The Green Apple Research Project:

Health Outcomes of a Green Housing Retrofit for Older Adults in Phoenix, Arizona

Final Report: August 2013

Arizona State University

with University of Florida and

Lawrence Berkeley National Laboratories

Health Outcomes of a Green Housing Retrofit for Older Adults in Phoenix, Arizona

Arizona State University
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And the delightful residents of Sunnyslope Manor

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SUNS

Executive Summary

Challenges facing the American housing industry are many, but two that are particularly salient for the health of American homes and households are climate change and an aging population.

Concerns for the consequences of climate change and dwindling natural resources are resulting in numerous inventions, initiatives and practices to increase energy and water efficiency in our buildings and homes. But global warming also suggests increased health impacts in the home resulting from the changing nature and scope of air and environmental quality (Institute of Medicine 2011). The extent to which conventional green building and renovation practices contribute to potentially harmful environmental conditions that exacerbate or mitigate health conditions is an important question. With increasing public investment in green and energy-efficient housing improvements, it is important to assess the collateral benefit such improvements may have in enhancing health conditions of residents and indirectly deterring healthcare costs.

In conjunction with these environmental changes are demographic ones, notably the aging of the American population. By 2030, an estimated 71 million Americans – 25% of the population — will be over the age of 64. The homes in which they live are central to the lives of older adults; surveys estimate that 80% to 90% of their time is spent in their homes. As a consequence, older adults are particularly susceptible to effects of detrimental indoor environmental conditions because of the amount of time they spend in their homes as well as declining physiological capacities (muscular, respiratory, skeletal, visual and the like).

This research study contributes to the nascent body of research examining green and energy efficient building practices on resident health by focusing on a vulnerable resident population: low-income seniors living in assisted housing. Two overarching research questions directed this study:

1. To what extent does indoor environmental quality of homes improve following housing renovations of the American Recovery and Reinvestment Act (ARRA) Green Retrofit Program?

2. To what extent do health outcomes of seniors improve following designated housing renovations of the ARRA Green Retrofit Program?

In addition to these, two ancillary research questions were addressed:

3. What is the cost-benefit of these building improvements in light of both renovation costs and anticipated healthcare costs and savings?

4. What is the use and effectiveness of age-specific educational materials developed for this particular resident sample in informing and motivating residents to maintain their renovated homes in a healthy manner?

The research site for investigating these questions was Sunnyslope Manor, a project-based Section 8 apartment complex in Phoenix, Arizona, owned and operated by the City of Phoenix Housing Department. The project consists of a single three-story, 116-unit building constructed circa 1970. Sunnyslope Manor was selected as the site for this research because the timing of a $1.7 million grant from the U.S. Department of Housing and Urban Development for a green retrofit made it possible to perform a panel (i.e. longitudinal) study of the effect

of the green remodel on the indoor environmental quality of residents' homes and on residents' reported health and residential quality assessments. Sunnyslope Manor represents the building age and scale of many federally assisted residential complexes retrofitted in HUD's ARRA Green Retrofit Program.

The retrofit included numerous building, systems, appliance, and materials changes and upgrades, detailed in the full report. Major renovations included: roof upgrades (insulation, primer, coating); upgrades of PTAC units in apartments; entire kitchen and bathroom remodel; new ceiling fans in units; window replacements (low-E coated, double pane); new flooring, paint and cabinetry that were no or low VOC; and ADA updates in bathroom and kitchen of a few units.

Research Design and Methodology

Given the field nature of this study, this research utilized a one-group pre-test, post-test research design. We collected data of the same residents and apartment units once before the renovation (referred to as Panel 1, or P1) and twice after the renovation was completed (Panels 2 and 3, or P2 and P3). The second panel occurred approximately three months after a resident's apartment had been renovated; and the third panel occurred approximately a year after the retrofit. Lacking a control group, we compared findings to proxy or threshold measures: (1) health data of the same questionnaire items from national and Arizona samples of lower-income older adults during the same years of our data collection; and (2) standards and thresholds of indoor air and climatic conditions.

Seventy-seven residents from 74 units participated in the study at the time of Panel 1 (i.e. pre-renovation, June-July 2010). Attrition occurred by panel 2. Being a panel study, residents who did not participate in Panel 1 were ineligible to participate in subsequent panels. The sample in Panel 2 consisted of 59 residents and 55 units who had participated in panel 1 (data collection occurred primarily May-September 2011). The Panel 3 sample, collected primarily June-July 2012, included 57 residents and 53 units (allowing residents who could not participate in Panel 2 to do so at P3).

