ Once a month
2 ○ Once a quarter
3 ○ Twice a year
4 ○ Once a year or less often
5 ○ Never
6 ○ Don't know
7 ○ Don't have one

**39.** A. Do you use a stand-alone air filter, air purifier or air cleaner in the house?

1 ○ Yes (SPECIFY BRAND OR MODEL: ________________________________)
2 ○ No ⟶ **GOTO Q40**

B. **IF YES**: Did the literature for that unit say that it creates ozone, "supersaturated oxygen," or something similar?

1 ○ Yes
2 ○ No
3 ○ Don't know

**40.** Thinking of how you operate your heating and air-conditioning system, what temperature settings on the thermostat do you usually use when the house is occupied during waking hours and sleeping hours? (PLEASE ENTER THE TEMPERATURES IN THE TABLE BELOW.)

| | Degree (F) | Don't know | Turn Off/ Does not apply |
|---|---|---|---|
| Heating mode: | | | |
| Waking........... | ______ | _____ | _____ |
| Sleeping.......... | ______ | _____ | _____ |
| Cooling mode: | | | |
| Waking | ______ | _____ | _____ |
| Sleeping ......... | ______ | _____ | _____ |

**41.** How often, if ever, do you use the thermostat's fan switch to circulate air in the home without any heating or cooling going on? (This is normally done by putting the fan switch to "On" or "Manual" and not by adjusting the heating or cooling settings.)

1 ○ Frequently
2 ○ Sometimes
3 ○ Rarely
4 ○ Never
5 ○ Not Applicable

**42.** A. Do you have a gas water heater?

1 ○ Yes
2 ○ No ⟶ **GO TO Q43**

B. Where is your gas water heater located?

1 ○ Garage
2 ○ Other space outside the house
3 ○ Other space inside the house
4 ○ Attic
5 ○ Crawlspace
6 ○ Don't know

## WHOLE-HOUSE VENTILATION SYSTEMS

**43.** A whole-house ventilation **system** is one that is designed and intended to provide ventilation with outdoor air to meet the needs of the whole house. Whole-house ventilation systems:

- run continuously or intermittently throughout the day
- are controlled automatically rather than manually by a switch

A. Do you have a whole-house ventilation system, such as the type of whole-house ventilation system that has air inlets that bring <u>outdoor air</u> into the duct system of a central heating and air conditioning system and uses that duct system to distribute fresh air throughout the house. A variation of this type of system has an outside air inlet and fan that is connected to its own duct system rather than to the duct system connected to the central heating and air conditioning system.

1○ Yes, Freshvent

2○ Yes, other (Please indicate the name of the system, or brand or model, if known)

___________________________________

3○ No

○ Do you have an exhaust fan system, which usually consists of one or more continually or intermittently operating exhaust fans often in a bathroom or laundry room? These exhaust fans are more efficient and quieter than a normal bathroom fan. (*Do **not** include a whole-house fan, which is a large exhaust fan that is mounted in the ceiling and is usually operated manually to bring in cooler air to cool off the house during summer evenings and nights.)*

1○ Yes (Please indicate the name of the system, or brand or model, if known)

___________________________________

2○ No

○ Do you have a heat-recovery ventilator or an energy-recovery ventilator system that is designed to provide ventilation to the whole house?

1○ Yes (Please indicate the name of the system, or brand or model, if known)

___________________________________

2○ No

D. Does your house have some other type of whole-house ventilation **system** that is designed to bring in outdoor air automatically to provide ventilation to the whole house?

1○ Yes (Please indicate the name of the system, or brand or model, if known)

___________________________________

2○ No

**IF YOU ANSWERED "YES" TO ANY OF THE 4 QUESTIONS (A, B, C, or D) ABOUT WHOLE-HOUSE VENTLATION SYSTEMS, PLEASE CONTINUE.**

