Public Interest Energy Research (PIER) Program

FINAL COLLABORATIVE PROJECT REPORT

INDOOR ENVIRONMENTAL QUALITY AND HEATING, VENTILATING, AND AIR CONDITIONING SURVEY OF SMALL AND MEDIUM-SIZED COMMERCIAL BUILDINGS

Prepared for: California Energy Commission

Prepared by: University of California Berkeley Survey Research Center and Lawrence Berkeley National Lab

California Environmental Protection Agency
AIR RESOURCES BOARD

AUGUST 2011

CEC-500-2011-038

Prepared by:

Primary Author(s):
Thomas Piazza
Survey Research Center
2538 Channing Way #5100
University of California
Berkeley, California 94720-5100

Michael Apte
Lawrence Berkeley National Laboratory
Berkeley, CA 94720

Contract Number: 500-02-023

Prepared for:
California Energy Commission

Marla Mueller
Contract Manager

Linda Spiegel
Office Manager
Energy Generation Research

Laurie ten Hope
Deputy Director
ENERGY RESEARCH AND DEVELOPMENT DIVISION

Robert P. Oglesby
Executive Director

and

California Air Resources Board

Ash Lashgari
Contract Manager
Research Division

Eileen McCauley
Manager
Atmospheric Processes Research Section
Research Division

DISCLAIMER

This report was prepared as the result of work sponsored by the California Energy Commission. It does not necessarily represent the views of the Energy Commission, its employees or the State of California. The Energy Commission, the State of California, its employees, contractors and subcontractors make no warrant, express or implied, and assume no legal liability for the information in this report; nor does any party represent that the uses of this information will not infringe upon privately owned rights. This report has not been approved or disapproved by the California Energy Commission nor has the California Energy Commission passed upon the accuracy or adequacy of the information in this report.

ACKNOWLEDGEMENTS

The authors wish to thank all of the participants in this study for taking the time to complete the questionnaires. Thanks are also extended to the members of the Expert Advisory Committee for its helpful suggestions and critique. The members were: William Fisk, Laura Kolb, Deborah Gold, Jed Waldman, John Girman, Pete Jacobs, and Steven Emmerich. The committee was instrumental in guiding a year-and-one-half search and discussion on the proper approach to this research. Committee members provided advice that carried the California Energy Commission Title 24 and California Air Resources Board Indoor Air Quality staff from conceiving of this research as a global request for a proposal to a more measured and nuanced phone survey and building a respondent database to a field inspection program. Their individual assistance in alerting the authors to difficult challenges in this research, identifying ways of overcoming those challenges, and reviewing every aspect of the study has been of critical importance to its success. Thanks also go to David Faulkner of Lawrence Berkeley National Laboratory and Deborah Bennett of the University of California, Davis, for their contributions to the survey questions.

This research was funded by the California Energy Commission, Public Interest Energy Research Program, through Contract 500-02-023 with the California Air Resources Board, which managed the research. The work at the University of California at Davis was supported through a subcontract from the California Air Resources Board under California Air Resources Board Contract Number 05-347. This report is submitted in fulfillment of that contract. The work at Lawrence Berkeley National Laboratory was supported through a subcontract from the University of California at Davis. Additionally, all work conducted at Lawrence Berkeley National Laboratory is supported by the Director, Office of Science, Office of Basic Energy Sciences, of the U.S. Department of Energy under Contract No. DEAC02-05CH11231.

PREFACE

The California Energy Commission 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 services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California. The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions. PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Indoor Environmental Quality and Heating, Ventilating, and Air Conditioning Survey of Small and Medium-Sized Commercial Buildings is the final report for the project Contract Number 500-02-023, conducted by University of California Berkeley Survey Research Center. The information from this project contributes to PIER's Energy-Related Environmental Research Program.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

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: 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: www.arb.ca.gov/research/indoor/indoor.htm.

ABSTRACT

In this study, a telephone survey and supplementary mailback survey were used to collect relevant details on ventilation and indoor environmental quality in small and medium-sized commercial buildings constructed after 1978 with floor area between 1,000 and 50,000 square feet and with no more than three stories. Due to the difficulty and expense of identifying and sampling only recently constructed buildings, the sample was limited to the fastest growing counties. The survey was designed to identify a key contact who was the most appropriate individual at each building site to respond to detailed questions regarding the physical configuration and operations and maintenance of the building. A total of 476 telephone surveys focusing on building characteristics and indoor air quality and 71 supplementary surveys focusing on ventilation were completed.

In general the findings were that a broad variety of air contaminant sources are present in small and medium-sized commercial buildings and that, furthermore, the building owners and managers did not know much about their heating, ventilating, and air conditioning system; the emission sources and concentrations; indoor air quality, and ventilation. The results will be used by the California Energy Commission to guide the development of future building energy design standards that protect indoor air quality and comfort in California small and medium-sized commercial buildings, by the California Air Resources Board to improve exposure assessments of indoor and outdoor air pollutants, and by both agencies to help interpret the field results obtained from a follow-up study.

Keywords: Small and medium commercial buildings, indoor air quality, ventilation, air contaminant exposure guidelines, air exchange rate, carbon monoxide, building envelope tightness, exhaust fans, formaldehyde, garage air contaminants, indoor air contaminant emission rates, indoor air contaminant sources, indoor air quality, mechanical ventilation systems, natural ventilation, nitrogen dioxide, particulate matter, ventilation standards, volatile organic compounds, windows

Please use the following citation for this report:

Piazza, Thomas, and Michael Apte (University of California Berkeley Survey Research Center). 2011. *Indoor Environmental Quality and Heating, Ventilating, and Air Conditioning Survey of Small and Medium Size Commercial Buildings.* California Energy Commission. CEC-500-2011-038.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Background

People spend 87 percent of their time in buildings to shop and for health needs, but mostly to work. Small and medium-sized commercial buildings are the most likely workplaces for nonindustrial, nonagricultural American workers. Small and medium-sized commercial buildings are generally defined as any low-rise (no more than three story) building with fewer than 50,000 square feet, and one or more rooftop heating, ventilating, and air conditioning (HVAC) units. For example, these buildings are found in strip malls. The rooftop HVAC unit is likely to be underpowered and oversubscribed, and the ventilation systems rarely inspected or cleaned. Small and medium-sized commercial buildings are generally not equipped with demand control ventilation. Those such as dry cleaners and restaurants may have indoor emission sources. There is likely substantial variability in types of small and medium-sized commercial buildings, their HVAC units (power and maintenance), and their ventilation systems. Yet, researchers know very little about indoor air quality, ventilation practices, or the HVAC equipment within them. A 2002 national indoor air quality research plan developed at the Lawrence Berkeley National Laboratory identified small commercial buildings as a priority area of inquiry.

Purpose

The California Energy Commission establishes energy efficiency standards for buildings and appliances. These standards promote efficient energy use. However, it is necessary to ensure that these requirements also maintain or improve indoor air quality. California's Energy Efficiency Standards for Residential and Nonresidential Buildings were established in 1978 in response to a legislative mandate to reduce California's energy consumption. The standards (Title 24) are updated periodically to allow consideration and possible incorporation of new energy efficiency technologies and methods.

This project will help fill major gaps in the understanding of sources of indoor air pollution, the relationship between emissions and energy consumption, and approaches for improving indoor air quality while reducing or maintaining energy consumption. The project focuses on high-priority areas where rapid growth is occurring and major opportunities for improvement are available—small and medium-sized commercial buildings. This research will help provide the needed benchmarks in assessing the energy and indoor air quality performance of those buildings and will provide the basis for developing more energy-efficient and effective indoor air quality measures and technologies that the Energy Commission can use in developing building energy efficiency standards.

Broadly speaking, the California Air Resources Board (ARB) has the responsibility to identify and reduce Californians' indoor and personal exposures to air pollutants. Activities for meeting that goal include sponsoring research to obtain information needed for estimating indoor and personal exposures to air pollutants and assessing Californians' indoor and total air exposures to toxic air pollutants. Knowledge of small and medium-sized commercial buildings' ventilation

practices, indoor air quality conditions, and HVAC type and performance are critical for reducing Californians' indoor air exposure to air pollutants.

Objectives

The survey in this study intended to determine:

- HVAC/ventilation equipment and control characteristics in small and medium-sized commercial buildings, including newer technologies (such as Demand Control Ventilation, Thermal Displacement Ventilation, and air cleaning)
- HVAC/ventilation operation and maintenance characteristics in small and medium-sized commercial buildings
- Small and medium-sized commercial building functions, indoor sources related to function, and water damage history
- History of indoor air quality complaints in buildings and associated remedial actions

The data from this study were intended to be analyzed to assess the following:

- Small and medium-sized commercial buildings' operative conditions (such as ownership by business, management by contract, no mechanical ventilation) that are predictive of inadequate ventilation
- Small and medium-sized commercial buildings use types that are predictive of inadequate ventilation
- Categorization of risk among small and medium-sized commercial building classes based on a combination of ventilation adequacy, building function, and indoor sources
- Association between occupant indoor air quality complaints and various small and medium-sized commercial buildings factors, including predicted ventilation adequacy

Methods

A telephone survey and supplementary mailback survey were used to collect relevant details on ventilation and indoor environmental quality in small and medium-sized commercial buildings constructed after 1978 with floor area between 1,000 and 50,000 square feet and with no more than three stories. Small and medium-sized commercial buildings with rooftop ventilation and air conditioning units were of primary interest. These surveys were used to collect basic facilities, operation, and maintenance information on California small and medium-sized commercial buildings and to develop recruitment contacts for a follow-on study. Due to the proprietary nature of business operations and the diverse nature of building management in small and medium-sized commercial buildings, building recruitment was challenging.

A sample of commercial and public administration establishments was drawn from the Dun & Bradstreet database of establishments. Those establishments were contacted by telephone, and if the building housing the establishment was eligible for the survey, an interview was attempted with someone knowledgeable about the building characteristics. A supplementary

self-administered questionnaire was sent to those establishments cooperating in the telephone survey. This self-administered survey requested more detailed information on the HVAC equipment. The sample of establishments was limited to the fastest-growing counties in each of five climate zones in California. In the end, 476 of the eligible establishments yielded a complete telephone interview, for an overall response rate of 35.3 percent. Seventy-one respondents returned the supplementary survey.

Results

Business size (by number of employees) was distributed as follows: 42 percent small (3 to 50), 48 percent medium (51 to 200), and 10 percent large (≥ 201). Table ES-1 shows the types of businesses represented, along with their floor area and date of construction.

Table ES-1. Characteristics of Buildings Represented in the Study

Business	**Percent**
Non-medical offices	24
Health care	10
Restaurant/food service	11
Food stores	2
Retail stores	13
Lodging	1
Public assembly	4
Services	16
Miscellaneous	10
Other	9
Floor Area	
1,000 ft² or less	2
1,000 to 5,000 ft²	23
5,000 to 10,000 ft²	18
10,000 to 20,000 ft²	22
20,000 to 50,000 ft²	36
Date of Construction	
1979 to 1985	26
1986 to 1990	18
1991 to 1995	14
1996 to 2000	16
2001 to 2005	19
2006 to 2008	7

Indoor sources investigated included moisture and mold, cooking, film processing, painting, new carpeting, and furniture. Table ES-2 shows the percentage of buildings in a building type with the various cooking appliances.

Table ES-2. Cooking Appliances in the Study's Buildings

Business Type	Cooking Appliances	Percent
Office buildings	toasters and microwave ovens	94
Restaurants	microwave ovens	84
	ovens *	86
	79% used gas ovens	
	30% used electric ovens	
	grilling or roasting	73
	frying	73
Food stores	toasters, microwave ovens, other cooking appliances	100
Retail stores	microwaves or toasters	83
	ovens (if they had a restaurant)	75
Health care	cooking appliances	96
Lodging	cooking appliances	80
Public assembly	cooking appliances	68
Auto repair	toasters and microwave ovens	60
Police, fire, post office	cooking appliances	95

* Some restaurants had both gas and electric ovens.

Table ES-3 shows the details on the buildings' new painting, carpeting, and furniture. These were identified because they represent potential sources of indoor pollution. Seventeen percent of the respondents said they had installed new carpeting on the first floor during the past year. Twenty-two percent of the respondents said they had new furniture on the first floor during the past year. For the buildings with new carpeting and furniture, Table ES-3 shows the distribution within those buildings.

Table ES-3. New Painting, Carpeting, and Furniture in the First Floor of the Study's Buildings During the Past Year

Activity	Percent
New Paint	43
New Carpeting	17
Nylon carpeting	78
Olefin carpeting	17
New Carpet Backing	
Styrene-butadiene	7
Carpet and Rug Institute (CRI) "Green" Label	21
New Carpet Pad	
Rubberized or resinated fiber	5
Rubber or reinforced rubber	4
Polyurethane foam	4
None	80
New Furniture	22
With solid wood	45
Composite wood product with wood or synthetic veneer	46
Fully encapsulated composite wood	16
Metal or plastic	57

Note: Amounts do not add to 100% because other materials were used.

Heating, ventilating, and air conditioning filtration approaches were standard, with limited evidence of any buildings employing higher efficiency filters. Heating and cooling thermostat setpoints were largely within the normal comfort band; however 32 percent of the buildings had cooling settings in the 70°F to 73°F (21°C to 23°C), and 6 percent below 70°F. This evidence of a high proportion of overly cooled spaces may provide an opportunity for easy reduction in wasted energy.

Conclusions

This survey provides a wealth of baseline information on California's small and medium-sized commercial buildings. It covers their building characteristics, sources of indoor contaminants, maintenance practices, building and HVAC operation, and cleaning practices. The building survey's strength lies in its high level of physical and operational details. No such information has been available on small and medium-sized business buildings to date.

The survey strongly suggests that the small and medium-sized commercial buildings stock is generally not designed or operated with sensitivity to the importance of ventilation, indoor environmental quality, or energy conservation. This evidence should be of value to California in understanding the contaminant exposures of workers and patrons of small and medium-sized commercial buildings, and in terms of policy and standards setting (for example, Title 24) to further the State's efforts to reduce energy consumption in the commercial building sector.

Note: All tables, figures, and photos in this report were produced by the authors, unless otherwise noted.

CHAPTER 1:
Introduction

California's commercial sector compressor-based cooling constitutes roughly 15 percent of total electricity consumption and total energy use in commercial buildings represented 10.8 percent of total statewide greenhouse gas (GHG) emissions in 2008 (Air Resources Board 2010). Small and medium commercial buildings (SMCBs) having total floor area less than 50,000 square feet, make up 96 percent of this sector. Prior to this study, virtually no research has focused on how heating, ventilating, and air conditioning (HVAC) systems are operated and maintained in these SMCBs. This is of particular interest since HVAC is the primary energy-consuming activity in most of these buildings, and it is also key to their indoor environmental quality (IEQ), as well as to occupant comfort and health.

The SMCB, as defined by the California Energy Commission, is any low-rise building (no more than three stories) that is served by package rooftop HVAC units. These buildings are found in, for example, strip malls, school facilities, and small office complexes, and often have one to several rooftop HVAC units. Clearly these buildings are very common to Californians, as workplaces and as sites for commercial, educational, and recreational activities. On average, Californians spend almost 90 percent of their time indoors; of that, 25 percent is spent away from home, primarily in commercial buildings (Jenkins et al. 1992). Thus, to the extent that the quality of the commercial indoor environment affects people's health and well-being, the time spent in SMCBs has the potential to significantly affect the quality of Californians' lives.

Indoor environmental quality in commercial buildings is affected by many factors. Building lighting, acoustics, thermal conditions, and air quality all contribute to IEQ. Indoor air quality (IAQ) is degraded by contaminant sources, while building ventilation is provided to mitigate or minimize the concentrations of these contaminants. Gaseous and particulate contaminant sources include the occupants themselves (bioeffluents), the materials and furnishings of the building, and the products and processes related to the building's function (e.g., retail products, office equipment, cooking fumes, typesetting solvents). Particulate matter (PM) is generated, suspended, and re-suspended indoors during activities and processes. Outdoor PM is also entrained into indoor air via mechanical and natural ventilation processes. The primary function of building ventilation is to remove these gaseous and particulate contaminants from the indoor air through dilution with fresh outdoor air. Filtration is provided in building ventilation systems to remove the airborne PM entering into and circulating within the building. Indoor contaminant sources and the HVAC system in the SMCB are at the nexus of its IAQ issues. Building occupants rely upon properly designed and functioning mechanical ventilation systems for acceptable IAQ.

The State of California, in Title 24 of their Code of Regulations (Building Energy Efficiency Standards; CEC 2005) provides specific requirements for ventilation in all non-residential building spaces with human occupancy. The prescribed ventilation rates are expected to be provided continuously throughout times of building occupancy, including a one-hour pre-occupancy purge of three air changes. Although natural ventilation can be used to meet the

code, the architecture and anticipated occupancy of a large proportion of SMCBs require mechanical ventilation to meet these requirements. The rooftop air handlers used in SMCBs must be working correctly to deliver the required amount of outside air to the building for ventilation. Poorly adjusted outside air dampers, overloaded or blocked air filters, improper fan speed settings, or discontinuous outside air supply fans can all contribute to suboptimal outside air supply and could lead to noncompliance with Title 24. Ventilation fan control systems that operate using a clock timer must be set properly to ensure uninterrupted ventilation during occupancy. Heating, ventilating, and air conditioning systems that cycle ventilation with thermal demand (a control system design that is not uncommon) do not comply with Title 24.

Due to the largely disaggregated, heterogeneous nature of commercial enterprise, information on SMCB operation and maintenance (O&M) is very limited. Research on large commercial buildings has shown that O&M is variable and that IEQ suffers due to poor maintenance. It is anticipated that information on SMCBs will reflect similar or greater variability. Access to a non-biased representation of the state of SMCB indoor air quality and O&M requires information collection through a statistically valid sample in California. Although such surveys are difficult to conduct, collection of this information is necessary for policymakers who must regulate building management to protect the health and safety of Californians.

The Toxic Air Contaminant Program and the Indoor Air Quality and Personal Exposure Assessment Programs of the California Air Resources Board (ARB) have mandates to assess Californians' exposures to Toxic Air Contaminants under Health and Safety Code Section 39660.5. These programs seek to reduce health risks from indoor air pollutants through the development of IAQ guidelines for the public, and through other measures. Collection of background information on IAQ in SMCBs is a critical mission needed to inform these guidelines and enact control measures.

There is a dearth of information on ventilation and IAQ in commercial buildings, with almost no existing literature on SMCBs in California or elsewhere in the United States. Among studies of commercial buildings, the U.S. Environmental Protection Agency's Building Assessment Survey and Evaluation (BASE) study of 100 buildings nationwide (Persily and Gorfain 2004) included 15 California building units (each unit being served by a single ventilation HVAC system). These buildings represented the large commercial building stock (> 100,000 square feet). The California Healthy Building Study (Fisk et al. 1993) researched IAQ and sick building syndrome in 12 California commercial buildings, again with a focus on larger facilities. The California Energy Commission (Energy Commission) conducted a building survey and energy efficiency field effort called the California Commercial End-Use Survey (CEUS) program. The survey includes information on building type and HVAC/ventilation system type; however, it does not include HVAC system type, filtration system characteristics, airflow rates, vintage of HVAC or ventilation systems, or design documents; nor does it have information on IAQ.

A telephone survey and supplementary mailback survey were used to collect relevant details on ventilation and IEQ in small and medium-sized commercial buildings with floor area between 1,000 and 50,000 square feet (ft^2), with no more than three stories, and constructed after 1978.

Questions were asked to meet the following study objectives:

- **Develop statewide survey information on ventilation characteristics of SMCBs:** Questions were asked about the design and performance specifications for the selected buildings regarding HVAC systems, for HVAC control systems, for natural ventilation provisions, and for air filtration systems.
- **Develop statewide survey information on the operation and maintenance characteristics of SMCBs:** Information was collected in the survey about the commissioning, inspection, testing, maintenance staff training, cleaning practices, and repair of HVAC, filtration, and control systems in the selected buildings.
- **Develop statewide survey information on basic construction details of SMCBs:** Questions were asked to determine the construction materials (e.g., wood frame, masonry, steel) of the buildings and the parameters affecting the airtightness of the building shell.
- **Obtain statewide survey data on indoor air quality (IAQ) characteristics of SMCBs:** Survey questions asked about potential sources of indoor pollutants, sources of nearby point emission sources (e.g., nearby dry cleaners), histories of moisture problems, and occupant complaints.
- **Characterize remedial actions that have been taken in SMCBs in response to IAQ issues:** Questions were asked about complaints or moisture problems encountered in the building and any steps that may have been taken to attempt to prevent IAQ problems.
- **Assess the correlation of SMCB building and/or equipment characteristics with the potential for poor ventilation and IAQ:** Questions were asked about the buildings' equipment and structural characteristics.
- **Obtain the data needed to identify the frequency distribution of various building use types, indoor occupancy and source types, and ventilation types in SMCBs:** The survey questionnaires asked questions about this to help guide the planning for a follow-on study and the sampling scheme to be used for it.

These objectives provided many challenges, which were primarily twofold. The first major challenge was to locate the small commercial buildings that were constructed after 1978. The second major challenge was to obtain very complex information from one or more key contacts who could respond to detailed questions regarding the physical configuration and operations and maintenance of the buildings selected. The first part of this report will detail how those challenges were met within the budget limitations for this project.

In the end, a total of 476 telephone interviews on building characteristics and indoor air quality and 71 supplementary self-administered surveys of ventilation were completed for the selected eligible buildings. The analysis is based on the data collected from those surveys.

CHAPTER 2:
Materials and Methods

Target Population and Eligibility

The study was targeted at the building managers of small and medium-sized commercial buildings in California. The buildings of interest were small and medium-sized commercial buildings with 1,000 to 50,000 square feet of floor space, no more than three stories high, constructed after 1978. Such buildings were likely to have the rooftop ventilation and air conditioning units that were of interest to the study.

It was not obvious what method should be used to collect the data of interest. In-person interviews would have been best, but the cost would have been prohibitive for the full data collection task. Consequently the first part of the study consisted of a survey, reported here, and the second part focused on actual physical measurements that could not be taken accurately any other way. The results of the measurements will be reported in a subsequent report.

Survey Method

Two survey methods were considered: a telephone survey and a mailback survey. A mailback survey would have been the less expensive choice and would have permitted the study to include more buildings, but a reliable list of eligible respondents was not available. A telephone survey would be more expensive, but it would allow for commercial establishments to be screened for eligibility. The difficulty with a telephone survey was that a telephone respondent could not be expected to have a high level of detail about the HVAC equipment at his or her fingertips, and that level was necessary.

In the end a compromise was worked out in discussions with ARB, the Energy Commission, Lawrence Berkeley National Laboratory (LBNL), and the Survey Research Center (SRC). A telephone survey would be used to locate eligible buildings and to ask questions that did not require a high level of technical information. Then a follow-up mailback survey would be sent either to the telephone respondent or to another identified person who would be asked to look up and record a substantial amount of detailed information about the HVAC equipment in the building and mail the completed survey back to SRC.

Sampling Strategy

A great deal of this project's difficulty and cost stemmed from the unavailability of a database of buildings that could be used to identify SMCBs constructed after 1978. Because the target buildings are only a small minority of all commercial buildings in the State, methods had to be devised to reach the target buildings efficiently.

One possibility considered was to select building owners from the DataQuick database, created from county real estate tax rolls. Pre-testing revealed, however, that county real estate tax rolls usually lacked information on the year of construction of a building and also frequently lacked the name and address of an individual who could be contacted about the building's HVAC systems.

The next sampling strategy considered was to use the Dun & Bradstreet (D&B) database of commercial establishments to select a sample of commercial and public administration buildings. Interviewers could then telephone each selected establishment and determine whether the building housing the establishment met the criteria to be included in the study. A pilot study revealed that this sampling strategy was an effective way to reach persons who could provide information on the eligibility of the building. However, only about 1 out of 20 buildings was eligible for the study, largely because most buildings were constructed before 1978. And the cost of screening 20,000 buildings, for example, to find 1,000 eligible buildings would have been prohibitive.

The sampling strategy eventually adopted was a variant of the D&B strategy. Commercial establishments would be sampled based on the D&B database, but the sample would be limited to the State's fastest-growing counties, since buildings in those counties were more likely to have been constructed after 1978.

This limitation of the sample to the fastest-growing counties was discussed extensively and agreed upon by ARB, the Energy Commission, LBNL, and SRC. The sample would no longer be representative of the buildings in the entire State, but steps would be taken to ensure that the sample covered important variations in climate zones and building sizes, as described below in Section 2.2. This distribution of the sample would allow analyses of the data to be used for illustrating characteristics of the population of buildings in the State, as well as for selecting buildings to be observed in more detail in a follow-on study.

Fastest-Growing Counties

The fastest-growing counties were identified by using certain summary statistics based on the McGraw-Hill Construction Dodge database. The Energy Commission made summary statistics available to SRC for this purpose. Specifically, the average numbers of square feet added in each county were compared for two groups of years: 1970 to 1979 and 1980 and later. Those counties with larger ratios of square feet added in 1980 and later, compared to 1970 to 1979, were considered the fastest growing, and therefore the most likely to have a higher percentage of buildings eligible for the study.

The highest ranking counties by this criterion were the following:

- Riverside
- San Bernardino
- Placer
- Kern
- San Luis Obispo
- Tulare
- San Diego
- Alameda

- Imperial
- Madera
- Kings

Climate Zones

There were five climate zones of major interest to the study: Coastal South, Coastal North, Inland South, Inland Central, and Inland North. The above list of counties covered most of those climate zones, but it was decided by ARB, the Energy Commission, LBNL, and SRC to replace a few of the counties with other counties that also had above-average growth rates. The requirements of the follow-on study, which would require visits to some of the sampled buildings, were also considered. The final agreed-upon list of counties included in the study, broken down by climate zone, was the following:

1. Coastal South
    - San Luis Obispo
    - San Diego
2. Coastal North
    - Alameda
    - Sonoma
3. Inland South
    - Riverside
    - San Bernardino
    - Imperial
4. Inland Central
    - Fresno
    - Kern
5. Inland North
    - Placer
    - Solano

Standard Industrial Classification (SIC) Codes

The D&B database included an SIC code for each establishment. These codes could be used to select the commercial and public administration buildings eligible for the study. The selection of SIC codes for the study is summarized in the following list:

- Definitely **excluded** from the study
    - Agriculture, Forestry, and Fishing
    - Mining
    - Construction
    - Manufacturing
    - Transportation, Communication, and Utilities
- Definitely **included** in the study
    - 50-51 Wholesale Trade
    - 52-59 Retail Trade
    - 60-67 Finance, Insurance, and Real Estate
    - 91-97 Public Administration
- Mostly included in the study
    - 70-89 Services
    - EXCEPT: 7992 (Public Golf Courses)
      7996 (Amusement Parks)
      82 (Education Services)
      8422 (Arboreta & Botanical or Zoological Gardens)

Sample Design

The sample was designed to select buildings of all sizes into the sample and to be distributed evenly over the five climate regions. Prior to selection, therefore, the D&B database was stratified by size and region. The distribution of establishments by size and region is shown in Table 1.