Data collection in each panel consisted of interviews of residents and indoor environmental quality (IEQ) testing of residents' apartment units. Research technicians/assistants collected the following data at each panel:

- Absolute air temperature was monitored and recorded every 15 minutes in kitchen, bedroom and living area, utilizing mobile Onset HOBO data loggers, over a 5-day period. One HOBO (living room) also measured relative humidity (RH).
- Blower door tests for measuring CFM50, an indicator of air infiltration.
- Particulate matter (PM) using Dustrack 8533 Samplers that provided real-time measurement of suspended particles in different size ranges. The samplers collected air in three different locations (balcony, kitchen and living area) for about 45 minutes total for each data collection period.
- Samples of formaldehyde, acetone, and acetaldehyde were collected over a 1-hour period using SKC Low-Flow Gas Pumps. Three samples were collected simultaneously in the living room, kitchen and the balcony.
- Residents reported health conditions from interviews with the resident at his/her home during the IEQ sampling period. A questionnaire (Health at Home survey) was developed from applicable questions of the National Health Interview Survey (NHIS) and from the Behavioral Risk Factor Surveillance System (BRFSS) for Arizona. While the survey covered a large range of health conditions, those most relevant to our study are: general health and life quality; respiratory conditions; emotional distress; fall incidence; functional limitations; and sleep. Additional open-ended and fixed-response questions were added beyond those from NHIS and BRFSS instruments to further clarify some of the health, falls/trips, smoking behavior, and functional assessments that particularly pertained to the retrofit.

- In addition to health questions, the Health at Home interview also addressed residents' perceptions and assessments of the environmental quality of their apartments as well as household activities/behaviors relevant to environmental quality. These items were derived from two sources: University of California Berkeley Center for the Built Environment's (CBE) Occupant IEQ Survey, residential version; and Healthy Housing Inspection Manual (HHIM), developed by the CDC and HUD.

When examining changes in indoor environmental quality (temperature, RH, CFM50, PM, aldehydes) from Panel 1 to Panel 2 (referred to as "P1P2" or immediate change) or from Panel 1 to Panel 3 ("P1P3" or longer-term change), we used a class of regression methods called fixed effects models. Since we did not have a control group but did have a longitudinal panel research design, these models were appropriate to our study design, where each individual (or the individual's apartment) acts as his or her own control. Potential mediating or moderating variables (such as resident's smoking behavior or floor level of unit) were handled by entering them into these regression models. For health data, fixed effects models were used when applicable; but since much of the health data was binominal or ordinal-level data, ordinal regression and various nonparametric techniques (e.g. Chi-square analysis, Mann Whitney U tests, etc.) were used as appropriate.

Researchers and housing providers acknowledge that resident behavior is a key component of healthy home practices as well as green practices such as energy efficiency (HUD 2001; Wener & Carmalt 2006). Engaging the Sunnyslope Manor community, third year undergraduate students in the Visual Communication Design studio course at Arizona State University undertook a 6-week project in Spring 2011, working with residents to create educational materials for maintaining a healthy home after the renovation. Components of the booklet are contained in the full report; copies of this brochure are available upon request. Questions about the use of the booklet were included in the Panel 3 interview.

Highlights of Findings

The full report contains results of the many analyses we undertook. Key findings are highlighted below, organized by chapter.

Did the Retrofit Result in Decreased Utility Consumption?

- Comparison of the pre- and post-renovation metered data shows energy consumption reduced from 1042 to 845 kWh annually, and water consumption from 5129000 to 4495000 CCF annually. These values amount to approximately 19% reduction in energy and 12% in water consumption, corresponding to the consultant's report.

Did Indoor Air Quality Improve After the Retrofit?

- Overall, there was no statistically significant change in PM levels before the renovation and afterwards (neither immediate nor longer term post-retrofit), except when controlling for covariates. Over the longer term (i.e. P1P3), units with residents who had lived longer at Sunnyslope Manor had a decrease in PM concentrations (but no effect on the indoor/outdoor ratio was noted), opposite that of the short term effect. Also, use of odor-masking products had no effect on changes in PM concentrations in the longer term but did when examining immediate change (i.e. P1P2).
- In general, smokers had higher PM concentrations, but no immediate or longer term change of concentration levels as a result of the renovation.
- Baseline (P1) formaldehyde levels were higher than reports in other studies of U.S. homes (see Gordon et al, 1999; Zhang et al, 1994a, 1994b), but with a similar distribution. The median formaldehyde concentration for pre-retrofit Sunnyslope Manor apartments was approximately 36 ppb, while one study of American homes (not new construction) showed a median of 17 ppb. Prior to the renovation, 32% of the SSM units had formaldehyde concentration levels that exceeded the California acute REL standard of 44 ppb.