**IF YOU ANSWERED "NO" TO ALL FOUR OF THESE, THAT YOU DO NOT HAVE SUCH A SYSTEM, PLEASE GO TO QUESTION 44 ON PAGE 10.**

## WHOLE-HOUSE VENTILATION SYSTEMS (*Cont'd*)

E. Was the operation of the system explained to you when you bought or moved into the house?

1 ○ Yes

2 ○ No

F. Do you feel you understand how the system works?

1 ○ Yes

2 ○ No

G. Do you feel you understand how to operate it properly?

1 ○ Yes

2 ○ No

How is the system typically used in each season? Indicate whether the system use is continuous (left on all the time), somewhat frequent, infrequent, or is never used in that season. (PLEASE CHECK ONLY ONE BOX FOR EACH SEASON.)

| | Continuous | Somewhat frequent | Infrequent | Never |
|---|---|---|---|---|
| H. Summer | 1 ○ | 2 ○ | 3 ○ | 4 ○ |
| I. Fall | ○ | ○ | ○ | ○ |
| J. Winter | ○ | ○ | ○ | ○ |
| K. Spring | ○ | ○ | ○ | ○ |

L. What do you like about the system? (CHECK ALL THAT APPLY)

1 ○ Fresh air

2 ○ Quiet

3 ○ Reduced odors

4 ○ Reduced energy costs

5 ○ Reduced allergies

6 ○ Reduced concern about indoor air quality

7 ○ Other (SPECIFY: ____________________)

8 ○ None of the above

M. What ***don't*** you like about the system? (CHECK ALL THAT APPLY)

1 ○ Too noisy

2 ○ Too drafty

3 ○ Increases odors

4 ○ Hard to operate

5 ○ Hard to maintain

6 ○ Too expensive

7 ○ Too quiet

8 ○ Not effective (SPECIFY WHAT MAKES THE SYSTEM NOT EFFECTIVE: ______ ____________________________________)

9 ○ Other (SPECIFY: ____________________)

10 ○ None of the above

N. Why did you choose the system? (CHECK ALL THAT APPLY)

1 ○ Came with the house

2 ○ A household member has health condition

3 ○ Wanted filtered fresh outdoor air

4 ○ Affordable cost

5 ○ Good reliability

6 ○ Reduced energy costs

7 ○ Other (SPECIFY: __________________)

O. Please list any additional problems or provide any additional comments you have on the system.

[1] ○ NONE or SPECIFY: __________________

______________________________________

______________________________________

______________________________________

## SPECIAL CHOICES

**44.** What special measures or choices have you or the builder taken to improve the quality of the air in your home? (CHECK ALL THAT APPLY)

- a ○ Upgraded my central air filter
- b ○ High efficiency vacuum cleaner with special features such as better filters to trap more particles
- c ○ Whole house vacuum
- d ○ Low-emission carpets, furniture, paint, or cabinets
- e ○ Hard flooring instead of carpeting
- f ○ Carbon monoxide alarm
- g ○ Special range hood (e.g. higher air flow, lower noise, etc.)
- h ○ Extra exhaust fans
- i ○ Whole house ventilation system
- j ○ Other (SPECIFY: ________________________)
- k ○ None of the above

## COMFORT AND ODORS

**45.** For any of the previous four seasons, please indicate if you have noticed a significant period when your house has experienced each of the conditions listed below. (IF NONE, LEAVE BLANK)

| | Summer | Fall | Winter | Spring |
|---|---|---|---|---|
| A. Too hot.......... | 1 ○ | 2 ○ | 3 ○ | 4 ○ |
| B. Too cold........ | ○ | ○ | ○ | ○ |
| C. Too dry ......... | ○ | ○ | ○ | ○ |
| D. Too humid..... | ○ | ○ | ○ | ○ |
| E. Too drafty ..... | ○ | ○ | ○ | ○ |
| F. Too stagnant (not enough air movement) | ○ | ○ | ○ | ○ |
| G. Too dusty...... | ○ | ○ | ○ | ○ |

**IF ALL ARE NONE:** Check here ○

**46.** Similarly, have you noticed, seen, or smelled mold or mildew in the following locations? (IF NONE, LEAVE BLANK)

| | Summer | Fall | Winter | Spring |
|---|---|---|---|---|
| A. Bathroom .. | 1 ○ | 2 ○ | 3 ○ | 4 ○ |
| B. Basement or crawl space ......... | ○ | ○ | ○ | ○ |
| C. Walls or ceilings...... | ○ | ○ | ○ | ○ |
| D. Carpets...... | ○ | ○ | ○ | ○ |
| E. Closets ...... | ○ | ○ | ○ | ○ |