Table 1: Distribution of Establishments in the D&B Frame

	Size (number of employees)			
	Small (3–50)	**Medium (51–200)**	**Large (201–1000)**	**Total**
Region				
1. Coastal South	49,559	2,047	354	**51,960**
2. Coastal North	28,389	1,262	180	**29,831**
3. Inland South	41,032	1,607	219	**42,858**
4. Inland Central	16,803	696	120	**17,619**
5. Inland North	9,044	353	43	**9,440**
Total	**144,827**	**5,965**	**916**	**151,708**

Stratification by Size and Region

The D&B database does not contain information on the size of each building. However, it does contain a count of the number of employees in each establishment. Although the correlation between the number of employees and the size of the building is not perfect, there is enough of a correlation to use the number of employees as a rough proxy for square footage. In other words, by stratifying the D&B database by the number of employees in each establishment, it was possible to ensure a distribution of the sample over buildings of various sizes.

For purposes of stratification by the number of employees, it was sufficient to divide the D&B database into three categories:

- small: 3–50 employees
- medium: 51–200 employees
- large: 201–1000 employees

Notice that establishments with only one or two employees were excluded, since the buildings that they were housed in were the ones most likely to fall under the minimum required building size of 1,000 square feet. Establishments with more than 1,000 employees were also excluded, since they were the ones most likely to be housed in buildings over the maximum allowable building size of 50,000 square feet.

The overwhelming majority of the establishments in the D&B database fall into the "small" category (3 to 50 employees). A simple random sample of establishments would therefore have generated a sample of mostly small buildings. To include more medium-sized and larger

buildings in the sample, it was necessary to sample the "medium" and "large" strata at a higher rate than the "small" stratum.

Furthermore, since the southern regions of the State are much more populated than the northern regions, a random sample of buildings would have resulted in a sample distributed primarily in the South. To distribute the sample evenly across the various climate zones, it was necessary to oversample the northern regions. And since it was desirable to include more medium-sized and larger buildings in every region, it was necessary to stratify on both variables simultaneously and oversample the medium and larger buildings within each region.

Allocation of the Sample to the Various Strata

Given the uneven distribution of the population of establishments and buildings across the various climate regions and size categories, each size-region stratum was sampled separately. Each region was allocated 1,500 selections as its initial sample size. Within each region, the medium- and large-size categories were oversampled, compared to the more numerous small-size category.

The final allocation of the sample is shown in Table 2.

Table 2: Allocation of the Sample to Region and Size Strata

	Size (number of employees)			
	Small (3–50)	**Medium (51–200)**	**Large (201–1000)**	**Total**
Region				
1. Coast - South	600	600	300	**1,500**
2. Coast - North	720	600	180	**1,500**
3. Inland - South	681	600	219	**1,500**
4. Inland -Central	780	600	120	**1,500**
5. Inland - North	1,104	353	43	**1,500**
Total	**3,885**	**2,753**	**862**	**7,500**

The target sample size for each region-size category was communicated to Dun & Bradstreet, which drew simple random samples from each of those categories. The total number of establishments initially selected for the study was 7,500. This number of selections was greater than were expected to be used for the study, but it was necessary to have extra cases available, since the rate of eligibility and the eventual response rate were unknown.

Division of the Sample Into Random Replicates

Data collection was expected to be rather challenging. It was expected that many of the selected buildings would be ineligible for the study and many of the informants at eligible buildings would refuse to complete the interview. So the plan was to select a large initial sample and use only a random part of it, as needed, to obtain at least 400 completed interviews.

The sample in each of the 15 region-size strata shown in Table 2 was divided at random into 10 segments, called "replicates" because each segment was a randomized replication of the full stratum. Field work was started with a few of the replicates, and then more replicates (complete or partials) were added as time and budget allowed. By the end of the study, 3,986 of the full sample of 7,500 establishments had been put into the field. The outcome of the attempts to interview an informant at those 3,986 establishments is presented in Chapter 3.

Questionnaire Design

Before beginning the data collection phase of the study, a list of questions was developed by LBNL, ARB, UC Davis, and Energy Commission researchers to ask SMCB occupants to report on the design and performance specifications for HVAC systems, for HVAC control systems, for natural ventilation provisions, and for air filtration systems in SMCB in California.

The list also contained questions about the O&M characteristics of SMCBs, their basic construction details, the parameters affecting airtightness of the buildings, potential indoor pollutant sources, nearby point emission sources, and any histories of moisture problems. This list also contained questions to help assess the possible correlation between SMCB building and equipment characteristics and the potential for poor IAQ and ventilation.

In addition, the list of questions sought to obtain the data required to generate the frequency distribution of various building use types, occupancy, ventilation and source types in SMCBs, to help prepare and create a sampling frame for the follow-on study and to help refine its procedures.

Survey Research Center questionnaire construction experts assisted LBNL, ARB, and Energy Commission researchers by refining the questions to ensure that they were clear, unambiguous, unbiased, and well written, and that they contained answer categories that were comprehensive but not overlapping. Survey Research Center staff also suggested question ordering to maximize the effectiveness of the question series.

Focus Group as Part of Questionnaire Development

As part of the development of the questionnaire, SRC staff conducted a focus group for owners or building managers from a sample of SMCBs in the San Francisco Bay Area. Four 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. Prior to the focus group, all respondents were mailed a printed copy of the question list, to help them prepare for the group meeting.

There was concern among the research teams that some eligible respondents would be able to answer questions about the building itself but not about the details of the HVAC equipment, or

vice versa. This prompted the researchers to inquire during the focus group about the respondents' perception of whether they and others like themselves could answer both types of question sets.

There was general agreement among the focus group members that it would be relatively easy to answer the questions about the building by telephone, but that the detailed questions about the HVAC systems would be very difficult to answer by telephone. The participants indicated that as many as six different individuals associated with their buildings might have to be interviewed to get all of the survey questions answered. All agreed that the HVAC questions could not be answered without physically looking at the equipment, and that these questions would be hard to answer "off the cuff" on a telephone interview.

Members of the research team from ARB, LBNL, and SRC discussed the focus group results a few days after the event. Based on the focus group experience, the researchers decided that the best way to capture both the building information and the HVAC data would be to create two different questionnaires. Therefore, the building questions were prepared for data collection as a telephone interview, while the HVAC questions were made into a self-administered questionnaire that would be mailed to each respondent who completed the telephone (building) interview. The final questionnaires were revised accordingly and can be seen in Appendix C (telephone questionnaire) and Appendix D (HVAC questionnaire).

Procedures for the Telephone Interview

Telephone calls were placed to the number associated with each selected business or office. Any person answering the telephone at the selected business or office was asked four screening questions. These questions were used to determine whether or not the building in which the business or office was located qualified for the study:

- "How many stories is the building?"
- "Is the building ventilated by one or more package rooftop heating ventilation and air conditioning, HVAC units?"
- "What is the floor area of the building?"
- "Was the building built after 1978?"

If the telephone informant (the person who answered the screening questions) answered that the building was three (3) stories or less, that the building had at least one package rooftop HVAC unit, that the floor area of the building was between 1,000 square feet and 50,000 square feet, and that the building was built after 1978 (meeting all four conditions), the building was considered eligible for the study. The informant was then asked, "What is the name of the person who can best answer questions about the building and the operation of the building (not necessarily the operation of the HVAC system)?" Once that person was identified and located, telephone interviews were attempted with the person named.

The telephone interview had questions about the selected building only. The questions about the operation of the HVAC system of the building were in the printed and mailed self-administered questionnaire described later.

The telephone interviews were conducted by SRC interviewers using SRC's Computer-Assisted Telephone Interviewing (CATI) system. The Center has installed equipment and support facilities for telephone interviewing, based on the CATI system developed by Berkeley's Computer-assisted Survey Methods (CSM) program. Under this method, interview questions are stored in computer memory, recalled in programmable sequences, and displayed for each interviewer on a computer screen. Interviewers enter the answers given by the survey respondents directly into the computer by keying in the appropriate response codes, thus eliminating the need for separate data entry and cleaning phases. The Survey Research Center's CATI facility used for this project had 32 interviewing stations and 4 supervisor stations.

At the conclusion of the telephone interview, the respondents were asked to identify the person who could best answer the questions about the HVAC equipment, with this question:

- "We'd like to find out some more specific information about the operation and maintenance of the ventilation (HVAC) system used in your building. We don't want do this now, but we would like to send a questionnaire in the mail. Are you the best person to send it to?"

If they indicated they were the best person to send it to, their name and mailing address were obtained and the printed mail survey questionnaire was mailed to that person.

If the telephone respondents indicated that they were not the best person to talk with about the HVAC equipment, they were asked:

- "What is the name of the person who can best answer questions about the ventilation system and the operation and maintenance of the ventilation system?"

The HVAC mail questionnaire was then mailed to that person.

Procedures for the Self-Administered Mailback Questionnaire

The Self-Administered Questionnaire (SAQ) that contained the detailed questions about the building's HVAC system was mailed to the contact person named at the end of the telephone interview as the best person to answer questions about the ventilation system. A cover letter and a self-addressed stamped return envelope were included in the SAQ mailing.

The completed SAQs were returned to SRC. Upon receipt of each SAQ, the Survey Research Center made an entry in the sample control system database that indicated the questionnaire was returned. The SAQ was then sent to SRC's data entry department. Data entry staff entered the answers to each returned questionnaire into the CASES entry system.

A second entry of the completed SAQ was done, and any discrepancies between entry number one and number two were identified. Such discrepancies were then resolved by the data entry supervisor who reviewed the SAQ, and a final entry for the discrepancy was made.

A unique identification number was assigned to each selected building and associated with both the telephone interview and the SAQ, so that the data from both interview types could be combined for analysis.

Quality Assurance and Quality Control Procedures

Testing the Questionnaire

The research team, led by LBNL researchers, prepared an initial list of proposed questions to be asked for the project. The initial list of questions was tested in a number of ways to ensure that the research goals of the project were adequately met. These tests began as SRC, ARB, and LBNL researchers critiqued and revised the question wording, order, and format through an iterative process. This led to a draft of questions that all on the research team agreed were the core questions that needed to be addressed.

Pilot Testing

The research team determined that a pilot test should be conducted to evaluate the decision to break the question set into two instruments: a telephone interview for the building questions and a questionnaire about the more technically difficult HVAC system that would be mailed.

A sample of California businesses was drawn by Dunn & Bradstreet for the purpose of pilot testing the questions after the questionnaire was split into two instruments. Survey Research Center interviewers telephoned this sample of 184 buildings to identify eligible buildings and attempt to complete a telephone interview with someone associated with the building who could answer questions about it. Although many sampled buildings were found to be ineligible, a total of 17 interviews were conducted with representatives of eligible buildings, then, just as in the planned project methodology, each interviewed person was asked to complete a printed questionnaire about the HVAC equipment. After this testing, the research team determined that the Dunn & Bradstreet sample list would be an acceptable one to use for the full survey. The team also agreed that the strategy to conduct the building interview over the telephone and obtain the HVAC data via a mailed-out, self-administered questionnaire was the best way to conduct the study.

Final revisions were made to the questionnaires, based upon the feedback received during the pilot testing. This final draft was delivered to ARB for their approval. Once ARB approval was obtained, the building questionnaire was programmed for the CATI system, and the HVAC final version was sent to be printed. The interviewing staff was trained and production interviewing began on the project on June 2, 2008.

Data Management and Cleaning

All data for the building questions were collected via CATI. This technology, in which the interviewer sits at a computer workstation with a telephone and headset, allows the

interviewers to ask questions that are stored in the computer memory, recalled in programmed sequences, and displayed for each interviewer on a computer screen.

The Computer Assisted Survey Execution System (CASES) package is a CATI software program that allows interviewers to enter the responses to the survey questions directly into computer files. Since the responses entered are almost all pre-coded responses with numerical values to represent each answer (for example, 1 to represent 'Yes', and 5 to represent 'No'), the "data entry" of such closed-ended variables is automatic. The CASES program ensures that all pre-coded data entered by the interviewers have valid codes and that all logical checks are enforced. In addition, all open-ended question responses are entered verbatim by the interviewer and stored automatically in electronic files.

Some of the advantages of the CATI system, compared to ordinary telephone interviewing, allow for automatic quality assurance and quality control, such as:

- Skipping to certain questions based on the answers to previous questions. This is handled by the computer, thus eliminating a major source of interviewer error in complex paper and pencil questionnaires.
- Interview questions can be modified automatically to insert information already obtained, such as names, or to phrase questions appropriate to personal characteristics such as sex or marital status.
- Programming the questionnaire in such a way that only valid response codes are accepted. Discrepancies between the responses of more than one question can be identified, so that clarifications can be obtained while the respondent is still on the telephone.

Additionally, the HVAC questionnaire was programmed with the CASES software for the direct data entry (DDE) of returned printed questionnaires. Besides the relevant program features identified above for the CATI interview, SRC used "gold standard" methods to ensure that the highest quality data was entered. Those gold standard measures were as follows:

- After receiving completed self-administered questionnaires from the field, the cases were numbered sequentially and filed according to work assignments.
- A direct data entry instrument using CASES 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 completed this process were 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.

Interviewer Training

All interviewers received training prior to the start of this project on general interviewing techniques, as well as on the intent of the questions specific to this study. With this training, interviewers would immediately recognize whether or not a valid response was given and be able to probe appropriately and neutrally for a response.

In an effort to obtain as high a response rate as possible, all interviewers received substantial training to help avoid initial refusals as well as to convert previous refusals. Once a case was coded as a refusal, it was returned to the field approximately one week later, for another attempt at completing the survey. Refusal conversion specialists were assigned the cases for these additional attempts.

Monitoring of Telephone Interviewers

Supervisory staff carefully monitored the performance of all interviewers every week. Immediate feedback was given to each interviewer regarding appropriate reading of the questions and answer choices, and for correct and neutral probing of ambiguous responses. Approximately 10 percent of experienced interviewers' telephone surveys were monitored each week, and the less-experienced interviewers had approximately 15 to 20 percent of their surveys monitored.

When an interviewer's work is "monitored," a supervisor remotely observes the interviewer's computer screen and listens, in real time, to both sides of the interview conversation (interviewer and respondent) without either party being aware of the third party. For all surveys conducted by CATI at SRC, as a measure of full disclosure, the interviewer reads a statement to the respondent that "the interview may be monitored for quality control purposes."

Outcome of the Sample of Establishments

Table 3 shows the various outcomes for the selected establishments. Of the 3,986 establishments selected for the study by Dun & Bradstreet, about two-thirds were ineligible for this study. Since the D&B database did not include information on the square footage of the building, the number of floors, the location of HVAC units, or the year the building was constructed, this rate of ineligibility was not surprising.

Among the 1,348 selected establishments that were determined to be eligible for the study, about two-thirds did not participate, mostly because of outright refusals. In the end, 476 of the

eligible establishments yielded a complete telephone interview, for an overall response rate of 35.3 percent.

The rate of completion of the supplementary HVAC self-administered questionnaire was not as great as had been hoped. The HVAC questions were too extensive and too complex to complete at the time of the telephone interview, so they were put into a supplementary HVAC questionnaire that were mailed to someone after the telephone interview had been completed. Most of the 476 telephone respondents were willing to receive the HVAC questionnaire, but only 57 fully completed HVAC questionnaires were returned, and another 14 partially completed (and partially usable) questionnaires were returned. Nevertheless, these 71 HVAC questionnaires provided some useful data for the analysis.

Table 4 shows how the significant outcome results were distributed among the fifteen strata made up of the five regions and the three size strata. The first column shows how many of the originally sampled establishments were subselected and put into the field for the telephone interview. Although the original allocation of the sample to the five regions was equal (1,500 establishments in each region), the number subselected for actual interviewing (based on budget projections) was a little more than half of that, and the proportion varied a little by region. Note that the total across all the strata is 3,986, which is the total at the top of Table 3.

The second column of Table 4 shows how many of the establishments put into the field and called were found to be eligible for the survey. Overall, only about one-third met the criteria for inclusion in the survey, and this varied somewhat across the various strata.

The final column of Table 4 shows how many of the eligible establishments actually yielded a completed telephone interview. Overall, the response rate was 35 percent, but it varied somewhat by region and especially by size. The informants reached in the smaller establishments often did not have the time available to do the telephone interview. The overall response rate for the small establishments was only 29 percent, compared to 42 percent for the medium and large establishments.

Within each region the larger establishments were oversampled, compared to the smaller ones. In fact nearly half of all the larger establishments in the target counties were included in the sample. Nevertheless, the completed sample is predominantly comprised of small- and medium-sized buildings (based on number of employees) simply because there are so many of them in the State.

The information in Table 4 could be used to construct weights for further data analysis. The unweighted data analysis included in this report provides basic and useful descriptive information about California SMCBs. However, given the complexity of the sample design, an estimation of the statewide prevalence of certain building characteristics would require a weighted analysis that goes far beyond the scope of the current project.

Table 3: Outcome of the Sample of Establishments

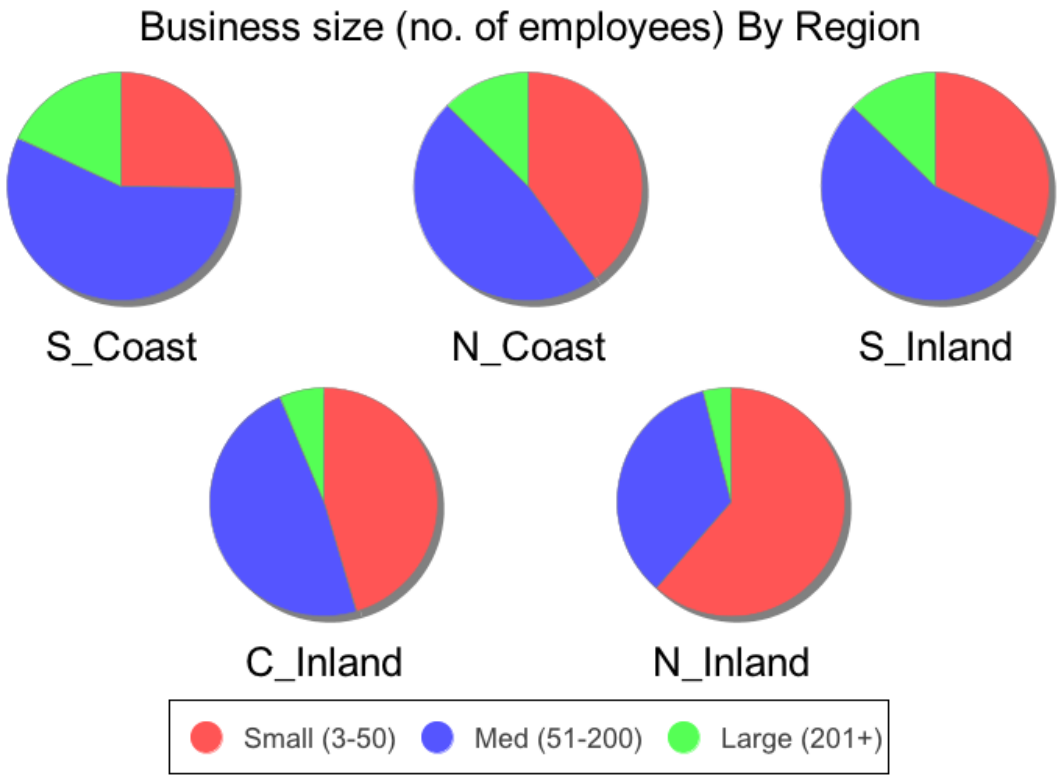
	Number	Percent of Total	Percent of Eligible
Total Establishments Selected	3,986	100.0	
Ineligible listing			
Out of business	368	9.2	
Residence	206	5.2	
Language barrier/other	36	.9	
Duplicate listing	11	.3	
Outside California	5	.1	
Subtotal	626	15.7	
Ineligible for this study			
Building has 4+ floors	231	5.8	
No rooftop HVAC unit	553	13.9	
Building too large or small	500	12.5	
Built before 1978	728	18.3	
Subtotal	2,012	50.5	
Total Ineligible	2,638	66.2	
Eligible for this Study	1,348	33.8	100.0
Non-response			
Informant refusal	122	3.1	9.1
Respondent refusal	453	11.4	33.6
No one ever available	230	5.8	17.1
Establishment not located	67	1.7	5.0
Total Non-Response	872	22.0	64.7
Completed Phone Interviews			
With supplementary HVAC	71	1.8	5.3
Without supplementary HVAC	405	10.2	30.0
Total Completed Phone Interviews	476	11.9	35.3

Table 4: Distribution of Sample by Region and Size Strata

Region / Size	Put into Field	Eligible	Completed
1. Coast-South / Small	312	115	21
Medium	312	123	47
Large	156	40	15
2. Coast-North / Small	396	100	32
Medium	330	95	38
Large	99	22	10
3. Inland-South / Small	354	112	33
Medium	312	119	56
Large	114	33	13
4. Inland-Central / Small	405	148	50
Medium	312	130	53
Large	63	17	7
5. Inland-North / Small	608	215	62
Medium	189	78	35
Large	24	6	4
TOTAL	3,986	1,353	476

The distribution of the completed telephone interviews within the five regions can be seen more easily from the following pie charts in Figure 1. Notice that the medium-sized buildings dominate in the first four regions; whereas, the small buildings make up the majority of the sample in the Inland-North region.

Figure 1: Distribution of Completed Interviews Within Each Region



Source: Author(s)

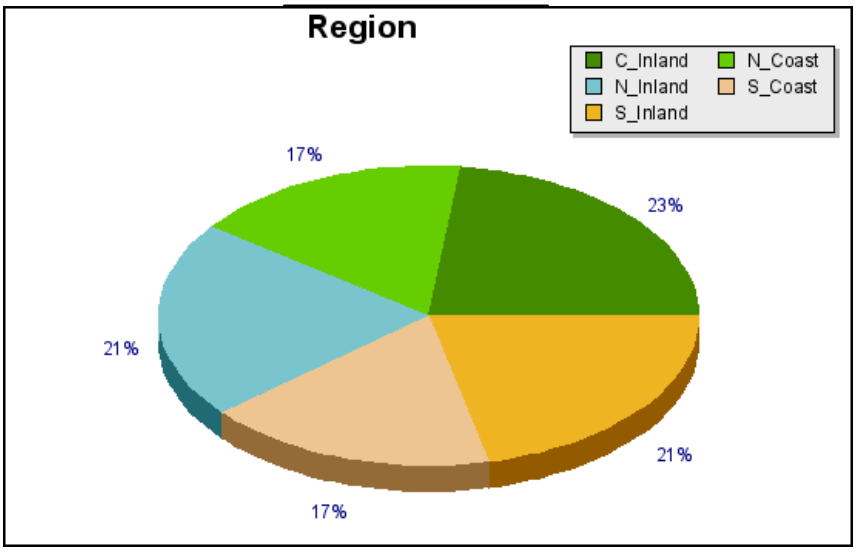
CHAPTER 3:
Results

Univariate Results of the Telephone and HVAC Surveys

Survey Characteristics

The study was conducted in five distinct climate regions of California. A total of 476 building respondents were interviewed over the telephone, with 17.4 percent of the buildings in the South Coast and 16.8 percent in the North Coast. Buildings located in the South Inland, Central Inland, and North Inland regions represented 21.4 percent, 23.1 percent, and 21.2 percent of the survey, respectively. See Figure 2.

Figure 2: Distribution of Completed Telephone Surveys by Region



Source: Author(s)

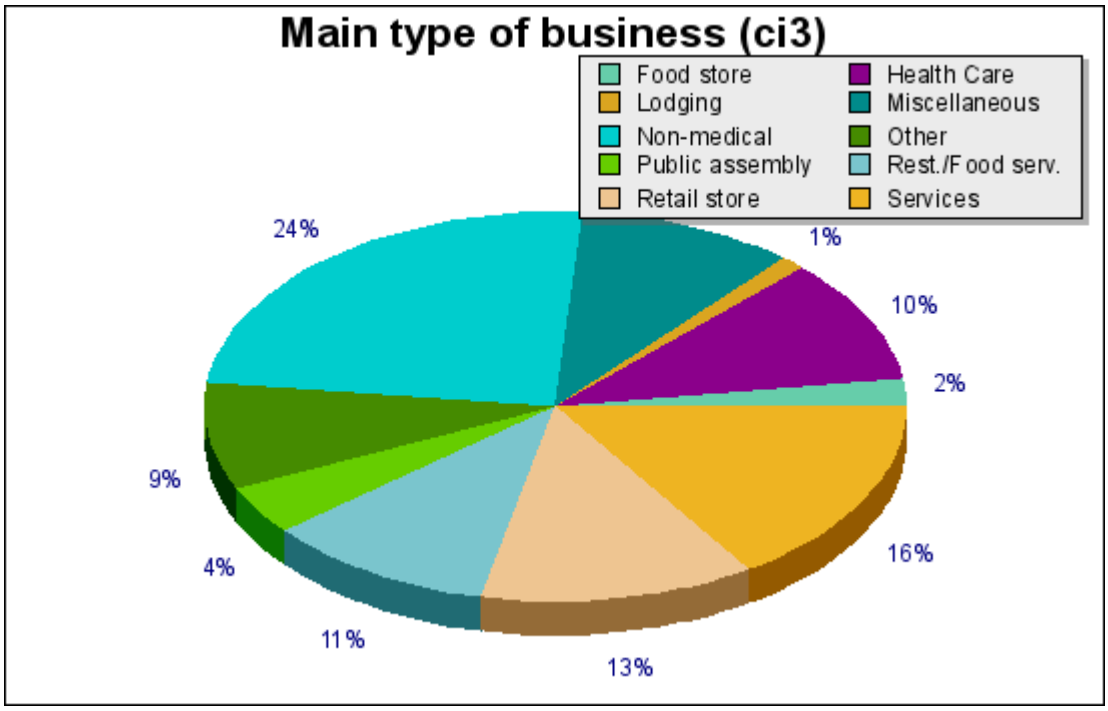
The buildings were divided by business size, with 41.6 percent being small businesses (3 to 50 employees), 48.1 percent being medium sized businesses (51 to 200 employees), and 10.3 percent consisting of large businesses (201 or more employees).

The main type of each survey respondent's business was given. Business types surveyed are listed in Figure 3 and Table 5. The contact did not necessarily represent the entire building, but reported the main business in the building. The main business represented in the survey are distributed as follows: 24.4 percent non-medical offices, 15.8 percent services, 12.6 percent retail stores, 10.7 percent restaurant/food service, 10.3 percent health care, 10.1 percent miscellaneous, 8.8 percent "other," 4.0 percent public assembly, 2.3 percent food stores, and 1.1 percent lodging.

The business types were sub-categorized, and those details follow here. Of the non-medical offices 1.7 percent identified themselves as data processing/computer centers, while 98.3 percent specified that they were "other." See Appendix A, #1, for the other types of business reported.