- The most significant long-term changes are observed in the formaldehyde concentrations. Formaldehyde concentrations show a statistically significant decrease from P1 to P3. This decrease held after controlling for most mediating building characteristics and personal/behavioral factors, including use of household cleaning products.
- While there were increased levels of acetone and acetaldehyde in units over the short term (P1P2), this difference dissipated by the third panel. However, indoor/outdoor ratios of acetone increased both in immediate and longer term panels, even after controlling for the mediating building and personal/behavioral variables.

Did Indoor Climate Conditions (Temperature, Relative Humidity, Air Infiltration) Improve after the Retrofit?

- Indoor unit temperatures remained fairly constant between P1 and P2, suggesting that the renovation had little immediate effect on indoor temperatures.
- Decreases noted in mean and minimum temperatures between Panels 1 and 3 suggest that added roof insulation, roof primer, and Uni-Seal coating may have contributed to improving control of indoor temperatures.
- The number of instances where temperatures exceeded 81°F (ASHRAE threshold) are also significantly fewer from the first to final panel, further suggesting that renovations had a positive impact on indoor temperatures by minimizing and stabilizing temperature extremes.
- Curiously, thermal variability increased from Panel 1 to Panel 3; this pattern was marginally significant between P1 and P2.
- While mean relative humidity did not change over time, RH variability significantly increased in both post-retrofit panels in relation to Panel 1.
- Surprisingly, there were no statistically significant changes in air infiltration after the retrofit, either immediately or longer term.

Did Reported Health Conditions Change After the Retrofit?

A key reason for selecting health questions from the NHIS and BRFSS surveys was to compare responses on the same health items of our SSM residents with those of U.S. and Arizona low-income older adults. This would allow us to gauge whether the degree of change (from pre-retrofit to P3) in health among SSM residents differed from the degree of change (of same time period) of national and state-level samples. Unfortunately at the time of this report, we were unable to make this comparison because 2012 data for NHIS and BRFSS was unavailable. We intend to do so in future reports and articles of our study. However, we were able to compare health conditions of SSM residents with those of national and state samples for the time period covering the first two panels (2010, 2011). In those years, SSM residents were more likely than State or national samples to experience chronic health conditions (except asthma) and feelings that contribute to emotional distress. While SSM residents' reports of general health are similar to those of national respondents, their reports of feeling healthy/energy, life satisfaction, number of days of poor health, and days of unintentional sleep are significantly lower than their Arizona peers. Comparatively, SSM residents have more functional challenges with weight-bearing activities and have higher incidence of pain in the lower back and neck than the national older adult respondents.

Key health findings among SSM residents include:

- SSM residents reported less emotional distress between Panels 1 and 3, one year after the renovation. There were no significant changes of other key health conditions, including respiratory health, general quality of health/life, and fall incidence. Analysis of functional limitations is still ongoing.
- Emotional distress was significantly correlated with number of functional limitations at baseline and the third panel. At panel 3 emotional distress was also correlated with times fallen and quality of health/life.

- At panel 3, there was a significant inverse correlation between emotional distress and perceptions of their home environment, particularly satisfaction with kitchen air quality, satisfaction with kitchen lighting, satisfaction with kitchen temperature, lighting comfort, satisfaction with visual comfort.
- P1P3 reductions in how often the apartment exceeded 81°F (ASHRAE threshold) resulted in reports of improved quality of health/life, reduced emotional distress, and increased number of hours sleeping.
- P1P2 changes in formaldehyde concentrations contributed to residents' reported quality of life/health and reduction in emotional distress. Between Panels 1 and 3, this formaldehyde change contributed only to reduction in emotional distress score.

Did Resident Perceptions and Behaviors Change After the Retrofit?