**IF ALL ARE NONE:** Check here ○

**47.** Since you have lived in this house, has it had any of the following conditions? (CHECK ALL THAT APPLY)

- a ○ Significant condensation on windows or other indoor surfaces?
- b ○ Roof leaks?
- c ○ Plumbing leaks?
- d ○ Wall or window leaks?
- e ○ Flooding?
- f ○ Poor site drainage?
- g ○ Bothersome carpet odors?
- h ○ Bothersome cabinetry odors?

[i] ○ Other unpleasant odors? (SPECIFY: __________ ___________________________________________)

[j] ○ Other moisture problems? (SPECIFY: ________ ___________________________________________)

[k] ○ None of the above

How would you rate the air quality in your home during each season of the past year? Indicate whether the air quality in your home was typically very acceptable, acceptable, barely acceptable, or not acceptable. (PLEASE CHECK ONLY ONE BOX FOR EACH SEASON.)

| | Very acceptable | Somewhat acceptable | Barely acceptable | Not acceptable |
|---|---|---|---|---|
| **48.** Summer.... | [1] ○ | [2] ○ | [3] ○ | [4] ○ |
| **49.** Fall........... | ○ | ○ | ○ | ○ |
| **50.** Winter...... | ○ | ○ | ○ | ○ |
| **51.** Spring....... | ○ | ○ | ○ | ○ |

## HEALTH

Please answer the following questions for your household. Enter zero or a number under each age group category for each characteristic.

| Characteristics of Household Members | Number of Adults: 18 yrs old or older | Number of Children | |
|---|---|---|---|
| | | 6-17 years old | 5 years old or younger |
| **52.** Total number in household................. | #______ | #______ | #______ |
| **53.** Number who smoke | #______ | #______ | #______ |
| **54.** Number who have allergies to outdoor pollen, mold, or grass (doctor-diagnosed).... | #______ | #______ | #______ |
| **55.** Number who have allergy to common indoor agents such as household pets, dust mites, or cockroaches (doctor-diagnosed).... | #______ | #______ | #______ |

| | *Number o* | *Number of Children* |
|---|---|---|

| *Characteristics of Household Members* | *Adults: 18 yrs old or older* | *6-17 years old* | *5 years old or younger* |
|---|---|---|---|
| **56.** Number who have allergy to other (or unknown) airborne agents (doctor-diagnosed) ................ | #______ | #______ | #______ |
| **57.** Number who have asthma (doctor-diagnosed) ................ | #______ | #______ | #______ |
| **58.** Number who have other breathing/lung problems (doctor-diagnosed) ................ | #______ | #______ | #______ |

## COOKING

**59.** On average how many total hours a day does someone cook in the house using either the stovetop or the oven, counting only the time that the stovetop or oven is turned on? Do not include use of a microwave oven.

| Weekday | Weekend |
|---|---|
| # _______ hours/day | # _______ hours/day |

**60.** What type of stovetop do you use most often?

1 ○ Gas

2 ○ Electric

**61.** Does that stovetop have an exhaust fan or "range hood"?

1 ○ Yes, it has a range hood with a fan in it that blows air back into the room

2 ○ Yes, it has a range hood with a fan that exhausts the air to the outdoors

3 ○ Yes, it has a downdraft ventilator built into it

4 ○ No

5 ○ Don't know

**62.** Is the (most frequently used) oven gas or electric?

1 ○ Gas

2 ○ Electric

**63.** Where is it located?

1 ○ Directly above or below the stovetop

2 ○ Built-in, not near the stovetop

3 ○ Other (DESCRIBE: ____________________)