The healthcare business type was broken down into 8.2 percent hospital, 8.2 percent nursing home, 14 percent dental office, 2.0 percent orthodontist, 29 percent medical office, 22 percent clinic/outpatient, and 16 percent "other." Write-in business types for the "other" category included physical therapy, chiropractic, social services/mental health care, optical shop, blood collection, "pharmacy where they make drugs," blood banking, and headquarters for home care and hospice nursing.

Figure 3: Distribution of Main Business Type in the Telephone Survey



Source: Author(s)

Food service businesses consisted of 31 percent fast food/self-serve, 5.9 percent specialty/novelty, 61 percent table service, and 2 percent "other" (identified as "fast food – sit down"). Food stores were broken down into 46 percent supermarket, 18 percent specialty/ethnic, 9.1 percent convenience, and 27.3 percent "other." The "other" food store category was specified as "convenience with gasoline" and "wholesale food."

Retail businesses interviewed included 15 percent department/variety, 1.7 percent warehouse/club, 22 percent shop in strip mall, 23 percent auto sales, and 38 percent "other." See Appendix A, #2, for a list of the "other" business types reported.

Table 5: Types of Businesses Surveyed, and Percentage Distribution of Each

Business Type	Distrib. Percent	1st Business Sub-category	Distrib. Percent	2nd Business Sub-category	Distrib Percent
non-medical	24.4	data processing/computer	1.7	none	
		other	98.3		
health care	10.3	hospital	8.2	none	
		nursing home	8.2		
		dental office	14		
		orthodontist	2		
		medical office	29		
		clinic/outpatient	22		
		other	16		
restaurant/food svc	10.7	fast food/self serve	31	none	
		specialty/novelty	5.9		
		table service	61		
		other (fast food - sit down)	2		
food stores	2.3	supermarket	46	none	
		specialty/ethnic	18		
		convenience	9.1		
		other (convenience with gasoline, wholesale food)	27.3		

Table 5: Types of Businesses Surveyed, and Percent Distribution of Each (continued)

Business Type	Distrib. Percent	1st Business Sub-category	Distrib. Percent	2nd Business Sub-category	Distrib Percent
retail stores	12.6	department/variety	15	multi-purpose	14
		warehouse/club	1.7	clothing store	7
		shop in strip mall	22	drug store	2
		auto sales	23	hardware store	5
		other	38	furniture store	2
				flooring store	2
				bookstore	3
				dept. store	3
				auto. related	~21
lodging	1.1	hotel	80		
		resort	20		
public assembly	4	religious (worship only)	5.3		
		mixed use	32		
		health/fitness	16		
		movie theater	5.3		
		performing arts theater	5.3		
		other	36		
services	15.8	auto repair	6.7		
		gas station	4		
		non-automotive services	4.1		
		other	--		
misc./other	18.9	assembly/lt mfg	10		
		police/fire	40		
		other	50		

A second set of questions regarding retail stores asked for more detail on the "type of retail" if the respondent stated that they represented a retail business. "Multi-purpose" stores made up 14 percent of the responses (examples from the survey instrument were Target, Walmart, and

Kmart, although this is misleading because these businesses are typically larger than 50,000 ft^2), followed by clothing stores (7 percent). Drug stores, hardware stores, furniture stores, flooring stores, bookstores, and department stores were less common, making up 2 percent, 5 percent, 2 percent, 2 percent, 3 percent, and 3 percent, respectively. A full 63 percent of the retail stores did not respond to any of the above types, but information supplied showed that about one-third of these were automotive related, such as parts, dealerships, and tires sales. Other business types given included florists, business supplies, convenience stores, toy stores, jewelers, electronics and appliances, building materials, equipment rental, and a number of different types of supply houses.

Lodging business was split by 80 percent hotel and 20 percent resort. Public assembly was split into 5.3 percent religious - worship only, 32 percent mixed use, 16 percent health/fitness, 5.3 percent movie theater, 5.3 percent theater - performing arts, and 36 percent "other." The "other" category included bowling association, arcade, family fun center including laser tag, school, middle school, gambling casino, and preschool.

Service businesses broke down into auto repair (6.7 percent), gas station (4 percent), non-automotive services (41 percent), and "other." See Appendix A, #3 for a list of the other service businesses reported.

The "other/misc" business types included 10 percent assembly/light manufacturing, 40 percent police/fire, and 50 percent "other." See Appendix A, #4 for the other miscellaneous business types reported.

The building was owned by the business owner in 47 percent of the cases and leased in 53 percent of the cases in the survey. Seventy-five percent of the businesses used only one floor in the building, 21 percent used two floors, and 2.9 percent used three floors.

The survey identified information on the locale in which the buildings were situated. The mix included 37 percent urban, 45 percent suburban, 11 percent rural, and 6.4 percent "something else." The non-specified category included commercial areas, fairgrounds, industrial, industrial park, auto mall, surrounded by water, waterfront, business park, mountains, near airport, near rail yard. A number of the responses entered in the non-specified category could have been coded into the specific questions provided, such as the common response "business district" that could have been coded as "urban."

The locale was also described by land use type. The survey identified 19 percent of the buildings as being in an industrial location, while 52 percent were in a commercial location, 17 percent in a residential/resort-like location, 1.5 percent agricultural, and 9.5 percent "something else." The responses from "something else" are listed above with the "locale" question.

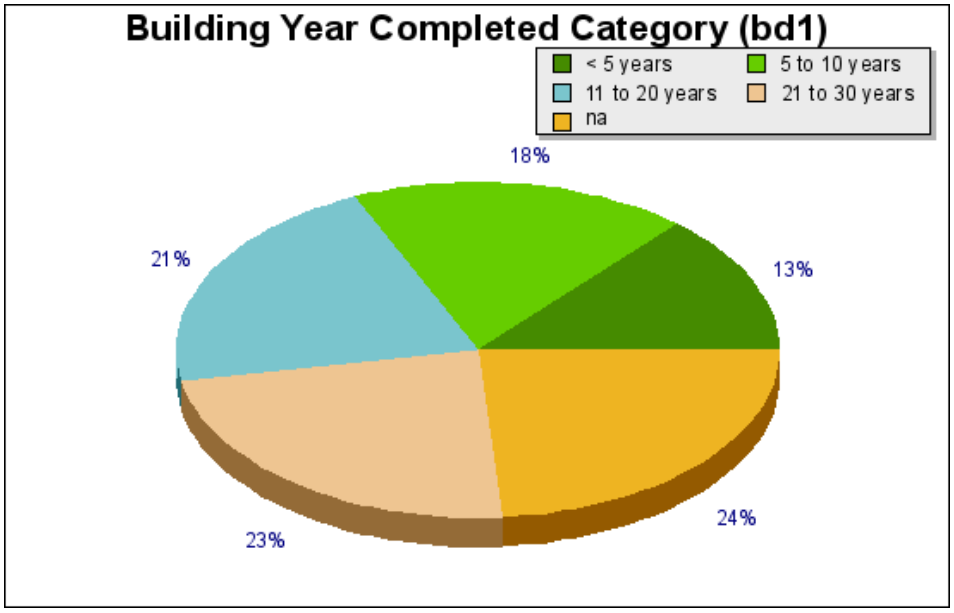
Building Characteristics

Information on building characteristics can be found in Table 6. Of the buildings in the telephone survey, 67 percent had only a single floor, while 28 percent had two floors, and 5 percent had three floors. The floor area of the buildings contacted ranged from 500 ft^2 to 50,000

ft², with 2 percent of the buildings having 1000 ft² or less, 22.7 percent having between 1000 and 5000 ft², 18 percent having between 5000 and 10,000 ft², 22 percent having between 10,000 and 20,000 ft², and 36 percent having between 20,000 and 50,000 ft².

The buildings' dates of construction ranged from 1989 to 2008 (Figure 4). Twenty-seven percent of the buildings were constructed between 1979 and 1985, 18 percent between 1986 and 1990, 14 percent between 1991 and 1995, 16 percent between 1996 and 2000, 19 percent between 2001 and 2005, and 7.2 percent between 2005 and 2008.

Figure 4: Years Since Surveyed Building Was Completed, at Time of Survey (2009)

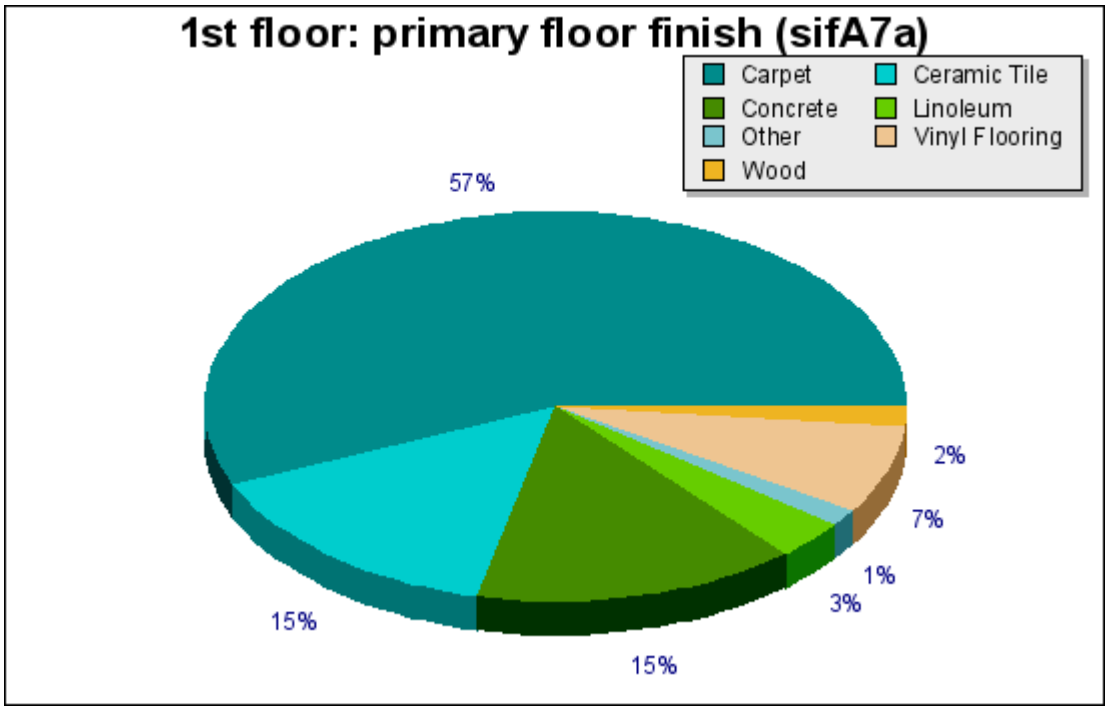


Source: Author(s)

Major renovations of, or additions to the buildings were identified by 22 percent of the respondents, while 78 percent said that the buildings had not been modified. Of those buildings that were modified, 4.3 percent occurred between 1976 and 1990, 4.3 percent between 1991 and 1995, 18 percent between 1996 and 2000, 26 percent between 2001 and 2005, and 47 percent between 2006 and 2008. Renovations included a new ventilation system (40 percent), new windows or doors (42 percent), weatherization (26 percent), or "other." See Appendix A, #5, for a list of the other renovations reported.

The survey asked what types of floor finishes that the buildings had (Figure 5). On the first floor, carpeting was common to 79 percent of the buildings, while wood flooring was present in only 7.4 percent, tile in 51 percent, concrete in 31 percent, vinyl flooring in 32 percent, linoleum in 25 percent, and "other" in 7 percent. The primary floor finish on the first floor was carpet for 57 percent of the buildings, wood in 1.7 percent, ceramic tile in 15 percent, concrete in 15 percent, vinyl in 7.2 percent, linoleum in 3.2 percent, and "other" in 1.5 percent. Other first floor materials that were related by the respondents include marble, slate, stone, travertine, granite, laminate, epoxy coating, spray on rubber, polyurethane, vinyl composition tiles, rubber carpet, non-ceramic composite tile, Pergo, and rubber matting.

Figure 5: Primary Floor Finish on the First Floor of Buildings



Source: Author(s)

On the second floor, carpeting was used in 93 percent of the buildings, wood in 7.9 percent, ceramic tile in 33 percent, concrete in 6.1 percent, vinyl flooring in 18 percent, linoleum in 18 percent, and "other" in 3.5 percent. The primary floor finish was carpet in 89 percent of the buildings and wood in 4.4 percent. Ceramic tile, concrete, linoleum, and "other" were present in 1 percent to 2 percent of the buildings' second floors.

Table 6: Distribution of SMCB Survey Building Characteristics

a. Building Characteristics: Number of Floors

Number of Floors	Distribution (%)
One floor	67.0
Two floors	28.0
Three floors	5.0

Table 6: Distribution of SMCB Survey Building Characteristics (continued)

b. Building Characteristics: Floor Area

Floor Area (ft^2)	Distribution (%)
< 1000	2.0
1000 - 5000	22.7
5000 - 10000	18.0
10000 - 20000	22.0
20000 - 50000	36.0

c. Building Characteristics : Date of Construction

Date of construction	Distribution (%)
1979 to 1985	27.0
1986 to 1990	18.0
1991 to 1995	14.0
1996 to 2000	16.0
2001 to 2005	19.0
2006 to 2008	7.2

Table 6: Distribution of SMCB Survey Building Characteristics (continued)

d. Building Characteristics : Date of Construction

Major renovations	Distribution (%)		Distribution (%)
Yes	22	**Date**	
		1976 to 1990	4.3
		1991 to 1995	4.3
		1996 to 2000	18.0
		2001 to 2005	26.0
		2006 to 2008	47.0
		Type	
		New ventilation	40.0
		New windows or door	42.0
		Weatherization	26.0
		Other	8.0
No	78		

e. Primary Floor Finish

Type of Finish - Primary Floor Finish	Distribution (%)
First floor	
Carpeting	57
Wood	1.70
Ceramic tile	15
Concrete	15
Vinyl	7.20
Linoleum	3.20
Other[a]	1.50

[a] includes marble, slate, stone, travertine, granite, laminate, epoxy coating, spray on rubber, polyurethane, vinyl composition tiles, rubber carpet, non-ceramic composite tile, Pergo, rubber matting

Table 6: Distribution of SMCB Survey Building Characteristics (continued)

e. Primary Floor Finish

Type of Finish - Primary Floor Finish	Distribution (%)
Second floor	
Carpeting	89
Wood	4.40
Ceramic, concrete tile, linoleum, other[a]	1–2
Third floor	
Carpet	100

f. Type of Finishing Present

Type of Finishing Present	Distribution (%)
First floor	
Carpeting	79
Wood	7.40
Ceramic tile	51
Concrete	31
Vinyl	32
Linoleum	25
Other[a]	7
Second floor	
Carpeting	93
Wood	7.90
Ceramic tile	33.00
Concrete	6.10
Vinyl	18.00
Linoleum	18.00
Ceramic, concrete tile, linoleum, other[a]	4

[a] includes marble, slate, stone, travertine, granite, laminate, epoxy coating, spray on rubber, polyurethane, vinyl composition tiles, rubber carpet, non-ceramic composite tile, Pergo, rubber matting

Table 6: Distribution of SMCB Survey Building Characteristics (continued)

f. Type of Finishing Present (cont'd)	
Type of Finishing Present	**Distribution (%)**
Third floor	
Carpet	100
Ceramic tile	27
Vinyl	21

g. Ventilation

	Distribution (%)		**Distribution (%)**
Did the building have windows that open?			
Yes	21	**Are they opened regularly?** Yes No	 51 49
No	79		
	Distribution (%)		**Distribution (%)**
Do you keep door(s) open regularly to facilitate ventilation?			
Yes	36	**How many doors do you keep open?** 1 2 3 4 >=5	 36 30 11 8 15
No	64%		

Table 6: Distribution of SMCB Survey Building Characteristics (continued)

h. Auxiliary Space Conditioning in First Floor

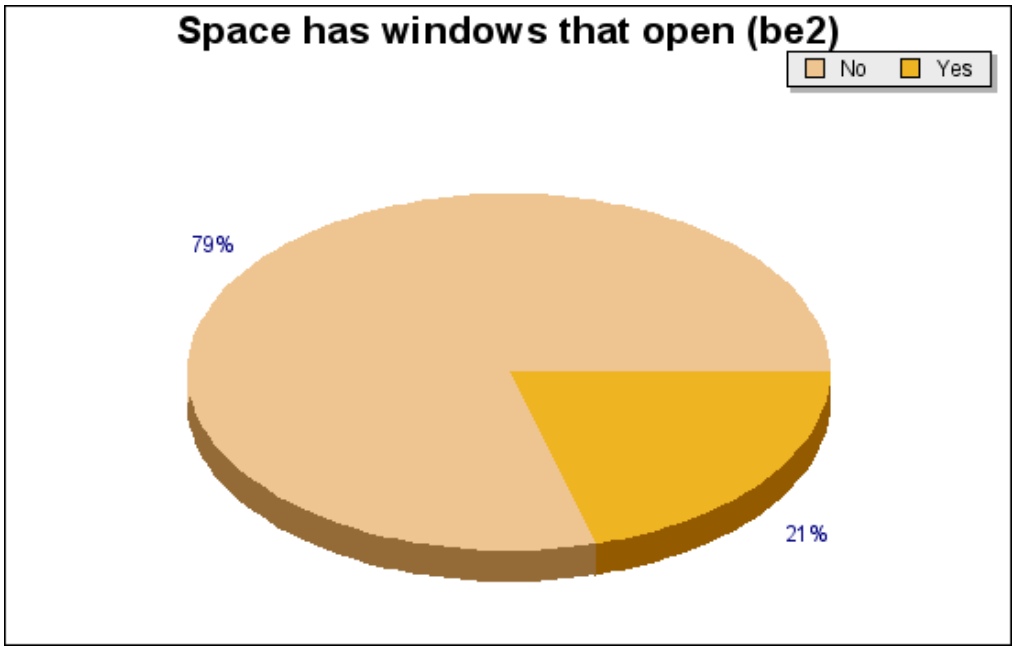
Auxiliary space conditioning	Distribution (%)	Number of Units	Distribution (%)
Air cleaners	11	1	30
		2	30
		3 to 5	20
		6 to 10	11
		>10	9
Humidifier	2	1	67
		2 to 3	33
Dehumidifier	2	1	50
		2	17
		>2	33
Desk fans	40	1	22
		2 to 5	53
		6 to 10	26
		>10	9
Space heaters	24		

On the third floors, carpet was present in 100 percent of the buildings, while wood, linoleum, and concrete were never identified. Ceramic tile was present in 27 percent of the third floor of buildings and vinyl flooring was present in 21 percent. Carpet was the primary finish in all of the third floors of the buildings.

Building Envelope

Windows that open were present in 21 percent of the buildings (Figure 6). Of those buildings with opening windows, 51 percent were reported to be opened regularly. Similarly, 23 percent of the buildings reported that they have doors that are kept open regularly that allow air to flow to or from outdoors, or between different ventilation systems. Of these buildings, 36 percent have one door open regularly, 30 percent have two open regularly, 11 percent have three doors open regularly, 8 percent have four open regularly, and 15 percent have five or more doors open regularly.

Figure 6: Percentage of Surveyed Buildings that Had Opening Windows



Source: Author(s)

Auxiliary Space Conditioning

The survey asked a series of questions regarding space-conditioning equipment.

When asked about the use of air cleaners on the first floor, 11 percent of the contacts stated that they were used. Of those buildings where they were used, 30 percent of the buildings had one unit, 30 percent used two, 20 percent use 3 to 5, and 11 percent use 6 to 10. More than 10 units were used on the first floor in about 9 percent of the buildings. The air cleaners were mechanical in about 44 percent of the cases and used pleated filters in 35 percent, ionizers in 13 percent, electrostatic precipitators in 16 percent, and ozone generators in 5 percent. Space heaters were used on the first floor by 24 percent of the buildings.

Only 2 percent of the buildings used a humidifier, and 2 percent used a dehumidifier on the first floor. About 67 percent of those using humidifiers used one unit, with 33 percent using 2 or 3. Similarly, about 50 percent of those using dehumidifiers used one unit, 17 percent used two units, and 33 percent used more than two units.

Desk fans were used on the first floor in 40 percent of the buildings. The number of desk fans used on the first floor ranged from 1 to 50 across the study: 22 percent have only 1 fan, 53 percent have 2 to 5 fans, 26 percent use 6 to 10 fans, and 9 percent use more than 10 fans.

Building Contaminant Source Information

Building contaminant source information from the survey is tabulated in Table 7. Water condensation was reported to ever be visible on windows or walls in 3.4 percent of the buildings. Of this small fraction of the sample with observed condensation, 88 percent saw it on

windows, 6 percent saw it on walls, and 6 percent of the buildings reported it on "other" places (unspecified). Visible condensation was seen at night in 13 percent of the buildings, and in the winter in 56 percent of the buildings, while 50 percent of those reporting visible condensation observed it at "other" unspecified times.

Visible water damage or mold was observed in 7 percent of the buildings. The survey also asked if there was water damage or mold in the past and found that it had been present in 20 percent of the buildings.

Table 7: Building Contaminant Source Information

a. Water

Water	Percent	Source	Percent	Source	Percent
water condensation	3.4	windows	88	night	13
		walls	6	winter	56
		other	6	other	50
water damage/mold	7				
past damage	20				

b. Cooking Appliances

Cooking Appliances	Percent use	Source	Percent use	Source	Percent use
office buildings	94				
restaurants	--	microwave oven	84	gas	80
		oven	86	electric	30
		grill/roast/fry	73	other	2
food stores	--	toaster/microwave/other	100		
retail stores	--	toaster/microwave	83	gas	40
with restaurant/café	14	oven	75	electric	100
		grill/roast	50		
		fry	50		

-- = Questions not asked from this group

Table 7: Building Contaminant Source Information (continued)

b. Cooking Appliances

Cooking Appliances	Percent use	Source	Percent use	Source	Percent use
health care buildings	96	oven	--	gas	67
with restaurant/café	6	grill/roast	80	electric	40
		fry	100		
Lodging	80	oven	--	gas	100
with restaurant/café	100	grill/roast	67	electric	0
		fry	33	other types	0
public assembly	68	oven	89	gas	75
with restaurant/café	50	grill/roast	67	electric	37.5
		fry	33		
auto repair business (no gas sales)	--	toaster/microwave/other	60		
gas stations (no restaurant/café)	--	toaster/microwave/other	67		
non-automotive service	0				
assembly/manufacture	--	toaster/microwave/other	100		
police/fire/post office	95	oven	27	gas	62
		grill/roast	14	electric	46
		fry	12	other	5

-- = Questions not asked from this group

Table 7: Building Contaminant Source Information (continued)

c. Carpet

New carpeting	Percent	Source	Percent use	Source	Percent use
(on first floor within one year)	17	nylon	78	styrene-butadiene backing	7.1
				CRI "green" label	
		olefin (polypropylene)	17	backing	21
				other carpet backing	--
New Carpet Pad (with New Carpet)	**Percent use**				
rubberized/resinated fiber pad	5				
rubber/reinforced rubber pad	4				
polyurethane foam pad	3.6				
no carpet pad	80				
other carpet pad	--				

-- = Questions not asked to this group

Table 7: Building Contaminant Source Information (continued)

d. Furniture

New furniture	Percent	Source	Percent use	
(on first floor within one year)	22	solid wood	45	
		composite wood product	46	
		fully encapsulated composite wood	16	
		metal or plastic	57	
		wood, leather, fabric, glass, nylon, vinyl mix	15	

e. Paint

Recent Interior Paint	Percent		
(on first floor within one year)	43		

f. Fire Damage

Fire Damage	Percent		
(on first floor within 13 years)	2		

g. Film Processing

Film Processing	Percent		
food stores	10		
multipurpose retail/drug store	22		
health care facilities	19		
assembly/manufacture	0		

-- = Questions not asked to this group

Table 7: Building Contaminant Source Information (continued)

h. Solvents

Solvents Used	Percent		
multipurpose retail	0		
health care facilities	9		
auto repair (no gasoline)	20		
gas stations	0		
assembly/manufacture	20		

i. Grinding and Buffing

Grinding and Buffing	Percent		
multipurpose retail/hardware	36		
health care facilities	26		
auto repair (no gasoline)	60		
assembly/manufacture	20		

j. Tires

Tire Storage	Percent		
multipurpose retail	0		
auto repair shop	80		
gas stations	0		
assembly/manufacture	0		

-- = Questions not asked to this group

Cooking Appliances

The survey asked extensively about the presence of cooking appliances in the buildings. Office buildings were asked if any toasters, microwave ovens, or other such appliances were in use; 94 percent stated that they were. Restaurants had more detailed questions, with 84 percent using microwave ovens, 86 percent using ovens (80 percent gas, 30 percent electric, and 2 percent another type). Grilling, roasting, and frying were each reported by 73 percent of the restaurants. All food stores surveyed used toasters, microwave ovens, and other cooking

appliances. Retail stores reported using microwaves or toasters in 83 percent of the cases and had a café or cafeteria in 14 percent of them. Ovens were in use in 75 percent of retail stores that had a restaurant, with 40 percent of them using a gas oven and 100 percent using an electric oven; 50 percent perform roasting or grilling, and 50 percent fry with oil.

Health care buildings stated that they use cooking appliances in 96 percent of the cases. Of the health care buildings contacted, 6 percent of them stated that they had a restaurant on the premises. Of these, 67 percent used all gas ovens, while 40 percent also used electric ovens; 80 percent of these restaurants grilled or roasted, and 100 percent fry some food.

Eighty percent of the lodging businesses use cooking appliances. Of the lodging places contacted, 100 percent of them stated that they had a restaurant or café on the premises. Of these, 100 percent used all gas ovens, while no electric or other types of ovens were used; 67 percent of these restaurants grilled or roasted and 33 percent fry some food.

Public assembly businesses stated that they use cooking appliances in 68 percent of the cases. Of the public assembly places contacted, 50 percent of them stated that they had a restaurant or café on the premises. Of these, 89 percent used ovens (75 percent used gas and 37.5 also used electric ovens); 67 percent of these restaurants grilled or roasted, and 33 percent fry some food.

Sixty percent of the auto repair businesses with no gas sales stated that they use toasters, microwave ovens, or other such appliances. Sixty-seven percent of the gas stations contacted use these appliances, but none have a restaurant or café. None of the other businesses in the service category, which excludes food service, reported using cooking appliances.

Assembly/manufacturing businesses all stated that they use toasters, microwave ovens, or other cooking appliances.

Police, fire, or post office facilities reported that they used cooking appliances in 95 percent of the businesses contacted. Of these, 27 percent reported that they use ovens (62 percent gas, 46 percent electric, and 5 percent an oven fuel other than gas or electric). Grilling or roasting was performed in 14 percent of the businesses, and oil frying in 12 percent.

Film Processing

Food stores provided film processing in 10 percent of those responding. Multi-purpose retail and drug stores provided this service in 22 percent of those contacted, as did 19 percent of the health care facilities. When assembly/manufacturing businesses were asked if they processed film or performed x-rays, 100 percent said they did not.

Solvents Used

The survey asked about the use of solvents such as turpentine, ammonia, or acetone in a number of business types.