**64.** Does it have its own exhaust vent to the outdoors?

1 ○ Yes

2 ○ No

3 ○ Don't know

**65.** When someone cooks with the stovetop, how often, if ever, do they use the exhaust fan or range hood?

1 ○ Always

2 ○ Only when odor or humidity seems to be an issue

3 ○ Sometimes

4 ○ Rarely

5 ○ Never

**66.** When someone cooks with the oven, how often, if ever, do they use the exhaust fan or range hood?

1 ○ Always

2 ○ Only when odor or humidity seems to be an issue

3 ○ Sometimes

4 ○ Rarely

5 ○ Never

## BATHROOM VENTILATION

**67.** When someone in the house takes a shower or bath, how often, is the bathroom exhaust fan used?

1 ○ Always

2 ○ Frequently

3 ○ Sometimes

4 ○ Rarely

5 ○ Never

6 ○ There is no fan → **SKIP TO Q71, PAGE 13**

**68.** How many bathroom fans do you have that are controlled as follows:

#______ With a timer knob or switch
#______ Come on when the light comes on
#______ Have a separate on/off switch
#______ Are on all the time

**69.** Why are bathroom fans used? (CHECK ALL THAT APPLY)

a ○ To remove moisture

b ○ To provide noise

c ○ To control odor

d ○ Comes on automatically when light is turned on

e ○ Other (PLEASE SPECIFY: _______________)

**70.** A. Are there times when the fan isn't used, even though the bathroom is steamy or has an unpleasant odor?

1 ○ Yes

2 ○ No ⟶ **SKIP TO Q71**

B. **<u>IF YES</u>**: Then, why is the fan not used? (CHECK ALL THAT APPLY)

1 ○ Window is open

2 ○ Don't think of it

3 ○ Too noisy

4 ○ Doesn't seem to help

5 ○ Don't want to use the energy

6 ○ Doesn't work

7 ○ Causes draft

**71.** How often, if ever, do people in your household open the bathroom window for ventilation?

1 ○ It is always open

2 ○ It is usually open

3 ○ Sometimes

4 ○ Rarely

5 ○ Never

## ADDITIONAL HOUSE CHARACTERISTICS

**72.** On average, how many times PER WEEK does your HOUSEHOLD do the following activities in your house? (Enter number of times PER WEEK, or zero if never)

| | Number of times used PER WEEK by ALL household members |
|---|---|
| Use the shower, or indoor Jacuzzi, or bath | #__________ |
| Use the dishwasher or washing machine | #__________ |
| Hang clothes to dry indoors..................... | #__________ |
| Boil water for cooking rice, pasta, etc. ..... | #__________ |

Create other sources of steam or water vapor (SPECIFY SOURCES AND NUMBER OF TIMES PER WEEK: ________________________________)

**73.** Are there dogs, cats, or other furry animals that regularly spend time in the house?

1 ○ Yes (SPECIFY: ________________________)

2 ○ No

**74.** What is the most common type of built-in cabinetry in the kitchen and bathrooms?

1 ○ Contains **any bare pressed wood or plywood** (no obvious covering on inside of cabinet)

2 ○ Contains **any covered pressed wood or plywood** (with laminate such as white melamine on inside of cabinet)

3 ○ Solid wood

4 ○ Other (SPECIFY: _______________________)

5 ○ Don't know

**75.** Approximately how many square feet of each of the following flooring types do you have? (Note: If you have area rugs, consider only the flooring underneath them.)

#_______ sq ft Vinyl or linoleum flooring
#_______ sq ft Wood or wood-based flooring
#_______ sq ft Carpeting
#_______ sq ft Stone or ceramic tile
#_______ sq ft Concrete or brick
#_______ sq ft Other: (SPECIFY: __________ __________________________)

**76.** How often are the carpets or rugs in your most heavily used rooms normally vacuumed?

1 ○ Twice per week or more often
2 ○ About once per week
3 ○ About every 2 weeks
4 ○ About every 3 to 4 weeks
5 ○ Less often

**77.** Which best describes the walls in your house?

1 ○ Mostly wallpaper
2 ○ Some wallpaper and some painted
3 ○ Mostly painted
4 ○ All painted
5 ○ Other (SPECIFY: ________________________)

**78.** Do you or other household members regularly use any of the following in your home? (CHECK ALL THAT APPLY)

| | Yes | No |
|---|---|---|
| A. Burn candles or incense....... | 1 ○ | 2 ○ |
| B. Paints, glues, or solvents (for hobbies, home repairs, or other purposes)................ | ○ | ○ |
| C. Pesticide sprays or foggers .. | ○ | ○ |
| D. Plug-in or spray deodorizers | ○ | ○ |
| E. Potpourri.............................. | ○ | ○ |