Multi-purpose retail stores all stated that they did not use solvents. Nine percent of health care facilities used solvents. Twenty percent of the auto repair shops with no gasoline sales that were contacted use solvents, but none of the gas stations contacted use solvents. Twenty percent of the assembly/manufacturing businesses contacted use solvents.

Grinding and Buffing

The survey asked about grinding and buffing in a number of business types.

Multi-purpose retail and hardware stores stated that they performed grinding and buffing in 36 percent of the buildings. Health care facilities performed grinding or buffing in 26 percent of those contacted. In the auto repair shops with no gasoline sales contacted, 60 percent perform these operations. Assembly/manufacturing businesses grind and buff in 20 percent of the cases contacted.

Tire Storage

All multi-purpose retail stores stated that they did not store tires; 80 percent of the auto repair shops do store tires. Of the gas stations contacted, none reported storing tires; likewise for assembly/manufacturing businesses.

Gas Station Special Sources

All of the gas stations contacted had a convenience store as part of the facility. Interestingly, none of the gas stations performed any automotive work.

Fire Damage

Two percent of the buildings reported having fire damage on the first floor. These fires had occurred over the last 13 years.

Recent Interior Painting

The survey identified that painting had been done on the first floor during the last year in 43 percent of the buildings contacted.

New Carpeting

The survey identified that new carpeting had been installed on the first floor during the last year in 17 percent of the buildings contacted. New nylon carpeting was installed in 78 percent of the cases, olefin (polypropylene), 17 percent. New styrene-butadiene carpet backing was used in 7.1 percent of these buildings, Carpet and Rug Institute (CRI) "Green" Label backing used in 21 percent, and "other." The "other" category responses included "no backing," "glued down," "recycled carpet," and "do not know." Carpet pad materials included rubberized or resinated fiber (5 percent), rubber or reinforced rubber (4 percent), polyurethane foam (3.6 percent), "no carpet pad" (80 percent), and something else ("rag pad," "replaceable squares").

New Furniture

The survey identified that new furniture had been installed on the first floor during the last year in 22 percent of the buildings contacted. In 45 percent of the buildings a new furniture material was solid wood (raw, wood finish, or painted). In 46 percent of them it was a composite wood product with wood or synthetic veneer. 16 percent of the buildings had furniture with fully encapsulated composite wood construction. Finally, 57 percent of the buildings had new metal or plastic furniture, and another 15 percent with a mix of wood, leather, fabric, glass, nylon, and vinyl materials.

Building Characteristics in the HVAC Survey

Of the buildings in the HVAC survey, 61 percent had a single floor, 33 percent had two floors, and 6 percent had three floors. Ceiling height of the first floor ranged from 8 feet to 27 feet. Seventy-four percent of the buildings had first floor ceiling heights between 8 feet and 10 feet, while 8 percent had 12-foot ceilings. The remaining 18 percent of the first floor ceiling heights were evenly distributed from 13 feet to 27 feet.

First floors with suspended ceilings were reported in about 83 percent of the buildings. Ceiling plenum depth ranged from 1 foot to 15 feet, with 62 percent being 2, 3 or 4 feet deep. About 15 percent of the buildings had ceiling plenums between 10 feet and 15 feet deep. Second floor ceiling heights ranged from 8 feet to 20 feet with 85 percent being from 8 feet to 10 feet high. Information on suspended ceilings on the second and third floors is poor, with 65 percent and 93 percent of the buildings not reporting, respectively. Of those with a response, 92 percent of the second floors and 75 percent of the third floors had suspended ceilings. The second floor ceiling plenum depth ranged from 1.5 feet to 8 feet, with 84 percent measuring 4 feet deep or less. Only two of the 71 buildings (3 percent) reported ceiling plenum depths; 1.5 feet and 4 feet.

Supplemental air conditioning devices were reported in 27 percent of the buildings and supplemental heating devices were reported in 27 percent of them.

The ventilation system in the space had been reconfigured in 37 percent of the buildings.

When asked for a count of air supply vents from the HVAC system in the building, 27 percent of the respondents did not reply. Of those who did, 13 percent reported 1 to 5 supply vents, 23 percent reported 6 to 10, 21 percent reported 11 to 30, 17 percent said 31 to 50, 13 percent reported 51 to 100, and 11 percent reported 101 to 250. Buildings reported supply vents in the ceiling in 94 percent of the cases, while wall vents were only reported in 9 percent. For those few buildings with wall vents, all of them reported that they were in the upper half of the wall, while 20 percent also reported vents in the lower half of the wall, None of the buildings reported that the wall vents were located in the middle of the wall or at multiple heights. Only one building (< 1 percent) reported supply vents in the floor. A summary question indicated that 94 percent of the buildings use ceiling diffusers as the primary air supply vent source, while 3 percent reported using upper half of the wall supply registers, and two more buildings (3 percent) reported fan coil/unit ventilators as the primary supply.

None of the buildings reported having fan coils or unit ventilators in the building, although only one respondent actually completed this question. It is not clear whether these types or supply components are used.

When asked for a count of air return vents from the HVAC system are in the building, 23 percent of the respondents did not reply, Of those who did, 36 percent reported 1 to 5 supply vents, 20 percent reported 6 to 10, 20 percent reported 11 to 20, 11 percent said 21 to 50, and 13 percent reported 51 to 100. Buildings reported return grilles in the ceiling in 98 percent of the cases, while (high side) wall vents were only reported in 2 percent.

No respondent (0 percent) provided the air flow supply rate of their air handlers. Outdoor air supply strategies varied across the buildings. Although 30 percent did not answer the question related to this, 24 percent of the respondents stated that they provide 100 percent outside air, 30 percent provide a fixed minimum outside air setting, 30 percent use an economizer cycle, 14 percent an enthalpy economizer cycle, and 2 percent stated "something else."

To maintain minimum outside air flow, 67 percent of the buildings use fixed damper position. Other methods include supply/return fan tracking (2 percent), intake airflow monitoring (7 percent), demand control ventilation (19 percent), and "something else." Minimum outside air damper settings ranged from 5 percent to 50 percent. Minimum outdoor air damper settings from 5 to 10 percent were reported in about 26 percent of the buildings, from 11 to 20 percent in 56 percent of the buildings, 20 to 28 percent in 13 percent of the buildings, and 30 to 50 percent in 4 percent of the buildings.

When asked the make and model of the HVAC unit with the greatest airflow capacity (Rooftop Unit #1) 41 of the 71 (58 percent) of the buildings did not respond. Of those that did respond, Trane was the most frequent manufacturer (37 percent), followed by Carrier (27 percent). Eight other manufacturers were listed, representing a share of 3 percent to 7 percent each. The reported companies include AAON, ARCO Aire, BDP/Carrier, Bryant, Janitorioh, Payne, Rheem, and York. A similar mix of manufacturers were reported for the second (Unit #2) or third (Unit #3) largest units in each building, but the frequency of missing responses increased with these questions.

Exhaust fans were reported as not used in 48 percent of the buildings. One to five exhaust fans were used in 29 percent of the buildings, 6 to 10 fans were used in 6 percent, and 25 fans were reported in use in 1 percent of the buildings. The survey asked for information on the details of up to five exhaust fans in use in the buildings. Only 13 percent of the buildings reported flow rates for the first fan. Of these fans, one-third were rated at 200 cubic feet per minute (CFM), another third were rated between 350 and 900 CFM, and the last third were rated between 1413 and 3044 CFM. As with fan flow, only 27 percent of the buildings reported floor area served by the exhaust fans; 43 percent of the buildings reported that the first fan served from 25 to 200 ft^2, another 21 percent served between 200 and 400 ft^2, and 29 percent of the buildings had the first fan serving between 400 and 2000 ft^2. One building's fan served 20,400 ft^2.

Information on exhaust fan control strategies was not answered by about 75 percent of the buildings. About half (47 percent) of those who answered used manual control of the exhaust fans, while 39 percent used time of day control, and 11 percent used temperature control. "Other" (not specified) control strategies were reported by 5 percent of those who answered the question. Makeup air supply was reported to be used by 45 percent of the buildings who answered the question. Responses for the additional four exhaust fans follow a similar pattern to those reported here, with increasing numbers of non-respondents. The details may be seen in Appendix F.

Package rooftop HVAC units (RTU) were reported as not used in 12 percent of the buildings. Twenty-one percent of the buildings used one RTU. Two to five RTUs were used in 35 percent

of the buildings, 6 to 10 RTUs were used in 16 percent, 11 to 25 were used in 12 percent, and 26 to 35 RTUs were reported in use in 3 percent of the buildings. The survey asked for information on the details of up to 3 RTUs in use in the buildings.

Particle filtration was reported in use in 97 percent of the buildings, with gaseous filtration in 2 percent and multifunction air cleaning reported in 2 percent (with 17 percent not reporting filtration type). None of the 71 buildings surveyed used an electronic air cleaner. None of the respondents were able to report the particle filtration make or model. Only three of 71 buildings reported particle removal efficiency ratings, i.e., MERV ratings, for filters in air handlers. There were two filter systems with a MERV rating of 8 and one filter system with a MERV rating of 12.

The filter bank area reported ranged from 3 ft^2 to 1350 ft^2, with 67 percent reporting 20ft^2 or less, 14 percent reporting between 21 and 100 ft^2, and about 19 percent reporting between 100 and 1350 ft^2. A full 70 percent of the respondents did not report filter bank area.

Rooftop unit filter media was polyester in two-thirds of the buildings responding to the question, 28 percent fiberglass, and 6 percent "other." Half of the respondents did not answer about filter material type. None of the respondents reported using roll type filters, only panel filters. Likewise, all of the reported panel filters were reported to be dry, with none reporting the use of viscous filter media.

Use of panel filter media was reported by 28 percent of the respondents, while 70 percent reported using pleated media, and 6 percent also reported using HEPA panel filters. No bag panel filters were reported. As with ventilation fans, responses for the additional two RTUs follow a similar pattern to those reported here, with increasing numbers of non-respondents for the additional RTUs. Again, the details may be seen in Appendix F.

The survey asked about the use of air washer systems with a RTU. All of those answering the question (about 65 percent) did not use an air washer. Similarly, only one of the 48 buildings responding to whether they use a humidification system answered in the affirmative (2 percent).

Response to the questions regarding filter make and model were also frequently not answered. The filter manufacturer for Rooftop Unit #1 (85 percent missing) was essentially evenly distributed across 10 companies. Econo Filter was listed for two buildings, while each of the following was listed for only one building: AAF International, Aeroplant, Ecoaire, Flanders, Glass Floss, Perfect Pleat, Purcolator, Purilator, and Tri Dib Filter. Units #2 and #3 had a similar mix of manufacturers as Unit 1.

Maintenance

HVAC Survey

About 75 percent of the buildings receive their routine maintenance from outside contractors, while the building manager, and janitorial staff provide it in 11 percent and 8 percent of the buildings, respectively. Six percent of the buildings reported receiving their maintenance in other unspecified ways.

Training of these maintenance personnel was largely (79 percent) through licensing, while 10 percent of the buildings reported that these staff held a certificate, and 7 percent had on-the-job training. A small fraction of buildings reported that their maintenance staff had either no training (1 percent) or "other" unspecified training (1 percent).

Package rooftop units are inspected on a regular schedule in 83 percent of the buildings, while 15 percent do inspect the systems, but not regularly. The survey reports that 2 percent of the buildings do not inspect their units. Of those buildings that regularly inspect their units, 52 percent do so every three months, and 19 percent do so more frequently. About 20 percent do the inspections between every four to every six months, while 7 percent only inspect their systems every year.

Particulate filters are used in the HVAC systems of 82 percent of the buildings, and of these, 86 percent of the buildings have them replaced on a regular schedule, while 14 percent do not replace them with regularity. Of the 86 percent of buildings that do replace their filters regularly, 54 percent do so every three months. About 23 percent replace them every one or two months, while about 18 percent replace them between every four and every six months. Five percent of the buildings replace them annually.

Electronic particulate filters were only used in 1 percent of the buildings surveyed. The respondent said that it was inspected and cleaned regularly, on a cycle of three months.

The survey asked about inspection of cooling/heating coils in the HVAC units. Fifty-eight percent of the respondents did not answer this question. Of those who did, 83 percent said that they regularly inspected them, 7 percent said that they inspected them but not regularly, and 10 percent said that they never inspect them. Fifty seven percent of the buildings that responded inspect the HVAC coils every three months, while about 25 percent inspect them more frequently, about 14 percent inspect them every four months and 5 percent only once a year. Note that these data are of poor quality because of the very high non-response rate.

The survey asked about cleaning of cooling/heating coils in the HVAC units. Fifty-four percent of the respondents did not answer this question. Of those who did, 72 percent said that they regularly clean their coils, 19 percent said that they clean them but not regularly, and 9 percent said that they never clean them. Twenty seven percent of the buildings responding clean the HVAC coils every three months, while about 23 percent clean them more frequently. About 24 percent clean them every four to six months and 32 percent only once a year. Note that these data are of poor quality because of the very high non-response rate.

Similarly, the survey asked about inspection of drain pans in the HVAC units. Sixty-eight percent of the respondents did not answer this question. Of those who did, 81 percent said that they regularly inspected them, 9 percent said that they inspected them but not regularly, and 9 percent said that they never inspect them. Fifty-two percent of the buildings inspect the HVAC drain pans every three months, while about 25 percent inspect them more frequently. About 16 percent inspect them every four to six months and 8 percent only once a year. Note that these data are of poor quality because of the very high non-response rate.

The survey also asked about cleaning of drain pans in the HVAC units. Ninety-one percent of the respondents did not answer this question. Of those who did, 14 percent said that they regularly clean their drain pans, 43 percent said that they clean them but not regularly, and 43 percent said that they never clean them. None of the buildings reported how frequently they clean their HVAC drain pans.

Although 73 percent of the buildings did not answer how frequently they conduct a test of the HVAC drain line, 26 percent of those who answered inspect the drain line every three months. About 26 percent inspect them more frequently, while 21 percent inspect them every four to six months, and 26 percent inspect them every 12 to 13 months. Again, note that these are poor quality data due to the low response rate.

The survey asked about inspection of HVAC ductwork. Forty-six percent of the respondents did not answer this question. Of those who did, 18 percent said that they regularly inspected ductwork, 42 percent said that they inspected it but not regularly, and 39 percent said that they never inspect ductwork. One-third of the buildings inspect the HVAC ducts every three months, while about 17 percent inspect them more frequently. About 33 percent inspect them every four to six months and 17 percent only once a year. Note that these data are of very poor quality because of the very high non-response rate.

The survey asked about cleaning of HVAC ductwork. Forty-eight percent of the respondents did not answer this question. Of those who did, 11 percent said that they regularly clean their ductwork, 22 percent said that they clean it but not regularly, and 68 percent said that they never inspect (clear) ductwork. One-third of those who state that they clean the HVAC ducts do so every three months, another 33 percent state that they clean them every four months, and the last third stated that they clean them only once a year. Note that these data are of extremely poor quality because of the very high non-response rate.

Information on rooftop HVAC unit testing and balancing was collected. About 18 percent of the respondents said that they test and balance their rooftop units, while 41 percent said that they do so, but not regularly. Another 41 percent say that they do not test and balance their rooftop HVAC units. Of those who do test and balance, 38 percent do so every three months, another 25 percent do it every four to six months, and 38 percent only once every year.

Operation

The telephone survey asked a series of questions regarding business hours at the buildings. The building was said to be open 24 hours per day, seven days per week (24/7) in 15 percent of those contacted. For those buildings not open 24/7, 98 percent opened in the AM, 2 percent opened in the PM on Monday–Friday (M–F). Similarly, for M–F, 5 percent of the building closed in the AM, and 95 percent closed in the PM. For Saturday schedules, 43 percent of the buildings open in the AM, 2 percent open in the PM, and 55 percent do not open. Closing on Saturday occurs in the AM for 6 percent and 38 percent in the PM (55 percent closed). For Sunday schedules, 29 percent of the buildings open in the AM, 3 percent open in the PM, and 67 percent do not open. Closing on Sunday occurs for 3 percent in the AM and 29 percent in the PM (67 percent closed).

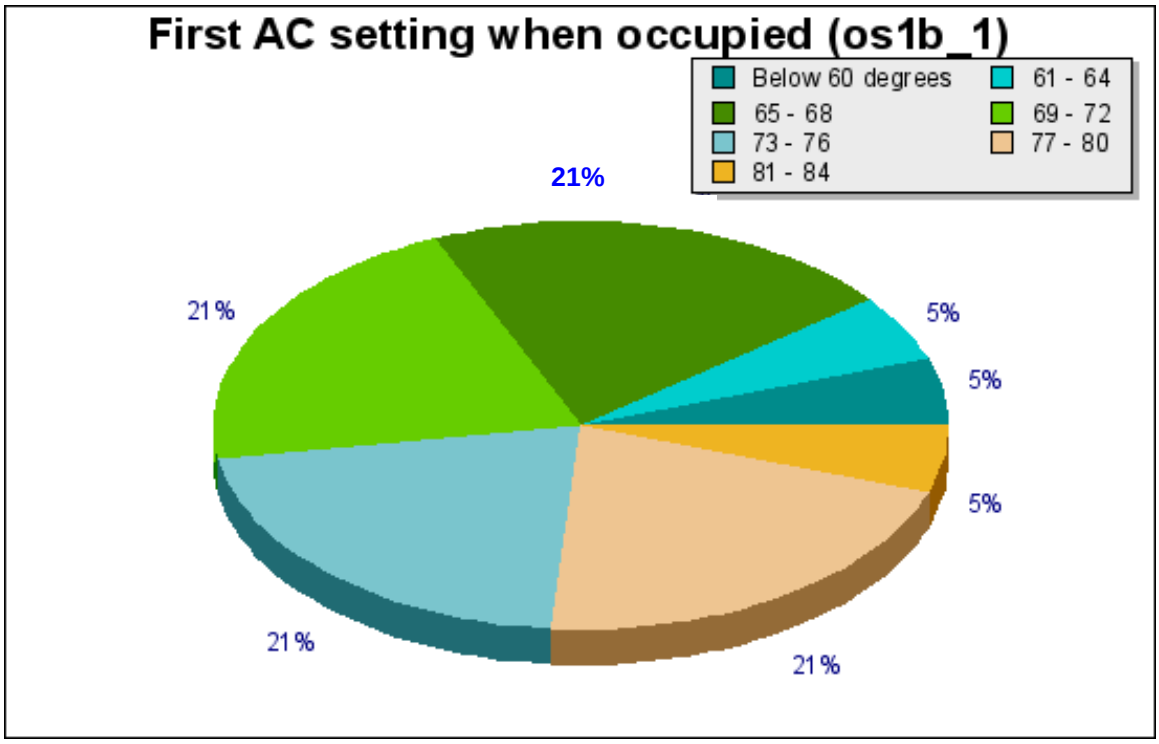
The distributions of opening and closing hours for the buildings that are open on particular days are shown in Table 8.

The survey also elicited information on the maximum number of employees and customers present in the buildings. The maximum number of employees ranged from 1 to 700 and the maximum number of customers ranged from none to over 1000. The distributions of these numbers are shown in Table 9.

Operating Schedule

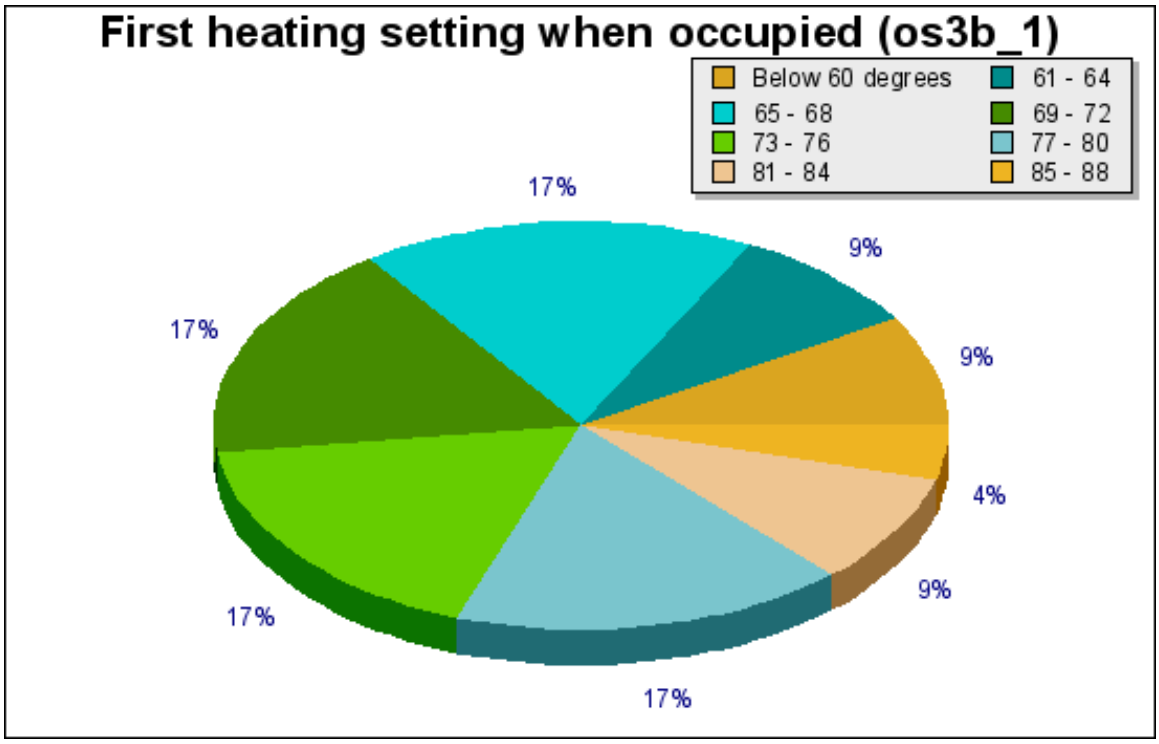
For most of the people who spent most of their time in the building in question (such as office workers), the telephone survey asked about the number of air conditioning temperature settings (when the building is occupied) and what those settings are. Fifty-four percent of the buildings use one thermostat setting, 45 percent use two or more settings, while 1 percent have their thermostats turned off or do not use them. Table 10 lists the distributions of first and second occupied thermostat temperature settings (also see Figures 7 and 8). Of interest is that 48 percent of the buildings reported both first and second thermostat settings ≤ 72°F (≤ 22°C).

Figure 7: First Air Conditioning Thermostat Setting When Occupied



Source: Author(s)

Figure 8: First Heating Thermostat Setting When Occupied



Source: Author(s)

Table 8: Opening and Closing Times of Businesses

Opening Time Monday-Friday	
< 6:00 AM	4.0%
6:00 AM–8:00 AM	29.0%
8:00 AM–10:00 AM	50.5%
10:00 AM–12:00 PM	14.6%
≥ 12:00 PM	1.49%
Closing Time Monday - Friday	
< 6:00 PM	47.0%
6:00 PM–8:00 PM	19.8%
8:00 PM–10:00 PM	12.4%
10:00 PM–12:00 AM	11.6%
12:00 AM–2:00 AM	4.7%
2:00 AM–4:00 AM	4.2%
Opening Time Saturday	
< 6:00 AM	3.9%
6:00 AM–8:00 AM	18.0%
8:00 AM–10:00 AM	43.3%
10:00 AM–12:00 PM	30.9%
≥ 12:00 PM	3.9%
Closing Time Saturday	
< 6:00 PM	27.4%
6:00 PM–8:00 PM	14.9%
8:00 PM–10:00 PM	26.0%
10:00 PM–12:00 AM	16.2%
12:00 AM–2:00 AM	14.9%
2:00 AM–4:00 AM	16.2%
Opening Time Sunday	
< 6:00 AM	0.8%
6:00 AM–8:00 AM	19.7%

Table 8: Opening and Closing Times of Businesses (continued)

8:00 AM–10:00 AM	26.8%
10:00 AM–12:00 PM	43.3%
≥ 12:00 PM	9.4%
Closing Time Sunday	
< 6:00 PM	8.7%
6:00 PM–8:00 PM	22.0%
8:00 PM–10:00 PM	21.3%
10:00 PM–12:00 AM	34.6%
12:00 AM–2:00 AM	7.1%
2:00 AM–4:30 AM	6.3%

Table 9: Maximum Employees and Customers Present in Buildings

Maximum Employees Present	
1–10	31.3%
11–20	15.0%
21–50	29.3%
51–100	16.3%
101–200	5.74%
201–500	1.76%
>500	0.44%
Maximum Customers Present	
None	7.55%
1–10	35.4%
11–20	13.7%
21–50	16.1%
51–100	6.61%
101–200	7.35%
201–500	9.69%
>500	3.79%

The survey also asked about the number of air conditioning temperature settings when the building is unoccupied. Thirty-one percent of the buildings use one unoccupied thermostat setting, 8 percent use two or more settings, and 57 percent have their thermostats turned off or do not use them when unoccupied. An additional 10 percent said that the building was always open or the question was otherwise not applicable. Table 10 lists the distributions of first and second unoccupied thermostat temperature settings. About 30 percent of unoccupied thermostat settings, when used, are reported to be ≤72°F (≤22°C).

Table 10: Thermostat Settings in ºF by Setpoints for Heating and Cooling

First Occupied Heating Thermostat Setting		**First Occupied AC Thermostat Setting**	
<60	0.8%	<60	0.5%
60–68	37.3%	60–68	11.1%
69–70	15.2%	69–70	11.1%
71–72	17.6%	71–72	24.0%
73–74	9.7%	73–74	22.6%
75–76	8.9%	75–76	16.2%
>76	10.5%	77–78	13.2%
		79–80	1.2%
		>80	0.2%
Second Heating Occupied Thermostat Setting (if > 1 settings used)		**Second occupied AC Thermostat Setting (if > 1 settings used)**	
<60	3.6%	<60	2.2%
60–68	38.1%	60–68	15.6%
69–70	11.9%	69–70	10.4%
71–72	23.8%	71–72	20.0%
73–74	11.9%	73–74	14.8%
75–76	3.6%	75–76	11.9%
>76	7.1%	77–78	9.6%
		79–80	9.6%
		>80	5.9%

Table 10: Thermostat Settings in ºF by Setpoints for Heating and Cooling (continued)

First Heating Setting when Unoccupied		First AC Setting when Unoccupied	
<60	14.8%	<60	3.6%
60–68	47.4%	60–68	10.1%
69–70	8.9%	69–70	6.6%
71–72	5.9%	71–72	9.5%
73–74	3.7%	73–74	7.7%
75–76	6.7%	75–76	9.5%
>76	12.6%	77–78	8.3%
		79–80	19.0%
		>80	25.6%
Second Heating Setting when Unoccupied (if > 1 settings used)		**Second AC Setting when Unoccupied (if > 1 settings used)**	
<60	6.7%	<60	0.0%
60–68	46.7%	60–65	19.1%
69–70	13.3%	66–70	9.5%
71–73	13.3%	71–72	4.8%
74–78	6.7%	73–74	9.5%
>78	13.3%	75–76	9.5%
		77–78	14.3%
		79–80	23.8%
		>80	9.5%

For most of the people who spent most of their time in the building in question (such as office workers), the telephone survey also asked about the number of heating temperature settings (when the building is occupied). Sixty-one percent of the buildings use one thermostat setting, 33 percent use two or more settings, and 5 percent have their thermostats turned off or do not use them. Table 6 lists the distributions of the first and second occupied heating thermostat temperature settings. Of interest is that the survey reports first and second thermostat settings > 74°F (> 23°C) at rates of 19 percent and 11 percent, respectively.

The survey also asked about the number of air conditioning temperature settings when the building is unoccupied. Twenty-eight percent of the buildings use one unoccupied heating thermostat setting, 6 percent use two or more settings, and 56 percent have their thermostats

turned off or do not use them when unoccupied. An additional 10 percent said that the building was always open or the question was otherwise not applicable. Table 10 lists the distributions of first and second unoccupied thermostat temperature settings. About 20 percent of unoccupied thermostat settings, when used, are reported to be > 74°F.

HVAC Survey

The HVAC (mailed) survey also queried about thermostat setpoints. The most common cooling setpoint range (49 percent) was 74°F to 76°F (23°C to 24°C) , while 32 percent of the buildings cool to 70°F to 73°F (21°C to 23°C) and 13 percent of the buildings cool to 77°F to 80°F (25°C to 27°C). Six percent of the buildings set their thermostats between 60°F and 69°F (16°C to 21°C).

Many buildings (25 percent) set their thermostats above 80°F when unoccupied, while 19 percent set it between 77°F and 80°F, 1.5 percent set it between 74°F and 77°F, 4.4 percent have settings between 70°F and 73°F, while 2.9 percent of buildings set their thermostats below 70°F when unoccupied. Interestingly, 34 percent of the buildings recorded a setting of "0" in the survey, suggesting that they turned the thermostat off when the building was unoccupied.

Thermostat setpoints for heating when the building is occupied range from 68°F to 80°F (20°C to 27°C). Sixty-one percent of the buildings report having settings between 68°F and 70°F, while 23 percent had settings from 71°F to 73°F (22°C to 23°C). Only 7.3 percent and 4.4 percent of the buildings report setting temperatures between 74°F and 76°F, and between 77°F and 80°F, respectively. No buildings reported setting temperatures above 80°F. One-and-a-half percent of the buildings recorded a setting of "0" in the survey, suggesting that they did not use heating.

Many buildings (46 percent) set their thermostats below 68°F when unoccupied, while only 1 percent set it above 80°F, 8.7 percent set it between 68°F and 70°F, 1.5 percent set it between 74°F and 76°F. A full 38 percent of the buildings recorded a setting of "0" in the survey, suggesting that they turned the thermostat off when the building was unoccupied.

The survey reports that 57 percent of the buildings start the HVAC system before the building is occupied. Seventy-four percent of those who do start the HVAC before daily occupancy do so to only heat or only cool the space, while 26 percent do so for both heating and cooling periods. Most commonly (39 percent), the building HVAC system comes on 60 minutes before occupancy, while 32 percent of buildings bring the system on 30 minutes or less before occupancy. About 19 percent of buildings operate the HVAC for between 60 minutes and 2 hours before occupancy. About 11 percent appear to leave their building's HVAC systems on continuously (this 11 percent consists of four buildings, of which only two were open 24 hours a day).

The survey also reports that the HVAC system is kept on after occupants have left the space in about 30 percent of the buildings. Most commonly (38 percent), the building HVAC system stays on 60 minutes after occupancy, while 32 percent of buildings leave the system on 30 minutes or less after occupancy. About 19 percent of buildings operate the HVAC for between 60 minutes and 2 hours after occupancy. About 11 percent appear to leave their building's HVAC systems on continuously.

The survey inquired about the use of the HVAC fan during occupancy, finding that about 21 percent of the buildings always left the fan on during occupancy. Only 1 percent of buildings reported that the HVAC fan was always left off during occupancy. Fan operation only during heating or cooling cycles was common to about 62 percent of the buildings, manual fan operation was only found in 13 percent of the buildings, fan operation on a scheduled timer was found to be the practice in about 23 percent of buildings, and the use of an occupancy sensor to activate the fan only occurred in 1 percent of the buildings. "Other" fan control strategies (unspecified) are used by 2 percent of the buildings.

When unoccupied, three percent of the buildings reported that they always leave their fan on, while 46 percent report that they always leave their fan off. Use of the fan during cycling of heating or cooling is common in 26 percent of the buildings when unoccupied. A scheduled fan timer is used in 19 percent of the buildings. It makes sense that no buildings use occupancy sensors to activate HVAC fans when unoccupied.

Cleaning

In 99 percent of the buildings surveyed, the respondents stated that cleaning of the first floor was done on a regular schedule. In 23 percent of the buildings cleaning was done during occupied hours, 54 percent during unoccupied hours, and 23 percent during both occupied and unoccupied periods. Building cleaning was performed 28 percent of the time during the day, 47 percent during the night, and 24 percent both day and night. Sixty percent of the buildings reported that an outside contractor did cleaning.

On the first floor, the survey reports that floors were cleaned with a wet mop in 87 percent of the cases, with 59 percent of these doing it daily, 18 percent once a week, 11 percent twice a week, 2 percent every 2 weeks, and 0.5 percent monthly. About 8 percent of the building provided a range of frequencies of floor cleaning, ranging from three times a day on work days, to an irregular use and cleaning schedule, to on request only, to "when customers complain."

Similarly, first floor cleaning with a dry mop was reported by 44 percent of the contacts. Daily cleaning was reported 74 percent of the time, weekly 9 percent, twice a week 8 percent, every two weeks 1 percent, and monthly 1 percent. About 7 percent of the respondents provided more detailed responses, including "as needed" to "all day long."

First floor cleaning with a vacuum cleaner was reported by 87 percent of the contacts. Daily vacuuming was reported 56 percent of the time, weekly 20 percent, twice a week 15 percent, every two weeks 1 percent, and monthly 1 percent. About 7 percent of the respondents specified "other," which was typically detailed with "as needed."

Window cleaner was used on the first floor in 89 percent of the buildings, with a frequency of daily (36 percent), once a week (23 percent), twice a week (5 percent), every two weeks (6 percent), monthly (13 percent), and "other" (16 percent).

Furniture cleaner was reported as being used on the first floor of 38 percent of the buildings with frequency of daily (25 percent), weekly (28 percent), twice a week (8 percent), every two

weeks (4 percent), and monthly (14 percent). Nineteen percent of the buildings reported "other," but this was not specified.

Furniture wax use on the first floor was reported for 40 percent of the buildings, with application frequency ranging from daily (5 percent), weekly (8 percent), twice a week (2 percent), bi-weekly (5 percent), monthly (23 percent), and "other" 56 percent. The specifics of the "other" response were not reported.

Bathroom cleaner application on the first floor was reported by 95 percent of the buildings. Sixty-seven percent of them use it to clean the bathroom daily, 15 percent weekly, 9 percent twice a week, 2 percent bi-weekly, and < 1 percent monthly; 5 percent stated that they used bathroom cleaner on an "other" frequency.

Bleach was used in first floor cleaning by 36 percent of the businesses. Fifty-five percent stated that they use it daily, weekly (17 percent), twice a week (9 percent), bi-weekly (4 percent), monthly (6 percent), and "other" (9.4 percent, not specified).

Use of soap and or detergent for cleaning on the first floor was reported by 82 percent of the businesses. This is done daily in 76 percent of the buildings, weekly (10 percent), twice a week (8 percent), bi-weekly (2 percent), monthly (< 1 percent), and "other" (4 percent, not specified).

Use of carpet cleaner for cleaning on the first floor was reported by 57 percent of the businesses. This is done daily in 4 percent of the buildings, weekly (4 percent), twice a week (< 1 percent), bi-weekly (2 percent), monthly (15 percent), and "other" (75 percent, not specified).

The survey identified that 24 percent of the buildings use other cleaning materials in the first floor that were not included in the questions above. These materials were not specified in the survey.

Propane floor buffers were said to be used on the first floor by 14 percent of the businesses.

The survey asked if there was any effort to use only "green" cleaning products, with 50 percent of the businesses reporting "yes."

A question asked where on the first floor the cleaning materials were stored. The janitor's closet was used in 58 percent of the buildings, 8 percent in another closet, 20 percent in a storage room, and 27 percent from "anywhere else" (examples: a wall-mounted unit, off site, under the kitchen sink, break room, under bathroom sink, garage outside, brought by janitorial service, maintenance office, table for cleaning stuff, chemical dispense system, various places, supply room, locked cabinet in back room, back dock, office, break room, sterilization room, housekeeping locker, and lab storage area.

Pesticide Application

Pesticide application on the first floor was reported by 61 percent of the businesses. Of those using it, 96 percent state that it is applied by an outside contractor, 2.6 percent by building staff, 2.2 percent by employees, and 1.5 percent by "other." Outdoor pesticide application was reported to be weekly by 4 percent of the buildings, monthly (64 percent), quarterly (17 percent), semi-annually (3 percent), not used (1 percent). Indoor first floor pesticide

application was reported to be weekly by 1 percent of the buildings, monthly (24 percent), quarterly (9 percent), semi-annually (4 percent), not used (35 percent), and "other" (27 percent).

Only 4 percent of the buildings reported storing pesticides onsite on the first floor. Of these, 14 percent used the janitor's closet, 57 percent used a storage room, or elsewhere (29 percent).

Occupant Environmental Satisfaction

A series of questions regarding occupant environmental satisfaction were asked. When asked if occupants complain about the indoor environment being too hot, 51 percent said yes. Of these, the frequency varied, with 19 percent having received a complaint once or twice, 43 percent not very often, 24 percent somewhat often, 8 percent very often, and 6 percent constantly.

A similar question asked about complaints of the building being too cold. About 19 percent had received complaints once or twice, 44 percent not very often, 20 percent somewhat often, 9 percent very often, and 8 percent constantly.

Excessive draftiness was complained about in 6 percent of the cases. The complaints had been made once or twice in 35 percent of the cases, not very often in 31 percent of the cases, somewhat often (27 percent), and constantly (7 percent).

Too little air movement was a source of complaint in 12 percent of the buildings surveyed. The complaints were made once or twice in 28 percent of the cases, not very often (44 percent), somewhat often (15 percent), very often (6 percent), and constantly (7 percent).

Odor complaints were reported in about 14 percent of the survey responses. Frequency of the complaints were as follows: once or twice (40 percent), not very often (33 percent), somewhat often (15 percent), very often (5 percent), and constantly (8 percent).

Other complaint types were not recorded very frequently, with 1.7 percent of the respondents saying that there was "something else." The complaints included: poor control of air flow direction from vents, mold, inoperable windows, wasps, allergy, varying on and off (ventilation?), and personal hygiene odors. Of those receiving such complaints the frequency was as follows: once or twice (50 percent), not very often (13 percent), somewhat often (25 percent), constantly (13 percent).

When asked when the last occupant complaint was made, 36 percent said "a few days ago," 29 percent said "a few weeks ago," 26 percent said "a few months ago," and 9 percent said "years ago." When asked about corrective actions that had been taken, 12 percent indicated that none was taken, 33 percent said that the building manager investigated, 20 percent stated that an outside contractor investigated, 47 percent responded that a supervisor had investigated, and 16 percent said that something else was done. The list of other corrective actions reported can be found in Appendix A, #6.

Stratified Results of the Telephone Survey

The survey data were stratified in four ways: by business type, floor area, age, and region. The objective was to better understand if major differences in the building characteristics exist between strata. Tables 11 through 14 provide the stratified data from these analyses. The

analysis focuses on selected questions from the survey that are particularly relevant to ventilation, potential indoor sources, building maintenance (cleaning), energy management, and occupant complaints. Unfortunately, the HVAC survey sample size is too small to provide useful information after stratification, so it is not included in these analyses. For the purposes of this analysis, the survey questions that were repeated for second and third floors were not included; only the first floor data are included, as this provides ample characterization of the buildings.

Stratified by Business Type

Indoor Contaminant Sources

Table 11 presents the survey results stratified by business type. Potential indoor contaminants selected for this analysis include floor finishing, furniture, new painting, new carpeting, and cooking appliances. The prevalence of carpet in the building ranged from 18 percent in food stores, to 100 percent in lodging and public assembly, while about half of the restaurants, and 84 percent of health care buildings had carpeting. Vinyl flooring was less prevalent, ranging for 8 percent in restaurants to about 50 percent in public assembly and health care buildings.

Table 11: Building Characteristics Stratified by Business Type
(Data are presented as percentage of respondents answering "yes.")

Question/Survey Strata	Non-Medical (Percent)	Health Care (Percent)	Restaurant (Percent)	Food store (Percent)	Retail store (Percent)	Lodging (Percent)	Public Assy. (Percent)	Services (Percent)	Misc. (Percent)	Other (Percent)
Indoor Contaminant Sources										
1st flr.: type of finish-carpet	94.0	83.7	46.0	18.2	61.7	100.0	100.0	78.7	89.6	90.5
1st flr.: type of finish-vinyl flooring	38.8	51.0	7.8	27.3	27.1		47.4	33.3	27.1	31.0
1st flr.: any fire damage		2.2	7.8		1.7		5.6	2.7	2.1	
1st flr.: any interior painting	34.5	55.3	49.0	40.0	28.8	40.0	55.6	46.7	34.8	61.9
1st flr.: any new carpet installed	18.3	19.1	11.8		6.8		16.7	18.7	21.3	33.3
1st flr.: new carpet type-natural fiber										
1st flr.: new carpet type-nylon	81.8	100.0			100.0			75.0	100.0	60.0
1st flr.: new carpet type-olefin	9.1		100.0				100.0	14.3		40.0
1st flr.: any new furniture installed	27.4	19.6	17.6		7.1	40.0	16.7	24.0	28.9	25.0
1st flr.: new furniture type-solid wood	48.1	44.4	44.4		25.0	100.0	33.3	50.0	33.3	40.0
1st flr.: new furniture type-comp. w/ veneer	33.3	44.4	55.6		75.0			61.1	50.0	55.6
1st flr.: new furniture type-encapsulated comp.	14.8	14.3						25.0	25.0	22.2
1st flr.: new furniture type-metal/plastic	55.6	88.9	33.3		50.0		66.7	61.1	50.0	66.7
1st flr.: new furniture type-other	14.8	33.3	11.1		50.0	50.0	33.3	11.1		
Natural Ventilation										
Space has windows that open	18.3	26.5	17.6		15.0	80.0	33.3	21.3	31.3	11.9
Windows are opened regularly	47.6	46.2	77.8		44.4	75.0	66.7	37.5	53.3	40.0
Doors are kept open	19.0	16.3	9.8	40.0	28.8	20.0	26.3	29.3	27.1	33.3

Table 11: Building Characteristics Stratified by Business Type (continued)
(Data are presented as percentage of respondents answering "yes.")

Question/Survey Strata	Non-Medical (Percent)	Health Care (Percent)	Restaurant (Percent)	Food store (Percent)	Retail store (Percent)	Lodging (Percent)	Public Assy. (Percent)	Services (Percent)	Misc. (Percent)	Other (Percent)
Evidence of indoor contamination										
Space has visible condensation	1.7	6.4	11.8	10.0			5.3	2.7	2.1	
Evidence of indoor contamination (continued)										
Visible condensation on windows	100.0	66.7	100.0				100.0	100.0	100.0	
Visible condensation on walls		33.3								
Space has water damage or mold	6.9	2.1	9.8		6.8	20.0	5.3	5.3	10.4	7.1
HVAC related questions										
1st flr.: air cleaners used	10.3	14.0	14.3		8.8		5.6	9.9	8.7	14.3
1st flr.: space heaters used	30.1	22.7	4.0	20.0	12.1		11.1	35.1	26.1	31.0
1st flr.: humidifiers used	1.8	6.8	2.0		3.5					2.4
1st flr.: dehumidifiers used	0.9	2.3	2.0	11.1	3.4			2.7	2.2	2.4
HVAC related questions (continued)										
Number of AC settings when occup.	49.1	42.9	66.0	70.0	56.7	25.0	47.4	58.1	56.3	55.3
Number of AC settings when unoccup.	30.1	28.6	44.0	25.0	38.6	40.0	11.1	32.9	32.6	17.1
Number of heating settings when occup.	62.1	52.1	69.4	66.7	52.5	75.0	52.6	62.2	66.7	64.1
Number of heating settings when unoccup.	26.8	22.4	30.0	37.5	31.6	50.0	11.1	36.6	25.0	17.5
Maintenance/cleaning										
1st flr.: cleaned on regular schedule	98.2	100.0	100.0	100.0	100.0	100.0	100.0	97.3	95.7	100.0
Cleaning when occupants present	27.9	40.4	54.9	66.7	46.6	80.0	55.6	46.6	61.4	52.4

Table 11: Building Characteristics Stratified by Business Type (continued)
(Data are presented as percentage of respondents answering "yes.")

Question/survey Strata	Non-Medical (Percent)	Health Care (Percent)	Restaurant (Percent)	Food store (Percent)	Retail store (Percent)	Lodging (Percent)	Public Assy. (Percent)	Services (Percent)	Misc. (Percent)	Other (Percent)
1st flr.: cleaned by outside contractor	76.8	53.2	30.0	55.6	58.6	40.0	38.9	67.1	54.5	61.9
1st flr.: cleaned with wet mop	80.6	97.9	96.1	100.0	78.9	100.0	88.2	89.7	90.9	79.5
1st flr.: cleaned with dry mop	27.3	45.2	44.0	77.8	48.1	40.0	50.0	49.2	48.8	50.0
1st flr.: cleaned with vacuum	98.2	93.6	56.0	55.6	82.8	100.0	100.0	84.5	90.7	95.2
1st flr.: window cleaner used	84.2	89.1	96.0	100.0	86.2	100.0	77.8	92.9	92.7	85.0
1st flr.: flr./furniture wax used	39.0	53.3	24.0	66.7	47.3	40.0	38.9	41.8	39.0	25.0
1st flr.: bleach used	25.6	52.4	52.0	44.4	19.2	80.0	33.3	34.5	36.6	40.5
1st flr.: carpet cleaner used	63.8	66.7	38.0	33.3	48.2	100.0	88.9	58.2	42.9	57.5
1st flr.: pesticide regularly applied	61.9	72.7	77.1	55.6	42.9	80.0	61.1	58.3	55.6	57.1
Occupant feedback										
Occupant complaints: too hot	55.2	61.7	44.9	11.1	39.7	60.0	55.6	50.7	45.7	61.9
Occupant complaints: too cold	57.8	63.8	44.9	44.4	39.7	60.0	72.2	56.2	43.5	59.5
Occupant complaints: too drafty	4.3	13.0	4.1	11.1			5.6	11.0	2.2	11.9
Occupant complaints: no air movement	10.3	17.0	6.1		5.2		16.7	16.4	17.4	11.9
Occupant complaints: odors	7.8	19.1	8.2		10.3	20.0	11.1	23.3	21.7	11.9
Occupant complaints: something else	2.6				1.7		5.6	1.4	2.2	2.4
Locale										
Surrounding area: rural, etc.	34.5	44.9	40.8	10.0	40.7	25.0	26.3	34.7	43.8	36.6
Surrounding area: industrial, etc.	30.2	10.2	2.0	10.0	10.0		5.3	24.0	29.2	23.8

New carpet was installed in about 7 percent of the retail stores with a prevalence of about 20 percent in most of the building types, with maximum prevalence of 33 percent for the "other" building type category. Of the buildings with new carpet, nylon was the most common carpet material used for non-medical, health care, retail, services, miscellaneous, and "other" facilities, with 60 percent to 100 percent using this material. Olefin carpet was the type most frequently used in restaurant and public assembly buildings. Installation of new natural fiber carpeting was not reported in the study.

The prevalence of new furniture installation ranged from 7 percent in retail stores to 40 percent in lodging businesses. Only food stores reported no new furniture, and the rates were reasonably similar for most other business types. One hundred percent of lodging places with new furniture reported installation of solid wood types, while 25 percent to 50 percent of other businesses reported having installed this material type. Furniture with composite wood material having veneer was installed in 33 percent of the non-medical buildings, 45 percent of the health care buildings, and about 50 percent to 75 percent of the building types, including miscellaneous, restaurant, "other," services, and retail. New encapsulated composite wood furniture was less prevalent across the business types, with about 15 percent installation in non-medical and health care buildings, to about 25 percent in the miscellaneous and "other" categories. New metal and plastic furniture was more popular, ranging from about 33 percent of the restaurants to 90 percent in health care buildings. Many of the buildings with new furniture had non-specified types of new furniture. Fifty percent of retail and lodging buildings with new furniture, and 33 percent of health care and public assembly buildings with new furniture, had non-specified types of new furniture.

Recent interior painting was reported in 30 percent to 62 percent of the businesses' buildings. Retail, non-medical and miscellaneous were least likely to have painted, while health care and public assembly buildings were most likely to have done so.

Fire damage was not very prevalent in the buildings, with 8 percent of the restaurants and 6 percent of public assembly being the most likely to have reported fire damage. Health care, retail stores, services, and miscellaneous businesses reported about 2 percent to 3 percent prevalence of fire damage, while lodging and non-medical retail reported none.

Natural Ventilation

The prevalence of buildings having windows that open varied considerably by business type. Only 11 percent of "other" businesses and 15 percent of retail stores reported having opening windows, while about 20 percent to 35 percent of restaurant, non-medical, services, health care, miscellaneous, and public assembly businesses did so. In contrast, a full 80 percent of lodging places reported having opening windows. Of those businesses that reported having opening windows, between 40 percent to 80 percent of them open them regularly. Restaurants and lodging places were the most frequent at reporting use of their windows regularly.

Leaving business doors open was reported by only 10 percent of restaurants, and up to 40 percent of food stores. Most other business types reported doors being kept open in about 20 percent to 30 percent of the cases.

Evidence of Indoor Contamination

Water damage, condensation, and mold are indicators of microbiological air contaminants. Two percent of non-medical businesses and 12 percent of restaurants reported visible condensation on interior surfaces. Retail stores and lodging places did not report condensation. Ten percent of food stores reported visible condensation, but none reported it on walls or windows, suggesting that they may have been observing it on freezer or refrigerator surfaces. With the exception of health care buildings (and food stores) all of the businesses that reported visible condensation observed it on windows. Respondents from health care buildings reported seeing condensation on windows and that was the only business to report seeing it on walls, where it was reported in 33 percent of responses. All of the businesses reported having water damage or mold, with response rates ranging from about 2 percent (health care) to 20 percent (lodging). Most business types had reporting prevalence in the range of 5 percent to 10 percent.

HVAC-Related Questions

Portable air cleaners were used in 6 percent to 14 percent of the buildings across all of the business categories except lodging and food stores.

Space heaters (presumably electric) were used in all of the businesses except lodging. The range of prevalence of space heater use in buildings by business type was almost ten-fold increase, from 4 percent in restaurants to 35 percent in services. Six of the ten business categories (non-medical, health care, food store, services, and "other") had a reporting prevalence above 20 percent.

Humidifier use was reported by about 2 percent of the non-medical and restaurant businesses, but the highest humidifier use was found at about 7 percent of the health care buildings. Lodging, public assembly, services, and miscellaneous businesses did not report using them. Dehumidifiers have similarly low prevalence of reporting, ranging from about 1 percent of non-medical businesses to about 11 percent of food stores. The prevalence of reporting by the businesses types that reported using them was, for the most part, in the 2 percent to 3 percent range. Again, no lodging and public assembly businesses reported using dehumidifiers.

Twenty-five percent (lodging) to 70 percent (food store) of the survey respondents reported using a single air conditioning (cooling) thermostat setting when the building was occupied. The prevalence ranged from about 40 percent to about 60 percent in seven of the ten business types. Most of the rest of the buildings reported using two or more thermostat settings. Similarly, for unoccupied periods, the reporting prevalence for single set points ranged from 11 percent (public assembly) to 44 percent. (restaurant); reporting in the range of 25 percent to 35 percent was common of most of the business types. Reporting of single heating set points during occupied time periods were more prevalent, and in the range of 50 percent to 70 percent, with the highest rate of reporting from lodging places, at 75 percent. Reporting of a single heating thermostat setting for unoccupied periods was lower in all of the business cases compared with the occupied settings, ranging from 11 percent for public assembly facilities to 50 percent for lodging; as with cooling, the most common range of single setting reports was from about 25 percent to 35 percent.

Maintenance/Cleaning

Cleaning on a regular schedule was reported for almost all business types, with the exceptions being non-medical, services, and miscellaneous, where 98 percent, 97 percent, and 96 percent of the buildings, respectively, reported regular cleaning practices. The practice of cleaning when occupants are present was reported across a fairly broad range across business types, ranging from about 30 percent for non-medical businesses to 80 percent for lodging. Most of the other businesses had a reporting prevalence ranging from about 40 percent to 55 percent.

Businesses reporting that outside contractors were used for cleaning services ranged from 30 percent for restaurants to about 77 percent for non-medical businesses. The prevalence of using these services is spread fairly evenly in the range across the other business types. Cleaning with a wet mop was very common, with the business type least likely to use that method being retail stores, with 79 percent reporting wet mopping; most of the business types had reporting rates above 85 percent, with food stores and lodging all reporting the practice. Dry mop use was less prevalent, ranging from about 27 percent (non-medical) to 78 percent (food stores); most of the businesses had reporting rates from 40 percent to 50 percent.

Vacuum cleaning was reported by businesses, with prevalence ranging from 56 percent (restaurant) to 100 percent (lodging and public assembly). More commonly (eight of ten business types), the vacuuming rate was above 85 percent.

Seventy-eight percent (public assembly) to 100 percent (food store and lodging) of businesses used a window cleaner; reporting rates were typically above 85 percent for all of the business types.

The rate of reporting of furniture wax use ranged from 24 percent (restaurant) to 67 percent (food store); the reporting rates for the business types were evenly distributed within this range.

Bleach use was reported in a range of 19 percent (retail stores) to 80 percent (lodging); the rate of reporting for most of the business types was between 30 percent and 55 percent. Carpet cleaner use was spread widely, with reporting rates between 33 percent to 38 percent (food store, restaurant) and 89 percent to 100 percent (public assembly, lodging); the other business types reported at rates ranging from 40 percent to 70 percent.

Reporting prevalence of regular pesticide application by businesses ranged from 43 percent for retail stores to 80 percent for lodging places. The percentage of buildings reporting the practice was fairly evenly spread across this range.

Occupant Feedback

Too Hot

The range at which the respondents reported occupant complaints of the building being too hot varied considerably by business type, ranging from 11 percent (food store) to 60 percent (lodging). With the exception of food store, the reporting prevalence ranged from about 40 percent to 60 percent.

Too Cold

Likewise, the range at which the respondents reported occupant complaints of the building being too cold varied considerably by business type, ranging from 44 percent (food store) to 72 percent (public assembly). With the exception of public assembly, the reporting prevalence ranged from about 45 percent to 60 percent.