F. Other sources of smoke or fumes (SPECIFY: _______________________)

**79.** A. Does the house have an attached garage, or a parking area beneath the home?

1 ○ Yes
2 ○ No ⟶ **GOTO Q80**

B. **<u>IF YES</u>**: How many functioning cars or trucks are typically parked there?

1 ○ Zero
2 ○ One
3 ○ Two
4 ○ Three or more

**80.** Please enter the <u>average number of hours per day</u> that no one is home on weekdays and weekends , for the daytime, evening, and nighttime periods indicated below. Enter zero for any period in which someone is always in the home.

| | | Weekday | Weekend |
|---|---|---|---|
| Daytime (up to 12 hours) | 6 AM - 6 PM | # ____________ | # ____________ |
| Evening (up to 5 hours) | 6 PM - 11 PM | # ____________ | # ____________ |
| Nighttime (up to 7 | 11 PM | # ____________ | # ____________ |

hours) 6 AM

**81.** After this survey, we would like to make some measurements of the air quality in the homes of some of the people who answered this questionnaire. Participants would receive their results and a small incentive payment. Would you be willing to participate in this second part of the study?

- [1] ○ Yes
- [2] ○ No

The next questions will help us interpret the results of the study. All responses will be kept confidential.

**82.** What is your household income?

- [1] ○ Under $35,000
- [2] ○ $35,000 - $49,999
- [3] ○ $50,000 - $74,999
- [4] ○ $75,000 - $99,999
- [5] ○ $100,000 - $149,999
- [6] ○ $150,000 or more

**83.** What ethnic or racial group do you consider yourself? (CHECK ALL THAT APPLY)

- [a] ○ Black or African-American
- [b] ○ Native American
- [c] ○ Hispanic or Latino
- [d] ○ Filipino
- [e] ○ Asian
- [f] ○ Pacific Islander

g ○ White or Caucasian, or

h ○ Some other group? (SPECIFY: ______________)

i ○ Mixed race (SPECIFY: ____________________)

**84.** A. Who in your household is most familiar with how the windows, doors, and fans are used to ventilate your home? (PLEASE CHECK THE ONE THAT BEST FITS)

1 ○ You

2 ○ Another person (SPECIFY OTHER PERSON: ___________________________________)

3 ○ Both you and another person (SPECIFY OTHER PERSON: ___________________)

4 ○ Don't Know

B. **IF YOU ANSWERED 2 OR 3 TO QUESTION 84 ABOVE**, did you consult with this other person to help complete this survey?

1 ○ Yes

2 ○ No

**Thank you for taking the time to help us with this important research.**

If you have any comments about the survey, or further information about indoor air quality or ventilation in your home, please provide them in the space below.

COMMENTS: ____________________________________

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

**IMPORTANT → GO TO LAST PAGE**

**85.** We want to send you a check for $30 to thank you for your help with this important study. To make sure our records are correct and that the check will reach you, please fill in your name and address. Please print.

Name: ______________________________________________

Address: ____________________________________ Apt # __________

______________________________ ____________ ____________
City State Zip code

## Thank you very much for your help

Now please mail this survey back to us in the enclosed envelope.
You don't need stamps.

**The Air Infiltration and Ventilation Centre** was inaugurated through the International Energy Agency and is funded by the following countries:

Belgium, Czech Republic, Denmark, France, Greece, Japan, Republic of Korea, Netherlands, Norway and United States of America.

The Centre provides technical support in air infiltration and ventilation research and application. The aim is to provide an understanding of the complex behaviour of the air flow in buildings and to advance the effective application of associated energy saving measures in both the design of new buildings and the improvement of the existing building stock.

Air Infiltration and Ventilation Centre
Operating Agent and Management
INIVE EEIG
Lozenberg 7
B-1932 Sint-Stevens-Woluwe
Belgium

www.aivc.org

Tel: +32 2 655 77 11
Fax: +32 2 653 07 29
inive@bbri.be
www.inive.org