Too Drafty

Two percent (miscellaneous) to 13 percent (health care) of respondents reported that their building was too drafty. On the high end, food stores, services, and "other" all had more than 11 percent reporting this complaint. At the low end, non-medical, restaurant, and public assembly all had reporting rates below 6 percent.

No Air Movement

Complaints of no air movement were reported more frequently than those of the building being too drafty. Reported complaints ranged from 5 percent (retail store) to 17 percent (miscellaneous); with the additional low rate for restaurants (6 percent), all other businesses had complaint rates above 10 percent. Food stores did not report complaints regarding too little air movement.

Odors

The reporting prevalence for odor complaints in buildings by business type ranged from 8 percent (non-medical) to 23 percent (services). With the exception of restaurant (8 percent), all other business types had reporting rates above 10 percent. Again, foods stores had no complaints communicated about odors.

Something Else

The survey asked if there were other types of complaints, not specified. With the exception of health care, restaurant, and lodging, the business types all had reporting rates in the range of 1 percent to 6 percent.

Locale

The businesses reported being located where they were surrounded by a rural environment at rates ranging from 10 percent (food store) to 45 percent (health care). With the exception of food stores, all of the business types had reporting rates ranging from 25 percent to 45 percent. Location in an industrial area was reported by the businesses at rates from 2 percent (restaurant) to 30 percent (miscellaneous, non-medical). Health care, food store, and retail stores reported being located in an industrial area about 10 percent of the time, while services, and "other" reported at rates of about 24 percent.

Stratified by Building Age

Indoor Contaminant Sources

Table 12 presents the survey results stratified by building age. The building age strata were set at < 5 years, 5 to 10 years, 11 to 20 years, and 21 to 30 years prior to the survey (2009). The prevalence of carpet in the building varied little, 76 percent to 87 percent across the age ranges. Vinyl flooring was also distributed fairly tightly across building ages, ranging from 29 percent (for buildings 5 to 10 years old) to 40 percent (for buildings < 5 years old).

New carpet was most prevalent in the buildings < 5 years old (40 percent) and least prevalent in the buildings 5 to 10 years old. Buildings 10 years old or newer all reported installing new nylon carpet, while only 63 percent of those 11 to 20 years old and 73 percent of those 21 to 30 years old reported using this carpet material. New olefin carpet was not reported to have been installed in buildings newer than 11 years, while 38 percent of those 11 to 20 years old and 20 percent of those 21 to 30 years old reported using olefin. Installation of new natural fiber carpeting was not reported in the study.

The prevalence of new furniture installation ranged from 16 percent in buildings from 5 to 10 years old to 29 percent in those 21 to 30 years old. With 22 percent of buildings 11 to 20 years old reporting, the newest buildings had almost the same rate of new furniture (28 percent) as the oldest. New furniture on the first floor often included solid wood furniture. For most types of businesses, when new furniture was present, 33 percent to 50 percent of the establishments used at lease some new furniture constructed of solid wood.

Furniture with composite wood material having veneer was installed in 71 percent of buildings < 5 years old, a rate much more frequent than that of older buildings, where the rate ranged from 36 percent to 48 percent. New encapsulated composite wood furniture was least prevalent in the newest buildings (14 percent), not reported as newly installed in buildings 5 to 10 years old, but installed at a rate of 25 percent in buildings 11 to 20 years old, and 19 percent in those 21 to 30 years old. The popular new metal and plastic furniture was installed at a rate of 57 percent in the newest buildings, 80 percent for those 5 to 10 years old, 47 percent for the 11- to 20-year-old category, and 56 percent in the oldest buildings. The survey identified that other non-specified types of furniture materials were installed in three older categories of buildings at rates of 20 percent, 19 percent, and 14 percent, respectively, in order of increasing age.

Recent interior painting was reported in the tight range of 39 percent to 47 percent across all age ranges.

Fire damage rates were 3 percent for buildings 11 to 20 years old and 4 percent for those from 21 to 30 years old; the newer buildings did not report fire damage.

Natural Ventilation

The prevalence of buildings having windows that open varied by almost a factor of three, increasing by age. The newest category reported that only 10 percent of the buildings had windows that open, while the prevalence was 14 percent, 22 percent, and 29 percent for those in the three older building categories, in order of increasing age, respectively. Of those businesses

that reported having windows that open, the newest buildings report never opening them, while 30 percent of buildings 5 to 10 years old, 48 percent of those 11 to 20 years old, and 54 percent of those 21 to 30 years old are opened regularly.

Business doors left open are reported by 10 percent of the newest buildings and in 20 percent to 30 percent of those in the oldest three building categories.

Evidence of Indoor Contamination

The newest buildings (< 5 years old) reported no evidence of indoor contamination. The prevalence of buildings reporting visible condensation on interior surfaces ranged from about 3 percent to 6 percent, in the three older building categories. Visible condensation was reported as being evident in 50 percent of buildings in the 5- to 10-year category, 88 percent of those 11 to 20 years old, and in 100 percent of those in the 21- to 30-year age range. One half of the buildings in the 5- to 10-year-old age range reported condensation on the walls, but no other age category reported this observation. Water damage or mold was reported in 4 percent to 6 percent of the buildings in the three oldest building age categories.

Table 12: Building Characteristics Stratified by Age of Building.
(Data are presented as percentage of respondents answering "yes.")

	< 5 years (%)	5 to 10 years (%)	11 to 20 years (%)	21 to 30 years (%)
Indoor Contaminant Sources				
1st flr.: type of finish-carpet	86.7	87.3	76.3	80.8
1st flr.: type of finish-vinyl flooring	40	29.2	32.5	33.1
1st flr.: any fire damage	.	.	2.7	3.9
1st flr.: any interior painting	40	38.9	47.3	45
1st flr.: any new carpet installed	26.7	11.1	20.5	22.7
1st flr.: new carpet type-natural fiber	.	.	.	.
1st flr.: new carpet type-nylon	100	100	62.5	73.3
1st flr.: new carpet type-olefin	.	.	37.5	20
1st flr.: any new furniture installed	27.6	15.5	21.5	29.4
1st flr.: furniture type-solid wood	28.6	50	40.9	47.2
1st flr.: furniture type-comp. w/ veneer	71.4	40	47.6	36.1
1st flr.: furniture type-encapsulated comp.	14.3	.	25	19.4
1st flr.: furniture type-metal/plastic	57.1	80	47.6	55.6
1st flr.: furniture type-other	.	20	19	13.9
Natural Ventilation				
Space has windows that open	10	13.9	22.3	28.5
Windows are opened regularly	.	30	48	54.1
Doors are kept open	10	26.4	19.5	27.7
Evidence of indoor contamination				
Space has visible condensation	.	2.8	6.2	3.8
Visible condensation on windows	.	50	85.7	100
Visible condensation on walls	.	50	.	.
Space has water damage or mold	.	4.2	6.2	4.6
HVAC related questions				
1st flr.: air cleaners used	6.9	5.9	11.9	16
1st flr.: space heaters used	26.7	16.9	19.3	26.8
1st flr.: humidifiers used	3.4	1.4	.	3.2
1st flr.: humidifiers used	3.4	1.4	.	3.2
1st flr.: dehumidifiers used	.	4.3	1.8	2.4
Number of AC settings when occup.	40	55.6	53.2	59.4
Number of AC settings when unoccup.	33.3	23.9	32.7	37.5
Number of heating settings when occup.	48.3	58.3	58.6	68.2
Number of heating settings when unoccup.	28.6	16.9	27.5	36

Table 12: Building Characteristics Stratified by Age of Building (continued)
(Data are presented as percentage of respondents answering "yes.")

	< 5 years (%)	5 to 10 years (%)	11 to 20 years (%)	21 to 30 years (%)
Maintenance/cleaning				
1st flr.: cleaned on regular schedule	100	97.2	99.1	97.7
Cleaning when occupants present	53.3	42	45.5	40.8
1st flr.: cleaned by outside contractor	66.7	65.7	53.2	59.2
1st flr.: cleaned with wet mop	86.2	90.8	91.7	87.5
1st flr.: cleaned with dry mop	56	46.7	46.5	38.7
1st flr.: cleaned with vacuum	96.7	89.9	86.4	91.1
1st flr.: window cleaner used	89.7	87.9	92.7	88.3
1st flr.: flr./furniture wax used	37.9	40	48.1	39.5
1st flr.: bleach used	19.2	34.5	39.6	36.8
1st flr.: carpet cleaner used	55.2	67.7	55.7	54.9
1st flr.: pesticide regularly applied	72.4	73.2	59	59.8
Occupant feedback				
Occupant complaints: too hot	50	56.3	52.3	45.7
Occupant complaints: too cold	60	47.9	57.7	54.3
Occupant complaints: too drafty	10.3	1.4	7.2	4.7
Occupant complaints: no air movement	10	12.7	16.2	10.2
Occupant complaints: odors	16.7	14.1	13.5	13.4
Occupant complaints: something else	3.3	.	3.6	1.6
Locale				
Surrounding area: rural, etc.	30	47.9	34.2	39.8
Surrounding area: industrial, etc.	13.3	16.7	15	20.8

HVAC-Related Questions

Air cleaners were used in 6 percent to 7 percent of buildings in the two newer age categories, 12 percent in the 11- to 20-year category, and 16 percent in the oldest buildings.

Space heater use was reported at the highest rates in the newest and oldest buildings, both at 27 percent, while the reporting rate was 17 percent in the 5- to 10-year category and at 19 percent in the 11- to 20-year age category.

Humidifier use was reported by about 3 percent of respondents in the buildings aged < 5 years, 1 percent for the 5- to 10-year group, and 3 years for the 21- to 30-year group (there were no respondents with these devices in the 11- to 20-year group). Dehumidifier use was reported by the 5- to 10-year group at a rate of 4 percent, while the 11- to 20-year and the 21-to 30-year group prevalences were 6 percent and 5 percent, respectively.

Use of a single air conditioning (cooling) thermostat setting during occupied building occupancy was reported by 40 percent of the newest building group, while the older groups

had single settings in 56 percent, 53 percent, and 59 percent of the cases for the three older age groups in succession, respectively. For unoccupied periods, the reporting prevalence for single set points ranged from by 33 percent of the newest building group, while the older groups had single settings in 24 percent, 33 percent, and 38 percent of the cases for the 5- to 10-year, 11- to 20-year, and 21- to 30-year categories, respectively. Reporting by age group of single heating set points during occupied time periods were 48 percent for the newest buildings, with rates increasing to 58 percent, 59 percent, and 68 percent as the reporting buildings were in successively older age categories. Reporting of single heating thermostat settings for unoccupied periods was lower in each age case compared with the occupied settings, with rates of 29 percent for the newest building up to 36 percent for the oldest. The 5- to 10-year-old category had a slightly lower reporting rate of 17 percent.

Maintenance/Cleaning

Cleaning on a regular schedule was reported by nearly all (97 percent to 100 percent) of the buildings for almost all building ages. The practice of cleaning when occupants are present was reported across a fairly broad range across building age, ranging from about 43 percent to 50 percent.

Businesses reported that outside contractors were used for cleaning services at rates ranging from 41 percent (21years to 30 years) to 53 percent (< 5 years). Cleaning with a wet mop was very common, ranging from 86 percent (< 5 years) to 92 percent (11 years to 20 years). Dry mop use was less prevalent, ranging from about 38 percent (21 years to 30 years) to 56 percent (< 5 years).

Vacuum cleaning was reported by age, with prevalence ranging from 86 percent (11 years to 20 years) to 97 percent (< 5 years).

Window cleaner use was virtually identical across age groups, with rates ranging from 88 percent to 93 percent.

Similarly, the rate of reporting of furniture wax use was very consistent across age groups, ranging from 38 percent (< 5 years) to 48 percent (11 years to 20 years).

Bleach use was reported in a range of 19 percent (< 5 years) to 40 percent (11 years to 20 years). Carpet cleaner use rates were very consistent across age groups, ranging from 55 percent (< 5 years) to 67 percent (5 years to 10 years).

Reporting prevalence of regular pesticide application by age group was at rates ranging from 72 percent (< 5 years) to 59 percent (11 years to 20 years). The percentage of buildings reporting the practice does appear to be lower in the two older groups.

Occupant Feedback

Too Hot

The range at which the respondents reported occupant complaints of the building being too hot varied little by age, with all groups reporting at rates between 46 percent (21 years to 30 years) to 56 percent (5 years to 10 years).

Too Cold

Likewise, the range at which the respondents reported occupant complaints of the building being too cold varied only slightly, ranging from 48 percent (5 years to 10 years) to 60 percent (<5 years)

Too Drafty

The reporting prevalence by occupants complaining of the building being too drafty was highest, at 10 percent for the newest buildings, while those in the older three categories had rates ranging from 1 percent to 7 percent.

No Air Movement

Complaints of no air movement were reported more frequently than too drafty. Reported complaints ranged from 10 percent (newest and oldest buildings) to 16 percent (11 years to 20 years).

Odors

The reporting prevalence for odor complaints by age also varied little, from 13 percent in the oldest buildings, to 17 percent in the newest building group.

Something Else

The survey asked if there were other types of complaints, not specified. The rates of these complaints ranged from 2 to 4 percent by building age.

Locale

By age, the businesses reported being located near a rural environment at rates ranging from 30 percent (< 5 years) to 48 percent (5 years to 10 years). Locale did not appear to be age dependent.

Location in an industrial area was reported by age at rates from 13 percent (< 5 years) to 21 percent (oldest buildings). Again, these data do not appear to be age dependent.

Stratified by Building Floor Area

Indoor Contaminant Sources

Table 13 presents the survey results stratified by building floor area. The floor area strata are set at ≤1000 ft^2 , 1,001 ft^2 to 5,000 ft^2, 5,001 ft^2 to 10,000 ft^2, 10,001 ft^2 to 20,000 ft^2, 20,001 ft^2 to 30,000 ft^2, and 40,001 ft^2 to 50,000 ft^2. For simplicity, we will refer to these categories as ≤1K, 1K, 5K, 10K, 20K, 30K, and 40K, respectively.

The prevalence of carpet in the building ranges from 43 percent (≤1K) to 92 percent (40K) at an almost monotonically increasing rate. Vinyl flooring prevalence across the building area was fairly tight, ranging from about 25 percent to 35 percent, with the exception of the 30K category, where 55 percent of the building reported using this material.

New carpet reporting prevalence ranged from 7 percent in the 30K buildings to 25 percent in the 40K buildings; the ≤1K group reported no new carpet. With the exception of the ≤1K buildings, new nylon carpet was installed in 67 percent to 100 percent of the buildings in each group. New olefin carpet was reported only in the 10K (33 percent), 20K (40 percent), 40K (20 percent) groups. Installation of new natural fiber carpeting was not reported in the study.

The prevalence of new furniture installation ranged from 10 percent in the 40K buildings to 30 percent in the 10K buildings. The ≤1K group did not have any new furniture. The 5K (27 percent) and 10K (28 percent) buildings had lower prevalence of new solid wood furniture compared with the 1K (50 percent), 20K (70 percent), and 40K (75 percent). Furniture with composite wood material having veneer was installed in about 35 percent to 45 percent of the 1K, 5K, and 10K and 50K buildings, and in about 60 percent to 70 percent of the 20K and 30K buildings. New encapsulated composite wood furniture was installed in the 10K (12 percent), 20K (60 percent), and 40K (43 percent) buildings. New metal and plastic furniture was installed at a rate of 33 percent (30K) to 75 percent (40K), with no apparent pattern relating to size. The survey identified that other non-specified types of furniture materials were installed at rates from 7 percent (1K) to 50 percent (40K), increasing with floor area.

Recent interior painting was reported in the tight range of 39 percent to 52 percent across all floor area groups.

Fire damage rates were most frequent in the smallest buildings (≤1K), at a rate of 14 percent—considerably more frequent than in the other size groups, where fire damage rates ranged from about 1 percent to 4 percent. No fire damage was reported in 5K buildings.

Table 13: Building Characteristics Stratified by Floor Area
(Data are presented as percentage of respondents answering "yes.")

Question/Survey Strata	≤1000 ft^2 (%)	1001 to 5000 ft^2 (%)	5001 to 10000 ft^2 (%)	10001 to 20000 ft^2 (%)	20001 to 30000 ft^2 (%)	30001 to 40000 ft^2 (%)	40001 to 50000 ft^2 (%)
Indoor Contaminant Sources							
1st flr.: type of finish-carpet	42.9	67.1	81	87.7	81.5	86.7	91.7
1st flr.: type of finish-vinyl flooring	28.6	30.3	32.2	31.5	35.2	55.2	25
1st flr.: any fire damage	14.3	1.3		4.2	1.9	3.4	
1st flr.: any interior painting	42.9	39.5	39	44.4	49.1	51.7	41.7
1st flr.: any new carpet installed		10.5	13.6	22.2	18.9	6.9	25
1st flr.: new carpet type-natural fiber							
1st flr.: new carpet type-nylon		100	75	66.7	60	100	80
1st flr.: new carpet type-olefin				33.3	40		20
1st flr.: any new furniture installed		18.4	19.3	30.3	18.9	10.3	25
1st flr.: furniture type-solid wood		50	27.3	27.8	70		75
1st flr.: furniture type-comp. w/ veneer		35.7	36.4	44.4	60	66.7	37.5
1st flr.: furniture type-encapsulated comp.		7.1		11.8	60		42.9
1st flr.: furniture type-metal/plastic		42.9	54.5	61.1	70	33.3	75
1st flr.: furniture type-other		7.1	9.1	11.1		33.3	50
Natural Ventilation							
Space has windows that open		31.6	18.6	15.3	13.2	26.7	11.1
Windows are opened regularly		54.2	90.9	45.5	42.9	25	50
Doors are kept open	42.9	28.9	15.3	20.5	22.2	16.7	16.7

Table 13: Building Characteristics Stratified by Floor Area (continued)
(Data are presented as percentage of respondents answering "yes.")

Question/Survey Strata	≤1000 ft² (%)	1001 to 5000 ft² (%)	5001 to 10000 ft² (%)	10001 to 20000 ft² (%)	20001 to 30000 ft² (%)	30001 to 40000 ft² (%)	40001 to 50000 ft² (%)
Evidence of indoor contamination							
Space has visible condensation		6.6	3.4	2.8	5.6		2.8
Visible condensation on windows		80	100	100	100		
Visible condensation on walls		20					
Space has water damage or mold	14.3	2.6	6.8	8.3	5.6	6.7	8.3
HVAC related questions							
1st flr.: air cleaners used		17.1	14.5	4.4	3.9	6.9	9.7
1st flr.: space heaters used	14.3	19.7	19	39.1	26.4	13.8	26.5
1st flr.: humidifiers used			3.6	1.5		3.4	
1st flr.: dehumidifiers used		1.3				3.4	3
Number of AC settings when occup.	57.1	72.4	53.4	51.4	51.9	46.7	40
Number of AC settings when unoccup.	28.6	36.8	29.8	31.9	30.8	17.9	32.4
Number of heating settings when occup.	57.1	71.1	63.8	59.7	54.7	60	48.6
Number of heating settings when unoccup.	14.3	27.6	16.4	31.9	25	22.2	29.4
Maintenance/cleaning							
1st flr.: cleaned on regular schedule	100	97.4	98.3	98.6	100	100	97.1
Cleaning when occupants present	42.9	54.1	47.4	32.9	47.2	44.8	44.1
1st flr.: cleaned by outside contractor	42.9	51.4	52.6	68.6	58.5	69	85.3
1st flr.: cleaned with wet mop	71.4	89	87.3	78.8	82.7	92.6	90.3
1st flr.: cleaned with dry mop	.	44.8	40.8	35.9	44.4	44	55.6
1st flr.: cleaned with vacuum	57.1	81.1	92.9	90	94.2	96.4	88.2
1st flr.: window cleaner used	85.7	95.9	83.3	84.8	88.2	92.9	86.7
1st flr.: flr./furniture wax used	28.6	29.2	23.1	45.3	42	55.6	62.5

Table 13: Building Characteristics Stratified by Floor Area (continued)
(Data are presented as percentage of respondents answering "yes.")

Question/Survey Strata	≤1000 ft^2 (%)	1001 to 5000 ft^2 (%)	5001 to 10000 ft^2 (%)	10001 to 20000 ft^2 (%)	20001 to 30000 ft^2 (%)	30001 to 40000 ft^2 (%)	40001 to 50000 ft^2 (%)
Maintenance/cleaning (cont'd)							
1st flr.: bleach used	71.4	37.9	41.7	33.3	39.1	30.4	20
1st flr.: carpet cleaner used	28.6	50	60.4	58.2	66.7	75	74.2
1st flr.: pesticide regularly applied	28.6	56.2	58.9	60.9	62	58.6	73.5
Occupant feedback							
Occupant complaints: too hot	28.6	43.4	48.3	59.2	50.9	67.9	64.7
Occupant complaints: too cold	28.6	40.8	53.4	66.2	43.4	71.4	64.7
Occupant complaints: too drafty	14.3	3.9	7	2.8	7.5	7.4	11.8
Occupant complaints: no air movement		10.5	15.5	19.7	17	10.7	11.8
Occupant complaints: odors		3.9	15.5	21.1	7.5	17.9	20.6
Occupant complaints: something else		1.3	1.7	2.8		3.6	
Locale							
Surrounding area: rural, etc.	28.6	44	37.9	37	37.7	46.7	38.9
Surrounding area: industrial, etc.	.	13.2	18.6	23.3	33.3	13.3	19.4

Natural Ventilation

The prevalence of buildings having windows that open varied by floor area, decreasing fairly consistently from 32 percent in 1K buildings to 11 percent in 40K buildings; the exception being the 30K group with a prevalence of 27 percent. The ≤1K buildings did not report windows that open. Of those businesses that reported having windows that open, the prevalence of those reporting regular use of them ranged from 25 percent (30K) to 91 percent (5K); there did not appear to be a floor area relationship; however, with the exception of these extremes, the rate was consistently within 43 percent to 54 percent.

Business doors left open were reported by 43 percent of respondents from the smallest buildings, and by about 15 percent to 30 percent of those that were larger.

Evidence of Indoor Contamination

The smallest buildings (≤1K) reported no observation of condensation. The prevalence of buildings reporting visible condensation on interior surfaces ranged from about 3 percent to 7 percent, across the floor area categories. Visible condensation on windows was reported as being evident in 80 percent of the 1K buildings and in 100 percent of those in the 5K, 10K, and 20K groups, while none was reported in the 30K and 40K buildings. Condensation on walls was reported by 20 percent the 1K buildings, and by no other size group. Water damage or mold was reported in 14 percent of the ≤1K group and in a range of 3 percent to 8 percent of the other building size categories.

HVAC-Related Questions

Air cleaners were used in 4 percent (10K and 20K) to 17 percent (1K) buildings, with the larger buildings having somewhat less reporting of their use; their use was not reported by the ≤1K group.

Space heater use was reported in all building sizes, with the lowest rates being 14 percent for both the ≤1K group and the 30K group. The rates do not appear to be building-size related, and the highest reporting was from the 10K group (39 percent).

Humidifier use was reported by only the 5K (4 percent), 10K (2 percent), and 30K (3 percent) groups. Dehumidifier use was reported at a rate of 1 percent by the 1K group and about 3 percent by both 30K and 40K groups.

Use of a single air conditioning (cooling) thermostat setting during occupied building periods was reported by 40 percent of the largest (40K) building group, while the smaller groups had single settings ranging from about 50 percent to 60 percent, with the exception of the 1K group, which reported using single settings 72 percent of the time. For unoccupied periods, the reporting prevalence for single set points ranged from by 18 percent (30K) to 37 percent (1K); the 30K group prevalence appears to be the exception, while the rest of the building sizes report in a fairly tight band from about 30 percent to 40 percent. Reporting by building size group of single heating set points during occupied time periods were in the range of 50 percent to 70 percent. Reporting of single heating thermostat settings for unoccupied periods was in the range of 14 percent (≤1K) to 32 percent (10K), with no clear relationship between building size and thermostat setting.

Maintenance/Cleaning

Cleaning on a regular schedule was reported by nearly all (97 percent to 100 percent) of the buildings for almost all building sizes. The practice of cleaning when occupants are present was reported across a fairly broad range across building size, ranging from about 33 percent to 54 percent.

Businesses reported that outside contractors were used for cleaning services at rates ranging from 43 percent (≥1K) to 85 percent (50K), with the rates appearing to increase fairly consistently with floor area. Cleaning with a wet mop was very common, ranging from 71 percent (≤1K) to 93 percent (30K). Dry mop use prevalence ranged from 36 percent (10K) to 56 percent (40K), with all but the 40K buildings being very similar, within a 10 percent range.

Vacuum cleaning was reported by floor area, with prevalence ranging from 57 percent (≤1K) to 96 percent (30K), but the rates of all but the smallest buildings were above 80 percent.

Use of window cleaner use was very close across size groups, with rates ranging from 83 percent to 96 percent.

The rate of reporting of furniture wax use ranged from 23 percent (5K) to 63 percent (40K), with larger buildings trending toward a greater likelihood of using the product.

Bleach use was reported in a range of 20 percent (40K) to 71 percent (≤1K), and it followed a somewhat consistent downward trend in use with increasing floor area. Carpet cleaner use rates increased fairly consistently across size groups, ranging from 29 percent (≤1K) to 74 percent to 75 percent (40K and 30K).

Reporting prevalence of regular pesticide application by building size group increased fairly steadily, from 29 percent (≤1K) to 74 percent (40K).

Occupant Feedback

Too Hot

Occupants appear to more frequently complain of being hotter in larger buildings; reporting prevalence increased from 29 percent (≤1K) to 65 percent to 68 percent (40K, 30K) as the buildings got larger.

Too Cold

Building occupants also appeared to have greater frequency of complaints of being cold in larger buildings, but not with quite as convincing a trend as for "too hot"; the fewest complaints were from the ≤1K group (29 percent) and the most frequent were in the 30K group (71 percent).

Too Drafty

The reporting prevalence of occupants complaining of the building being too drafty was highest at 14 percent for the smallest buildings and second highest at 12 percent in the largest buildings. The rates for the rest of the building sizes were in the 3 percent to 8 percent range.

No Air Movement

Complaints of no air movement were reported more frequently than complaints of the building being too drafty. Reported complaints ranged from 11 percent (1K and 30K) to 20 percent (10K), with no apparent constancy by building size.

Odors

The reporting prevalence for odor complaints by building size varied from 4 percent in the smallest buildings to 21 percent in the 10K and 40K groups. These complaint rates do not appear to be size dependent.

Something Else

The survey asked if there were other types of complaints, not specified. The rates of these complaints ranged from 1 percent to 4 percent across building size.

Locale

By building size, the businesses reported being located near a rural environment at rates ranging from 29 percent (≤1K) to 47 percent (30K). Locale did not appear to be size dependent.

Location in an industrial area was reported by age at rates from 13 percent (1K and 30K) to 33 percent (20K). Again, these data do not appear to be age dependent.

Stratified by Region

Indoor Contaminant Sources

Table 14 presents the survey results stratified by region. The regional strata are identified as South Coast (SC), North Coast (NC), South Inland (SI), and Central Inland (CI).

The prevalence of carpet use ranges from 76 percent (SI) to 83 percent (SC); there was almost no difference by region. Vinyl flooring prevalence across the region was broader, ranging from about 25 percent (SC) to 44 percent (CI).

New carpet reporting prevalence ranged from 12 percent in the SI buildings to 26 percent in the SC buildings; the ≤1K group reported no new carpet. New nylon carpet was installed in 70 percent to 100 percent of the buildings in each region. New olefin carpet reporting rates ranged from 10 percent (NC) to 27 percent (CI) . Installation of new natural fiber carpeting was not reported in the study.

The prevalence of new furniture installation ranged from 16 percent in the SI buildings to 26 percent in the SC buildings. The prevalence of new solid wood furniture installation ranged from 37 percent in SC to 52 percent in CI. Furniture with composite wood material having veneer was installed in about 29 percent in CI buildings to 58 percent in SC buildings. New encapsulated composite wood furniture was reported in only 6 percent of SC buildings, and ranged to 33 percent in SI buildings. Reporting rates of new metal and plastic furniture installed in SC buildings were 37 percent and in 78 percent of NC buildings. The survey identified that other non-specified types of furniture materials were installed at rates from about 6 percent (NC) to 17 percent (CI).

Recent interior painting was reported in the tight range of 41 percent (NC) to 55 percent (CI).

Fire damage rates were 5 percent in the SC, and 1 percent in CI, with NC and SI reporting none.

Natural Ventilation

The prevalence of buildings having windows that open varied slightly by region, from 17 percent in SI to 23 percent in CI. Of those businesses that reported having windows that open, the prevalence of those reporting regular use of them ranged from 36 percent (CI) to 60 percent (SC).

Leaving business doors open was reported by 17 percent of the SI building respondents and up to 30 percent of those in NC.

Table 14: Building Characteristics Stratified by Region.
(Data are presented as percentage of respondents answering "yes.")

Question/survey Strata	S_Coast (%)	N_Coast (%)	S_Inland (%)	C_Inland (%)
Indoor Contaminant Sources				
1st flr.: type of finish-carpet	83.1	80	76.2	82.7
1st flr.: type of finish-vinyl flooring	25.3	27.5	35.3	43.6
1st flr.: any fire damage	4.9	.	.	0.9
1st flr.: any interior painting	54.9	40.5	44.4	42.7
1st flr.: any new carpet installed	25.6	20	12.1	20
1st flr.: new carpet type-natural fiber	.	.	.	.
1st flr.: new carpet type-nylon	80	70	100	72.7
1st flr.: new carpet type-olefin	20	10	.	27.3
1st flr.: any new furniture installed	26	23.8	16.3	24.8
1st flr.: furniture type-solid wood	36.8	38.9	40	52
1st flr.: furniture type-comp. w/ veneer	57.9	55.6	46.7	29.2
1st flr.: furniture type-encapsulated comp.	5.9	16.7	33.3	14.3
1st flr.: furniture type-metal/plastic	36.8	77.8	60	58.3
1st flr.: furniture type-other	15.8	5.6	13.3	16.7
Natural Ventilation				
Space has windows that open	18.5	21.3	16.7	22.7
Windows are opened regularly	60	47.1	64.7	36
Doors are kept open	25.9	30	16.7	20.9
Evidence of indoor contamination				
Space has visible condensation	1.3	2.5	5	4.5
Visible condensation on windows	100	100	80	80
Visible condensation on walls	.	.	.	20
Space has water damage or mold	8.5	5	11	3.6

Table 14: Building Characteristics Stratified by Region (continued)
(Data are presented as percentage of respondents answering "yes.")

Question/survey Strata	S_Coast (%)	N_Coast (%)	S_Inland (%)	C_Inland (%)
HVAC related questions				
1st flr.: air cleaners used	9.2	14.5	11.7	11.4
1st flr.: space heaters used	18.5	33.3	17.5	27.5
1st flr.: humidifiers used	3.8	.	1	2.8
1st flr.: dehumidifiers used	5.1	2.6	1	0.9
Number of AC settings when occup.	55.7	50.6	49	58.3
Number of AC settings when unoccup.	27.5	30.8	31	34
Number of heating settings when occup.	54.4	65.8	63.7	61.7
Number of heating settings when unoccup.	27.3	26.3	23	31.4
Maintenance/cleaning				
1st flr.: cleaned on regular schedule	98.8	98.8	100	98.1
Cleaning when occupants present	41.8	45.6	54.5	35.2
1st flr.: cleaned by outside contractor	65.8	64.6	49.5	63.2
1st flr.: cleaned with wet mop	92.1	86.8	88.2	85.3
1st flr.: cleaned with dry mop	43.1	40.3	47.7	42.3
1st flr.: cleaned with vacuum	91	88.5	85.6	87.7
1st flr.: window cleaner used	87.3	90.9	91.5	84
1st flr.: flr./furniture wax used	43.1	36.5	37.2	43.8
1st flr.: bleach used	37.3	32.4	39.1	38
1st flr.: carpet cleaner used	65.8	64.9	52.1	55.6
1st flr.: pesticide regularly applied	60.8	48.1	64.2	68.9
Occupant feedback				
Occupant complaints: too hot	51.3	55	49	57.8
Occupant complaints: too cold	60.3	61.3	52	52.3
Occupant complaints: too drafty	5.1	7.6	7.1	6.5
Occupant complaints: no air movement	12.8	13.8	11.2	10.1
Occupant complaints: odors	15.4	21.3	10.2	12.8
Occupant complaints: something else	1.3	5	1	0.9
Locale				
Surrounding area: rural, etc.	41.5	40.3	32.7	48.6
Surrounding area: industrial, etc.	29.3	23.8	16.7	13.6

Evidence of Indoor Contamination

The prevalence of buildings reporting visible condensation on interior surfaces ranged from about 1 percent in SC to 5 percent in SI and CI. Visible condensation on windows was reported as being evident in 80 percent of the SI and CI buildings and in 100 percent of those in SC and NC. Condensation on walls was reported only by 20 percent of the CI buildings and not in buildings in the other regions. Water damage or mold was reported in 4 percent of the CI buildings and as much as 11 percent of the SI buildings.

HVAC-Related Questions

Air cleaners were used in 9 percent of the SC and the prevalence ranged up to 15 percent for the NC buildings.

Space heater use was reported, with the lowest rates in SI, at 18 percent, and at the highest rates in NC, at 33 percent.

Humidifier use was reported in a range of 1 percent in SI buildings to 4 percent in SC buildings. Dehumidifier use rates ranged from 1 percent in CI and SI to 5 percent in SC.

Use of a single air conditioning (cooling) thermostat setting during occupied building periods was reported at 50 percent to 58 percent across all four regions. For unoccupied periods, the reporting prevalence for single set points ranged from 28 percent to 34 percent across all four regions. Reporting by region, single heating set points during occupied time periods were in the range of 54 percent to 65 percent. Likewise, across regions, reporting of single heating thermostat settings for unoccupied periods was in the range of 23 percent (SI) to 31 percent (CI), a fairly tight range.

Maintenance/Cleaning

Cleaning on a regular schedule was reported by nearly all (98 percent to 100 percent) of the buildings for all regions. The practice of cleaning when occupants are present was reported across a fairly broad range across building size, ranging from about 35 percent (CI) to 56 percent (SI).

Businesses reported that outside contractors were used for cleaning services, at rates ranging from 35 percent (CI) to 55 percent (SI). Cleaning with a wet mop was very common, ranging from 85 percent (CI) to 92 percent (SC). Dry mop use prevalence ranged from 40 percent (NC) to 48 percent (SI).

Vacuum cleaning was reported by region, with prevalence ranging from 86 percent (SI) to 91 percent (SC).

Use of window cleaner use was very close across regions, with rates ranging from 84 percent (CI) to 92 percent (SI).

The rate of furniture wax use across regions ranged from 37 percent (SI) to 44 percent (CI).

Bleach use was reported across regions in a range of 32 percent (NC) to 39 percent (SI). Carpet cleaner use rates by region ranged from 52 percent (SI) to 66 percent (SC).

Reporting prevalence of regular pesticide application by region ranged from 48 percent (NC) to 69 percent (CI).

Occupant Feedback

Too Hot

Reports of occupant complaints of being too hot were made in about half of the buildings, with prevalence ranging from 49 percent (SI) to 58 percent (CI).

Too Cold

The frequency of respondents reporting that they received complaints of their buildings being too cold was close to that of the "too hot" response; 52 percent (SI) to 61 percent (NC).

Too Drafty

The reporting prevalence of occupants complaining of the building being too drafty were low, and differed little across region, ranging from 5 percent (SC) to 8 percent (NC).

No Air Movement

Complaints of no air movement were also not very different across regions; they were reported about twice as frequently as a "too drafty" complaint. Reported complaints ranged from 10 percent (CI) to 14 percent (NC).

Odors

The reporting prevalence for odor complaints by region varied from 10 percent in SI to 21 percent in NC.

Something Else

The survey asked if there were other types of complaints, not specified. The rates of these complaints ranged from 1 percent to 5 percent across the regions.

Locale

By region, the percentage of businesses located near a rural environment ranged from 33 percent in the SI region to 49 percent in CI.

Location in an industrial area was reported by region at rates from 14 percent (CI) to 29 percent (SC).

CHAPTER 4:
Discussion

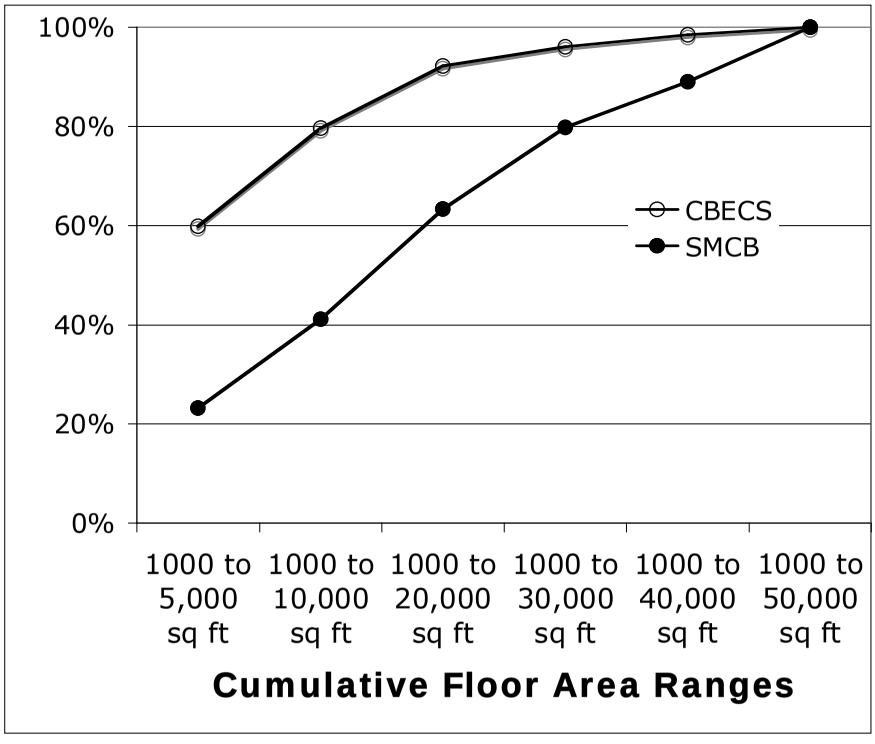
The survey was successful in gaining access to a wide range of business types in small- and medium-sized buildings within the state. However, the survey sample was not designed to provide a reliable inference to the entire population of SMCBs in California.

Comparison of SMCB and CBECS Samples

Figure 9 shows a comparison of the cumulative frequency of building floor area in this SMCB sample against the data collected in the Commercial Buildings Energy Consumption Survey (CBECS) conducted by the U.S. Energy Information Agency (CBECS, EIA 2003). The CBECS data used in this analysis are from a population-weighted sample drawn from U.S. Region 9 including California, Washington, Oregon, and Alaska. CBECS buildings in the 1000 to 50,000 ft^2 range were pulled from the dataset and stratified into the same floor area categories used in the SMCB analysis.

The cumulative distributions show that the SMCB floor area sample is skewed toward larger buildings, relative to CBECS. To the extent that the floor areas of buildings in non-Californian states in the CBECS dataset differ from California, this comparison may be faulty; however, it is not likely that the difference will be as large as that between the CBECS and the SMCB data.

Figure 9: Comparison between SMCB and CBECS Floor Areas



Source: Author(s)

This analysis underscores how important it is that the reader should not assume that these survey data could be extrapolated to the California SMCB population as a whole. As explained above in Section 2.2, the oversample of larger buildings was deliberate, to increase the number of large buildings in the sample. Furthermore, the sample was restricted to the fastest-growing California counties.

Data Collection Objectives

To focus this discussion, the data collection objectives of this project are recapped below. The survey intended to determine the following:

1. HVAC/ventilation equipment and control characteristics in SMCBs, including newer technologies (e.g., DCV, thermal displacement or underfloor ventilation, air cleaning)
2. HVAC/ventilation operation and maintenance characteristics in SMCBs
3. SMCB functions, indoor sources, where applicable the intensity of source usage, and water and fire damage history
4. History of IAQ complaints in buildings and associated remedial actions

Objective 1. Characterize HVAC/Ventilation Equipment

This objective was met using the HVAC survey mailed to willing participants. As discussed above, the acceptance rate for taking the survey was low, and the completion rate was even lower. However, the 71 somewhat complete surveys do provide information on the HVAC equipment used in the buildings.

All of the survey responses suggested that the buildings used very conventional HVAC system design. Few buildings reported using innovative or high performance HVAC approaches: 67 percent of the buildings operated outdoor air on a fixed damper setting; demand control ventilation was only evident in 8 of the 71 buildings. HVAC filtration approaches were very standard, with very limited evidence of any buildings employing higher efficiency filters; as an example, for the first RTU discussed, only one building used a 90 percent DOP efficiency HVAC filter and one using a MERV 12 filter. Three buildings did use HEPA filtration in RTU 1. No electronic filtration systems were observed.

Objective 2. HVAC/Ventilation Operation and Maintenance

As with the characteristics of the HVAC equipment, operation of the building systems can be characterized as very standard. Thermostat setpoints appear to be predominately sensible for both heating and cooling—although the 32 percent of the buildings having cooling settings in the 70°F to 73°F and 6 percent below 70°F is a rather high proportion of overly cooled spaces, with associated energy wastage and potentially poor thermal comfort. A smaller proportion of buildings appear to overheat—with only about 12 percent heating to temperatures above 74°F (23°C) , nonetheless this is again significant wastage and potentially a cause of uncomfortable conditions. Energy saving during unoccupied periods appears popular, as both cooling

temperatures substantially above and heating temperature substantially below occupied setpoints are typically used. However, again, it is clear that significant amounts of unnecessary heating and cooling during unoccupied periods occur in these SMCBs. More than a third of the buildings appear to turn off the space conditioning during unoccupied periods. Daily pre-occupancy startup of HVAC appears to be popular, with startup periods ranging from 30 to 60 minutes.

HVAC fan operation is an indication of ventilation supply; at least for systems that have outside air intake. Most of the buildings have fan operation only on thermostat cycling, an indicator of non-continuous ventilation. The use of occupancy sensor control of HVAC fans is almost non-existent.

Outside air supply is critical for maintaining good indoor environmental quality, particularly buildings that do not provide natural ventilation. Only about 10 percent of the buildings in the study opened windows regularly for ventilation. Similarly, only about 8 percent of the buildings used door opening for ventilation. The response rate for the exhaust fan use question in the HVAC survey was low, but from the data available, these fans appear to be predominantly bathroom fan size ventilators, inadequate for whole building ventilation. Thus, mechanical ventilation must provide outside air at rates that meet the ventilation requirements in Title 24. Unfortunately, none of the respondents provided the airflow rate of their air handlers. In addition, the low response in the HVAC survey limited the information gained on the mechanical ventilation supplied to the buildings. The questions on methods to control outdoor air do suggest that given a relatively low outside air percentage, even with substantial total supply airflow, the outside air supply rates are often low. That 38 percent of those answering do indicate using 100 percent outside air an economizer cycle suggests that these buildings may be receiving adequate ventilation. The 26 percent of buildings with outdoor air damper settings from 5 to 10 percent are likely not receiving enough outside air. Manual use of fan control and thermostat cycling of ventilation also suggest poor ventilation during significant parts of a day.

Information on HVAC maintenance from the survey is of poor quality because the response rate for answering these questions was very low. However, inference from those questions that were answered suggests that regular maintenance is the common practice for about 80 percent of the buildings. Some respondents did admit to only irregular maintenance practices, and a small percentage said that their systems were never maintained. The practices appear to be fairly similar for filter replacement, coil cleaning, drain pan and drain line cleaning. Duct inspection, balancing and cleaning seems to be much less common.

Objective 3. SMCB Functions, Indoor Sources, Where Applicable the Intensity of Source Usage, and Water and Fire Damage History

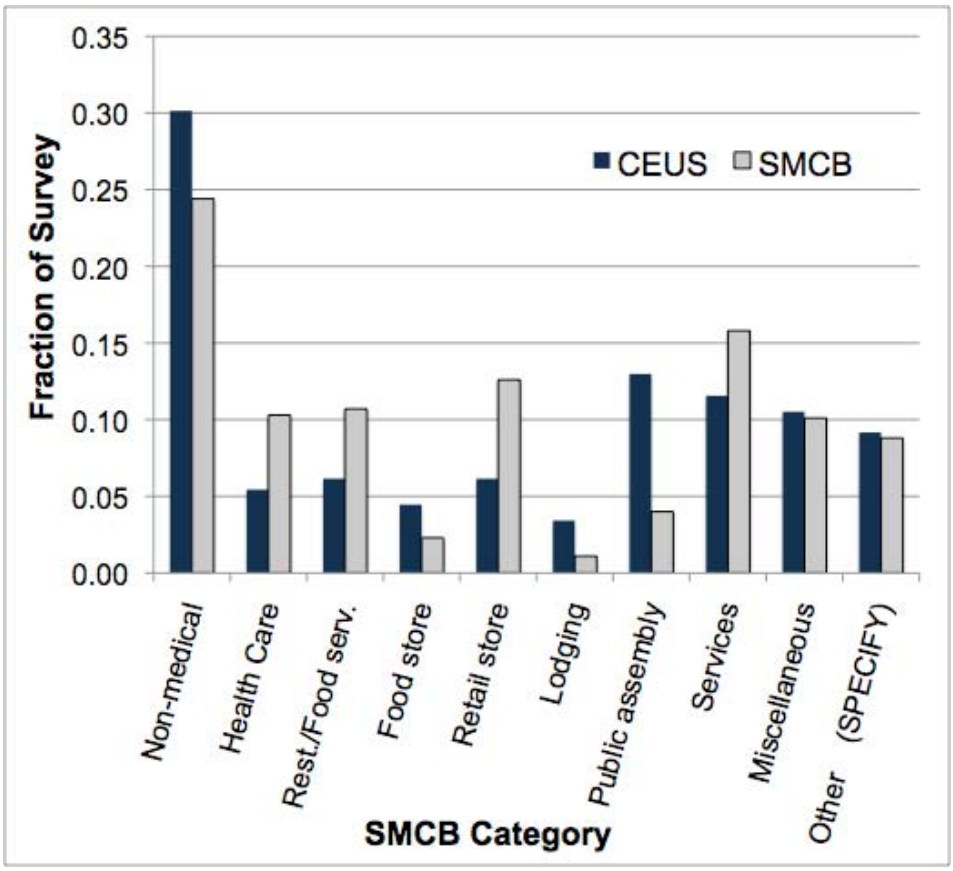
The buildings surveyed by telephone appear to have roughly met the survey goal of broadly representing the business types in the SMCB population. In Figure10, the SMCB business types are compared against a subset of the California End Use Survey (CEUS, Itron 2006) business categories that met the SMCB floor area definition of 1000 to 50,000 ft^2 (Brook 2006). The CEUS business type data were sorted into the same broad categories as the SMCB to create

comparable data sets. Although the comparison is not perfect, it is clear that they are not that different; SMCB was higher in the heath care, restaurant, retail store, and services categories, while CEUS was higher in the non-medical, lodging, and public assembly categories. All of the categories are represented in the SMCB data. Again, it is important to recognize that the SMCB dataset is not drawn a statistically representative sample of the California commercial building stock.

Potential pollutant sources identified in the buildings were related to major surface coverings such as floor and wall, furniture, processes in the buildings, cooking, and cleaning.

Carpet is clearly the most common floor covering, with concrete and wood following at less than half the prevalence. Carpet is considered a less desirable floor covering from an indoor air quality perspective for number of reasons; it becomes a sink for particulate contaminants that are tracked into it and for volatile and semi-volatile gases that are sorbed into it. These contaminants can then be re-emitted into the environment through mechanical re-suspension and off-gassing. Carpet is also a suitable environment for dust mite populations. When it gets wet it can become a source of mold and fungi that cause asthmatic, allergic, and toxic responses. Finally, although material formulations are in the process of improving, new carpet has historically been documented to be a source of elevated levels of a range of volatile organic compounds, either via direct emissions or through chemical reactions, that can be irritating and associated with chronic and long-term health effects (Chao et al. 2003; Girman et al. 2002; Gorny et al. 2002; Hart 1998; IOM 2004; IOM. 2000; Mendel et al. 2003; Park et al. 2006; Platts-Mills 2000; Warner et al. 2000; Weschler 2004).

Figure 10: Comparison of SMCB Business Type Category Survey Fractions vs. California End Use Survey (CEUS) Proportions for Buildings Between 1000 and 50,000 ft^2



New furniture (in the last year) using composite wood materials was common to about 10 percent of the buildings surveyed. Composite wood products are a documented source of formaldehyde and a major contributor to indoor levels of this compound, as well as other VOCs (Carter and Zhang 2007). New furniture was most common to Lodging businesses. It should be noted that 16 percent of the new furniture (about 3.5 percent of the total survey sample) used fully encapsulated composite wood products that would be likely to have much lower formaldehyde emissions.

Operations in the buildings are likely to be substantial sources of indoor air contaminants. Solvent use, grinding and buffing, film processing, and storage of tires are all processes that can increase pollutant loads and accompanying odors. The extent that these would be of health concern depends upon the particular materials used. Gasoline stations are a particularly important business type because of the potential for gasoline vapors (benzene is of concern) and automobile exhaust (e.g., particles, carbon monoxide, benzene, aldehydes) to be entrained into the building.

Cooking of some sort was common to almost all buildings surveyed. With the exception of restaurants, public assembly buildings, and food stores, cooking appears to be predominately limited to microwave heating and toasting. Where real cooking was done, indoor pollutant sources include gas appliances, roasting, grilling, and frying.

The process of cleaning buildings provides a means to maintain hygiene and ensure a safe, comfortable work environment. Thorough and regular cleaning reduces microbial loading on surfaces, settled dust from indoor and outdoor sources, and soiling on surfaces, a key activity for maintaining a healthy indoor environment. Virtually of the buildings surveyed reported regular cleaning, with half of the businesses doing it during unoccupied hours. Interestingly, almost half of the businesses indicated that they conducted cleaning while other occupants were present. Although cleaning is a necessary and required activity in buildings, it is perhaps the most common major source of indoor contaminants that crosses all business types. Modern cleaning materials consist of chemical compounds that in many cases can cause health effects. Many of the compounds are volatile and enter the air in gaseous form—typically volatile organic compounds. These compounds are commonly measured in commercial building environments, sometimes at concentrations of concern for health effects (Zock et al. 2007; Apte. and Daisey 1999; Hodgson and Levin 2003; Mendell 2007; Singer et al. 2006; Ten Brinke et al. 1998; Weschler 2004; Wolkoff et al. 2006).

Pesticide application is a source of indoor contaminants that can have adverse long-term effects on occupants. The high proportion of businesses that had outside contractors apply pesticide suggests that it is professionally applied. Hopefully, professional control of pesticide application rates indicates that occupant exposures are minimized relative to a "do it yourself" approach.

Visible water condensation was reported in a very small proportion of the buildings surveyed (3.4 percent), but water damage or mold was reported in about twice the number of buildings. As discussed above, excessive moisture is an indicator of potential indoor air quality problems. Additionally, water condensation suggests inadequate ventilation.

Fire damage was reported in about 2 percent of the buildings, and was restricted to the buildings in the two older age categories (11 years or older). Also of interest is that almost all of the reported fire damage was from the South Coast region.

Objective 4. History of IAQ Complaints in Building and Associated Remedial Actions

The survey collected information on occupant complaints regarding the thermal environment, air movement, and odors. These questions were by no means comprehensive in assessing possible impacts that the buildings had on the occupants. It is important to remember that survey respondents were speaking for all of the building occupants, and their answers are not precise as those that could be collected in a survey that directly queries the building occupants themselves. It is interesting that about the same proportion of buildings reported complaints of being too hot and being too cold, and the frequency of occurrence of these complaints were about the same as well. This situation persisted across all of the stratified analyses. Similar to the thermal questions, reported frequency of occupant complaints of the building being "too drafty" and that there was "no air movement" were about equal. Corrective actions in response to complaints were most likely to have come from inside the organization; i.e., manager (32 percent) or supervisor (47 percent), rather than by a contractor (20 percent) or some other unspecified entity (16 percent).

CHAPTER 5:
Summary and Conclusions

This survey provides a wealth of baseline information on the small- and medium-sized commercial buildings in California. It covers building characteristics of these SMCBs, sources of indoor contaminants, maintenance practices, building and HVAC operation, and cleaning practices. The survey was difficult to execute for a number of reasons, primarily due to limited access to buildings and because the individuals within the buildings' businesses did not always have the knowledge and availability to answer detailed questions.

The original intention of the survey team was to deploy the survey over the telephone, but it was eventually divided into a telephone component that dealt broadly with the building demographics, characteristics, operations, and other such factors and a mail-out questionnaire that focused on the technical details of the HVAC systems in the buildings. The telephone survey was moderately successful, and it produced 476 completed questionnaires. The HVAC survey was far less successful, with a total of 71 questionnaires returned, often not fully completed.

The strength of the survey results lies in the physical and operational details of the buildings that house the businesses that were contacted. No such information has been available on small- and medium-sized business buildings to date.

The information gathered in the survey provides a picture of a very "standard" SMCB population. Buildings are designed and operated as they have been doing traditionally for decades, which is no surprise.

A key policy issue for the Energy Commission and ARB is whether these buildings are adequately ventilated, meeting existing state standards and statutes. The SMCB study research has this as an important focus, and attempted to acquire outside air supply information for the survey buildings via the HVAC survey. The low response rate for this mail-out survey, compounded with the incompleteness of the returned surveys hindered assessment of ventilation. Fortunately, physical ventilation measurements are part of the SMCB protocol in the follow-on study. The reported use of doors and windows for ventilation, sizing and number of exhaust fans, and responses related to HVAC fan controls all lead to a suggested less-than-optimal ventilation scenario for the SMCBs. This situation must be addressed in future studies, particularly physical measurement studies. If the suspected low ventilation rates are found, the Energy Commission may wish to make tighter guidelines for HVAC design as well as require equipment that ensures that ventilation meets Title 24 requirements.

HVAC system maintenance and quality of air filtration in SMCBs is another key issue that may inform Energy Commission and ARB policies. Again, the HVAC survey response was low, although some general observations may be made. The quality of reported filtration efficiency was fairly low. Also, the information that 20 percent of the responding buildings had infrequent or no HVAC maintenance suggests that some policy intervention may be needed to improve this aspect of SMCB facility operation and maintenance. More research is needed to assess the

potential for improving IAQ in SMCBs through policy measures regarding equipment choices, operations, and maintenance.

Three key observations come from this survey that should be of considerable concern and interest by the State of California. First is the striking lack of knowledge regarding HVAC systems evidenced by the SMCB building management. Second is an almost complete lack of available information by the HVAC specialist on ventilation rates or outdoor air flow settings. Third, there is strong evidence of wasted energy in an overly large proportion of SMCBs, due to extreme thermostat settings for heating and cooling during both occupied and unoccupied periods.

This survey's findings do not provide sufficient information to indicate what the indoor air quality level is in the buildings. All of the factors are present in most, if not all, of the buildings to have very poor indoor environments, depending upon the amount of ventilation supplied. The ventilation question has not been answered adequately to make a conclusion regarding the indoor environments in the buildings that were surveyed. It is anticipated that the field measurement efforts of the SMCB follow-on study will provide further insight into the indoor environmental quality of these buildings.

The project as a whole brings several successes to the State of California and the buildings energy and environmental research communities. First, a database of buildings was created to support the follow-on, where field survey and measurements will be conducted. Second, a baseline dataset on the characteristics of SMCBs has been created with information on indoor sources and activities, as well as HVAC system configurations and operational setpoints. Third, attention has been drawn to the virtual lack of knowledge by building facilities management regarding HVAC equipment, ventilation rates, and ventilation systems. Finally, attention is drawn to the potential for energy savings through bringing thermostat settings into line with energy conservation recommendations.

CHAPTER 6: Recommendations

This study provides the baseline information on basic SMCB characteristics and the sources of indoor contaminants. Although information on the HVAC systems and how much ventilation is provided in California's SMCBs is difficult to collect, this study has begun the task that is needed to provide definitive answers to characterization of their IAQ.

The follow-on study is collecting detailed information on ventilation rates in a very small sample of Californian SMCBs (40 buildings). Although the additional information is expected to provide some insight into ventilation rates in these buildings, it will not be large enough, or representative enough, to justify reaching any broad conclusions regarding SMCB ventilation and indoor air quality.

To collect a large enough base of information on SMCB ventilation in California to justify such inferences, it will be necessary to conduct a physical inspection and measurement study on a large and statistically valid sample of buildings. Future work will be needed to collect measured data from a statistically drawn subset of SMCBs.

This being said, the survey does strongly suggest that the SMCB stock is not designed or operated with sensitivity to the value and importance of ventilation, indoor environmental quality, or energy conservation. This evidence should be of value to both the California Air Resources Board in terms of contaminant exposures of workers and patrons of SMCBs, and to the California Energy Commission in terms of policy and standards setting (e.g., Title 24) to further its efforts to reduce energy consumption in the commercial building sector.

References

Air Resources Board (2010), 2008 Emissions and Energy Use Projections from Planning and Technical Support Division (Staff Communication November 5, 2010).

Apte, M. G., and J. M. Daisey. 1999. "VOCs and 'sick building syndrome': Application of a new statistical approach for SBS research to U.S. EPA BASE Study data," in *Indoor Air 99.* Construction Research Communications, Ltd.: Edinburgh, Scotland. 117–122.

Brook, M. 2006. Personal communication with Martha Brook, California Energy Commission.

Building Energy Efficiency Standards; CEC 2005, http://www.energy.ca.gov/title24/2005standards/index.html

Carter, R. D., and J. S. Zhang. 2007. "Definition of Standard Office Environments for Evaluating the Impact of Office Furniture Emissions on Indoor VOC Concentrations." *ASHRAE Transactions* 113, Part 2, 466–477.

Chao, H. J., et al. 2003. "The work environment and workers' health in four large office buildings." *Environ Health Perspectives* 111(9): 1242–8.

EIA. 2003. Commercial Buildings Energy Consumption Survey (preliminary data). Energy Information Administration. Washington D.C. www.eia.doe.gov/emeu/cbecs.

Fisk, W. J., M. J. Mendell, J. M. Daisey, D. Faulkner, A. T. Hodgson, M. Nematollahi, and J. Macher. 1993. "Phase 1 of The California Healthy Building Study: A Summary." *Indoor Air* 3(4): 246–254. LBNL-51497

Girman, J. R., B. J. Baker, and L. E. Burton. 2002. "Prevalence of potential sources of indoor air pollution in U.S. office buildings," in *Proceedings of Indoor Air 2002.* Indoor Air 2002, Inc.: Monterey, California. 438–443.

Gorny, R. L., et al. 2002. "Fungal fragments as indoor air biocontaminants." *Appl Environ Microbiol 2002* 68(7): 3522–31.

Hart, B. J. 1998. "Life cycle and reproduction of house-dust mites: environmental factors influencing mite populations." *Allergy* 53(48 Suppl): 13–17.

Hodgson, A. T., and H. Levin. 2003. *Volatile organic compounds in indoor air: A review of concentrations measured in North America since 1990.* LBNL-51715. Lawrence Berkeley National Laboratory: Berkeley, California.

IOM. 2000. *Clearing the Air: Asthma and Indoor Air Exposure.* Institute of Medicine, National Academy of Sciences. Washington, D.C.: National Academy Press.

IOM. *Damp Indoor Spaces and Health.* 2004. Institute of Medicine, National Academy of Sciences. Washington, D.C.: National Academy Press.

Itron. 2006. *California End Use Survey (CEUS).* Consultant Report to the California Energy Commission by Itron, Inc. Sacramento, California. CEC-400-2006-005.

Jenkins, P. L., T. J. Phillips, E. J. Mulburg, and S. P. Hui. 1992. "Activity Patterns of Californians: Use of and Proximity to Indoor Pollutant Sources." *Atmospheric Environment* 26A(12): 2141–2148.

Mendell, M. J., 2007. "Indoor residential chemical emission as risk factors for respiratory and allergic effects in children: A review." *Indoor Air* 17(4): 259–277.

Mendell, M. J., et al. 2003. "Environmental risk factors and work-related lower respiratory symptoms in 80 office buildings: An exploratory analysis of NIOSH data." *Am J Ind Med* 43(6): 630–41.

Park, J. H., et al. 2006. "Fungal and endotoxin measurements in dust associated with respiratory symptoms in a water-damaged office building." *Indoor Air* 16(3): 192–203.

Persily, A., and J. Gorfain. 2004. "Analysis of Ventilation Data from the United States Environmental Protection Agency Building Assessment Survey and Evaluation (BASE) Study." National Institute of Standards & Technology. NISTIR 7145.

Platts-Mills, T. A. 2000. "Chapter 43. Allergens derived from arthropods and domestic animals." in *Indoor Air Quality Handbook,* J. D. Spengler, J. M. Samet, and J. F. McCarthy, Editors. McGraw-Hill: New York.

Singer, B. C., et al. 2006. "Indoor secondary pollutants from cleaning product and air freshener use in the presence of ozone." *Atmospheric Environment* 40: 6696–6710.

Ten Brinke, J., et al. 1998. "Development of new volatile organic compound (VOC) exposure metrics and their relationship to sick building syndrome symptoms." *Indoor Air* 8: 140–152.

Warner, J. A., et al. 2000. "Mechanical ventilation and high-efficiency vacuum cleaning: A combined strategy of mite and mite allergen reduction in the control of mite-sensitive asthma." *J Allergy Clin Immunol* 105(1 Pt 1): 75–82.

Weschler, C. J. 2004. "Chemical reactions among indoor pollutants: What we've learned in the new millennium." *Indoor Air* 14(Supplement 7): 184–201.

Wolkoff, P., et al. 2006. "Organic compounds in office environments—sensory irritation, odor, measurements and the role of reactive chemistry." Indoor Air 16(1): 7–19.

Zock, J. P., et al. 2007. "The use of household cleaning sprays and adult asthma: An international longitudinal study." *Am J Respir Crit Care Med* 176(8): 735–41.

Glossary

AC	Air Conditioning
ARB	California Air Resources Board
BASE	Building Assessment Survey and Evaluation
CASES	Computer Assisted Survey Execution System
CATI	Computer Assisted Telephone Interviewing
Energy Commission	California Energy Commission
CEUS	California End Use Survey
D&B	Dunn and Bradstreet
HVAC	Heating, Ventilating, and Air Conditioning
IAQ	Indoor Air Quality
IEQ	Indoor Environmental Quality
LBNL	Lawrence Berkeley National Laboratory
O&M	Operation and Maintenance
PM	Particulate Matter
RTU	Rooftop Unit
SMCB	Small and Medium Commercial Building
SRC	Survey Research Center
VOC	Volatile Organic Chemicals

APPENDIX A.
"OTHER SPECIFY" RESPONSES

This appendix contains the "other specify" responses given to some of the survey questions. They show the wide range of business types reported, as well as the extensive lists of renovations and corrective actions reported.

1. Non-Medical Office "Other" Business Types Reported

Accounting, Dentist and Doctor, and 1 vacancy

Auto repair, beauty supply

Auto sales

Automotive repair

Bail bonds

Casino

Church

Collision repair

Cosmetic manufactures

Country club/recreation, restaurant

Distribution

Distribution electronic products

Education- college, computer training, also nonprofit org.

Electronic retail

ESL classes for San Diego college dist.

Federal law enforcement

Headquarters building for tribal administration, and their law

Health and fitness club

Hospice and offices

IT

Just office

Manufacturing

Marketing and technology company.

Medical and non-medical offices

Music store

Nightclub

Offices

Job placement service office, flower shop

Pharmacy

Prison

Pump Warehouse and offices

Retail items sold and also car wash

Sell copiers

Sell lighting and audio video equipment

Senior living- retirement home

Steele distributor

Truck rental and lease

Underground utility surveys

Warehouse

Wholesale

2. Retail "Other" Business Types Reported

Ag Equipment like john deer

Building products

Cabinet showroom & offices.

Car wash

Comics

Construction and supply surveying

Construction supplies to large suppliers/contractors

Convenience store.

Equipment rental

Flowers.

Glass sales

Golf club place, semi-private. Retail store.

Industrial line of shops

Mini-mall

Motorcycle sales - free standing bldg

Office supplies

Outlet center

Retail facility for sales for water products

Retail flooring

Tire sales

WIC store

3. Service "Other" Business Types Reported

Administrative, health, music room

Adult day care

After school programs

Attorney office

Auto dealership

Auto sales and service

Automobile delivery service.

Call center for parks/recreation

Car dealership

Child care.

City administrative

Computer services

Consulting for handicapped (service center), other

Credit reporting/finances

Dry cleaning, clock shop

Educational

Engineering services for us navy

Environmental consulting

Equipment rental (heavy equip).

Furniture repair

Hair salon

Insurance services.

Mortgage loans

Nursing home

Offices for other companies.

Pest control

Police operations

Professional services?

Public service

Repairs

Retirement home - meals cooked for them

Sales and service water cleaning equipment

Social

Staffing services.

State water agency

Technology company - speech application software

Training, education and research related to disabled - schools, adult

Vocational skills center

4. Miscellaneous "Other" Business Types Reported

Army recruiting

Solar panel systems

City Hall

Construction, general contractor.

Decorative plumbing manufacturer/wholesale

Detention facility for juvenile delinquents.

Distributing, sales of communication products

Inventory on stores, hire clients to do inventory

Egg processing plant.

Financial benefits

Import shipping company.

Plumbing and heating

Real estate

Restaurant, golf shop, admin offices.

Ship manuals.

Silkscreen garments

Plastic molding/manufacturing

Warehouse/administrative

Warehousing.

Whole retail distributor

Wholesale distributor of taxi supplies

Wholesale parts sales.

5. List of Other Renovations Reported

4 bathrooms, two kitchens, a shower room

5000 sq. Ft. Added. Additional HVAC system installed

Added 6000 square feet

Added a new ac unit

Added a patio, and a door headed out to the patio, and some windows

Added some rooms and office spaces

Added washroom/ bathroom

Added whole other building in the back

Add-on

Bathroom was added

Built a new public washroom/bathroom

Built out top floor

Ceilings raised

Changed carpeting, booths, lamps.

Changed how the offices were configured

Created more warehouse space.

Drive thru window added

Dropped ceilings, new walls, etc.

Expanded the showroom about 15 ft

Facade, outdoors visible appearance, new meat case, dairy case, things

Fire repair

Flooring and electrical systems

Foamed the whole roof for energy efficiency.

HVAC units themselves replaced with new units

Interior offices, additional bathrooms added'; lunchroom redesigned

Interior wall; floor plan changes.

Interior/painting

Just interior tenant improvements, nothing to do with ventilation.

Kitchen

Made building larger

Metal bldg, added more passive ventilation

Modified and rerouted the ventilation systems.

New air conditioning units

New carpet, paint, that kind of thing.

New front office.

New roof

New rooms

Painting, new carpet

Partial ventilation systems

Particular to store.

Raised ceilings

Rearranged interior space- moved non-load-bearing walls.

Reconstruction of downstairs

Remodel interior

Renovated salad bar and booth

Replaced roof and paint

Replaced some HVAC units

Research Lab - lot of improvements in ventilation in that area.

Showroom and service area.

Spa

Sunroofs

Tenant improvement, kitchen

Two or three offices became one, main doors became double doors

Volume of space - added space office

Was a light industrial warehouse, converted it to offices, added atriums. At time, each suite had 1 or 2 HVAC/heat pumps

6. List of Other Corrective Actions Reported

The following is a list of corrective actions provided by survey respondents to the question of what actions were taken in response to indoor environmental quality complaints if they were not handled by an investigation by the building manager, an outside contractor, or a supervisor.

Upper management investigated and responded. New air conditioning unit came in as replacement.

Close door

An engineer in-house

An in-house engineer investigated

Inside crew handles complaints; outside contractor is brought in if crew cannot handle it.

Isolated employee complained and we turned the heat up a little no formal investigation needed - simple response by employees there at the time

Actually changed the thermostat.

Put on a sweater

Employees know where the thermostats are

Coworker

We just do what we want, if we're too hot or too cold, we fix it ourselves.

In-house engineer

Turned on desk fan.

Lowered the thermostat

AC wasn't turned on.

Complain to landowner to ask for section cooling but there isn’t much they can do

Corporate office took care of it.

Relocate guest, or adjust thermostat

Cleaned out

Building facilitator investigates

Readjusted temperature for employee complaint.

Samples smell bad - they close them up

Had thermostat fixed

Pipes replaced

Note should read the odor was being caused by a bad pipe, so the they had the pipe replaced

Air conditioner was repaired

The business is a hair salon and nail salon. Smells from different products used. Each station has an air purifier and doors are open @ times to let air circulate

Thermostat adjusted

Put a lock on the thermostat box - they were changing the temp. too much.

Had broken thermostat that needed to be replaced

Individuals change thermostat settings

We opened up an Economizer- they allow indoor smoking.

We just raised the temperature.

Took burnt toast out, toasted some new toast.

She plugged in space heater

Just turned the fan on.

Maintenance made adjustment on master stats.

Someone turned up the heat or turned it down.

Someone either used a space heater or put on a sweater.

Employees note it's cold, not customers

Turn heat up

Taken care of at station level, whatever the problem is

Staff took care of it

APPENDIX B.
SECOND AND THIRD FLOOR SURVEY RESULTS

1. Second Floor

Auxiliary Space Conditioning

The survey asked a series of questions regarding space-conditioning equipment.

When asked about the use of air cleaners on the second floor, 9 percent of the contacts stated that they were used. Of those buildings where they were used, 20 percent of the buildings had one unit, 40 percent used 2 units, 20 percent used 3 to 5 units, and 20 percent use more than 5 units. The air cleaners were mechanical in about 43 percent of the cases, used pleated filters in 29 percent, ionizers in 29 percent, and electrostatic precipitators in 14 percent of the cases. No ozone generators were reported.

Twelve percent of the building used space heaters on the second floor.

Only 3 percent of the second floor of buildings used a humidifier, and 1 percent used a dehumidifier on the second floor. The only building reporting the number of humidifiers used had two units. None of the respondents reported the number of dehumidifiers being used on the second floor.

Desk fans were used in 23 percent of the buildings. The number of desk fans used on the second floor ranged from 1 to 20 across the study: 22 percent had only 1 fan, 30 percent had 2 fans, 22 percent had 3–5 fans, and 26 percent had 10 or more fans.

Building Contaminant Source Information

Fire Damage

None of the buildings reported having fire damage on the second floor.

Recent Interior Painting

The survey identified that painting had been done on the second floor during the last year in 39 percent of the buildings contacted.

New Carpeting

The survey identified that new carpeting had been installed on the second floor during the last year in 14 percent of the buildings contacted. New nylon carpeting was installed in 75 percent of the cases, olefin (polypropylene) was installed in 25 percent. New styrene-butadiene carpet backing was used in 20 percent of the buildings, CRI “Green” Label backing used in 20 percent, CRI “Green” Label Plus backing used in 20 percent, and “other” in 40 percent. The “other” category responses included only “glued down.” Carpet pad materials included polyurethane

foam (10 percent), “no carpet pad” (70 percent), and something else (20 percent, a kind of rubber).

New Furniture

The survey identified that new furniture had been installed on the second floor during the last year in 18 percent of the buildings contacted. In 44 percent of the buildings a new furniture material was solid wood (raw, wood finish, or painted). In 61 percent of them it was a composite wood product with wood or synthetic veneer. About 33 percent of the buildings had furniture with fully encapsulated composite wood construction. Finally, 39 percent of the buildings had new metal or plastic furniture, and another 17 percent had a mix of wood, leather, fabric, glass, nylon, and vinyl materials.

Maintenance

In 99 percent of the buildings surveyed, cleaning of the first floor was reported on a regular schedule. In 18 percent of the buildings cleaning was done during occupied hours, 56 percent during unoccupied hours, and 26 percent during both occupied and unoccupied periods. Cleaning was performed during the daytime in 27 percent of the buildings, during the night in 52 percent, and both day and night in 21 percent. About 67 percent of the buildings reported that cleaning was done by an outside contractor.

On the second floor, the survey reports that floors were cleaned with a wet mop in 74 percent of the cases, with 59 percent of these doing it daily, 15 percent once a week, 14 percent twice a week, and 3 percent every two weeks. About 9 percent of the buildings provided a range of frequencies of floor cleaning, ranging from six times a day, on work days, to an irregular use and cleaning schedule.

Similarly, second floor cleaning with a dry mop was reported by 32 percent of the contacts. Daily cleaning was reported 72 percent of the time; weekly, 16 percent; and twice a week, 6 percent. About 6 percent of the respondents provided more detailed responses, including “as needed,” to “all day long.”

Second floor cleaning with a vacuum cleaner was reported by 96 percent of the contacts. Daily vacuuming was reported 58 percent of the time; weekly, 16 percent; twice a week, 16 percent; every two weeks, 2 percent; and monthly, 1 percent. About 7 percent of the respondents specified “other,” which was typically detailed with “as needed,” but one respondent stated that they vacuum three times a day.

Window cleaner was used on the second floor in 80 percent of the buildings, with a frequency of daily (40 percent), once a week (19 percent), twice a week (13 percent), every two weeks (4 percent), monthly (11 percent), and “other” (14 percent).

Furniture cleaner was reported as being used on the second floor of 41 percent of the buildings with frequency of daily (28 percent), weekly (28 percent), twice a week (10 percent), every two weeks (3 percent), and monthly (10 percent). Twenty-one percent of the buildings reported “other,” but this was not specified.

Furniture wax use on the second floor was reported by 31 percent of the buildings, with application frequency ranging from daily (9 percent), weekly (13 percent), twice a week (6 percent), monthly (22 percent), and "other" (50 percent). The specifics of the "other" response were not reported.

Bathroom cleaner application on the second floor was reported by 88 percent of the buildings. Seventy-four percent of them use it to clean the bathroom daily, 12 percent weekly, 7 percent twice a week, and 1 percent bi-weekly; 6 percent stated that they used bathroom cleaner on an "other" frequency.

Bleach was used in second floor cleaning by 26 percent of the businesses. About 67 percent stated that they use it daily, weekly (13 percent), twice a week (13 percent), and "other" (8 percent, not specified).

Use of soap and or detergent for cleaning on the second floor was reported by 73 percent of the businesses. This is done daily in 78 percent of the buildings, weekly (8 percent), twice a week (6 percent), bi-weekly (1 percent), monthly (1 percent), and "other" (5 percent, not specified).

Use of carpet cleaner for cleaning on the second floor was reported by 71 percent of the businesses. This is done daily in 1 percent of the buildings, weekly (3 percent), bi-weekly (1 percent), monthly (18 percent), and "other" (77 percent, not specified).

The survey identified that 7 percent of the buildings use other cleaning materials in the second floor that were not asked above. These materials were not specified in the survey.

Propane floor buffers were reported to be used on the second floor by 3 percent of the businesses.

The survey asked if there was any effort to use only "green" cleaning products, with 59 percent of the businesses reported "yes."

A question asked where on the second floor the cleaning materials were stored. The janitor's closet was used in 53 percent of the buildings, 3 percent in another closet, 7 percent in a storage room, and 16 percent "anywhere else."

Pesticide Application

Pesticide application on the second floor was reported by 41 percent of the businesses. Of those using it, 100 percent state that it is applied by an outside contractor. Outdoor pesticide application was reported to be weekly in 2 percent of the buildings, monthly (56 percent), and quarterly (21 percent). It was not used in 9 percent of the buildings. Indoor second floor pesticide application was reported to be monthly (25 percent), quarterly (5 percent), not used (36 percent), and "other" (34 percent).

Only 4 percent of the buildings reported storing pesticides on site on the second floor. Of these, 100 percent used the janitor's closet.

2. Third floor

Auxiliary space conditioning

The survey asked a series of questions regarding space-conditioning equipment.

When asked about the use of air cleaners on the third floor, 7 percent of the contacts stated that they were used. Only one of the buildings using air cleaners on the third floor provided information on how many they used; two. One in this building was a mechanical air cleaner, while a second one used pleated filters. No ionizers, electrostatic precipitators, or ozone generators were reported for third floor use.

Space heaters were used on the third floor by 7 percent of the buildings.

Only 7 percent of the buildings (1 building) used a humidifier, and the same one used a dehumidifier on the third floor. This building reported that they used four humidifier units but did not report the number of dehumidifiers being used.

Desk fans were used in 14 percent (two) of the buildings. Only one building reported the number of fans beings used on the third floor; two.

Building Contaminant Source Information

Fire Damage

None of the buildings reported having fire damage on the third floor.

Recent Interior Painting

The survey identified that painting had been done on the third floor during the last year in 29 percent of the buildings contacted.

New Carpeting

The survey identified that new carpeting had been installed on the third floor during the last year in 7 percent of the buildings. Nylon carpeting was installed in 100 percent of the cases. The only respondent that answered this type of carpet question reported use of styrene-butadiene carpet backing. Similarly, only one respondent reported on their third-floor carpet pad material, it being rubberized or resinated fiber.

New Furniture

The survey identified that no new furniture had been installed on the third floor during the last year.

Maintenance

In 100 percent of the buildings surveyed, cleaning of the third floor was reported on a regular schedule. In 14 percent of the buildings cleaning was done during occupied hours, 64 percent cleaned during unoccupied hours, and 21 percent cleaned during both occupied and unoccupied periods. Cleaning was performed during the day in 14 percent of the buildings,

during the night in 64 percent, and both day and night in 21 percent. About 71 percent of the buildings reported that an outside contractor did the cleaning.

On the third floor, the survey reports that floors were cleaned with a wet mop in 85 percent of the cases, with 73 percent of these doing it daily, 18 percent once a week, and 9 percent monthly.

Similarly, third floor cleaning with a dry mop was reported by 31 percent of the contacts. Daily cleaning was reported 75 percent of the time, and weekly 25 percent of the time.

Third floor cleaning with a vacuum cleaner was reported by 100 percent of the contacts. Daily vacuuming was reported 79 percent of the time and weekly 21 percent of the time.

Window cleaner was used on the third floor in 69 percent of the buildings, with a frequency of daily (44 percent), once a week (33 percent), and "other" (22 percent).

Furniture cleaner was reported as being used on the third floor of 54 percent of the buildings with frequency of daily (57 percent), weekly (14 percent), and "other" (29 percent, not specified).

Furniture wax use on the third floor was reported by 39 percent of the buildings, with application frequency ranging from daily (60 percent) and "other" 40 percent. The specifics of the "other" response were not reported.

Bathroom cleaner application on the third floor was reported by 92 percent of the buildings. Eighty-three percent of them use it to clean the bathroom daily and 17 percent weekly.

Bleach was used in third floor cleaning by 15 percent of the businesses. About 50 percent stated that they use it daily, and 50 percent use it weekly.

Use of soap and or detergent for cleaning on the third floor was reported by 77 percent of the businesses. This is done daily in 90 percent of the buildings and weekly in 10 percent.

Use of carpet cleaner for cleaning on the third floor was reported by 92 percent of the businesses. This is done daily in 8 percent of the buildings, weekly (8 percent), bi-weekly (8 percent), monthly (17 percent), and "other" (58 percent, not specified).

The survey identified that none of the buildings use other cleaning materials on the third floor.

No propane floor buffers were reported to be used on the third floor of the businesses.

The survey asked if there was any effort to use only "green" cleaning products, with 82 percent of the businesses reporting "yes."

A question asked where on the third floor the cleaning materials were stored. The janitor's closet was used in 57 percent of the buildings, 7 percent in another closet, 14 percent in a storage room, and 7 percent from "anywhere else.

Pesticide Application

Pesticide application on the third floor was reported by 62 percent of the businesses. Of those using it, 100 percent stated that it is applied by an outside contractor. Outdoor pesticide application was reported to be monthly in 50 percent of the buildings, quarterly (25 percent), not used (13 percent), and "other" in 25 percent of the cases. Indoor third-floor pesticide application was reported to be quarterly (13 percent), not used (63 percent), and "other" (25 percent).

A full 100 percent of the buildings reported storing pesticides for use on the third floor off-site.

Appendices

Appendix C: Telephone Questionnaire

Appendix D: HVAC Questionnaire

Appendix E: Codebook and Frequencies for the Indoor Environmental Quality and HVAC Survey of Small and Medium Commercial Buildings (SMCB)

Appendix F. Codebook for the Heating, Ventilation, and Air Conditioning SAQ (2008)

Appendix G. Pie Charts for SMCB Survey Responses

These appendices are available as a separate volume, publication number CEC-500-2011-038-APC-G.