- In Panel 3, 75% answered "much better" or "somewhat better" when asked how the renovation affected their emotions. Of those who said the renovation affected their emotions much or somewhat better, half of the respondents mentioned specific features of the renovation such as cabinets, stove, desk, and the like. Over a third mentioned ambient qualities, such as the renovation made the unit cleaner, brighter, or more open. One quarter responded favorably to the kitchen renovation in its entirety as making them feel better. One-fifth mentioned the floors, and the same percentage also mentioned a general "Overall" or "Everything" response.
- While there were no changes in residents' perceptions of thermal comfort or perceived lighting conditions either immediate or longer-term, residents' satisfaction with the air quality of their units was significantly higher at the final panel than prior to the retrofit.
- Examining household cleaning practices across panels, we found significant changes in use of any odor-masking products (such as candles, incense, air fresheners) between P1P2 and P1P3 but the changes did not follow a set pattern.
- Use of natural or "green" household cleaning products is common among Sunnyslope residents. Eight out of ten residents use homemade solutions from water, lemon, borox, vinegar, and the like; only 4% use store-bought commercial products that are designated "green."
- P1P2 changes in the unit's formaldehyde concentration as well as for the exceedance levels for the kitchen and living area was significantly related to residents' perceptions that their home environment contributed to various health problems. However, these formaldehyde patterns diminished in P1P3, with only P1P3 changes in the exceedance level of the kitchen significantly related to residents' perceptions of the contribution of their homes to their health.
- When asked about the educational booklet at Panel 3, 63% of the residents said they had received a copy of the booklet (if they said they did not receive a copy, we gave them one then). Of those who said they had received a copy, 88% said they had looked at it; and 70% said they had read a recommendation that was new to them. Most of these included particular homemade cleaning solutions and a few pertained to use of appliances or equipment.

Benefit Cost Analysis

- The estimates indicate that renovations that reduce the risk of injurious falls must reach a threshold of reducing injuries by approximately 0.5 injuries per resident per year to generate a benefit/cost ratio greater than one. The baseline to post renovation results show a 52% reduction, which greatly exceeds the minimum threshold. Our estimates provide a range based on the differences between the baseline and the two subsequent interviews.
- The estimates are subject to considerable uncertainty given the small numbers of residents in the database and the limitations on the ability to directly measure any causal relationships between the renovation elements for which costs are attributed to reductions in the risks for falls. Given the uncertainty inherent in the limitations of the data, we suggest that a reasonable estimate of the benefits and costs of the renovation on the health care costs of falls lies within the range presented.

- We have not addressed the potential benefits of improvements in air quality on avoided health care costs because of the absence of data that could be used to predict these long-term impacts. The ability to make such projections is also inherently limited by the multiplicity of chronic conditions that affected the residents at baseline and the expected continued deterioration of their health as they age.

Chapter 1

Background

1.1 The Conundrum of "Green = Healthy?"

With energy efficiency and green building practices increasingly embedded in residential renovations, the need to assess their impact on indoor environmental quality (IEQ) and human health becomes more critical "to ensure that green housing and healthy housing are in fact synonymous" (HUD 2009, p 8). Recent research in environmental health (e.g. Wargo 2010) suggests that the two do not *de facto* correspond and may even conflict. Until recently few green building certification programs mandated building materials, fixtures, appliances/systems, and other elements that directly reduced potential health hazards or enhanced health conditions and behaviors. Some green building practices even emphasized energy efficiency practices to the detriment or even neglect of indoor air quality, for example.

A change in focus is increasingly evident in the commercial industry. A 2012 survey (Bernstein et al 2013) of over 800 building-related firms in 62 countries found that although energy savings are by far the most critical environmental reason to build green, these building executives cited health and well-being factors as the most important social benefits driving green building, nearly double that of a similar survey in 2008. Turner's 2012 Green Building Market Barometer (2012) surveyed over 700 U.S. executives from building-affiliated industries such as architecture, construction, real estate development, brokerage, and the like. Survey results suggest that incorporating green features is driven by a desire to reduce cost, followed by an interest to improve the indoor environment for building occupants, and finally – and much less so – broader concerns about the impact of building on the global environment.

The extent to which increasing emphasis on health and indoor environmental quality is similarly pervasive and growing among residential builders is an open question at this time.

This research study contributes to the nascent body of research examining green and energy efficient building practices on resident health by focusing on a vulnerable residential population: low-income seniors living in assisted housing. While there are a number of research studies examining a single type of housing characteristic (e.g. structural hazards) on singular health outcomes (e.g. injuries), none examine the impact of multiple green building practices on prominent health concerns of seniors, particularly: respiratory ailments; joint and movement impairments; injuries; sleep; anxiety and other mental health conditions; falls; and functional limitations.

Concerns for the consequences of climate change and dwindling natural resources are resulting in numerous inventions, initiatives and practices to increase energy and water efficiency in our buildings and homes. But global warming also suggests increased health impacts in the home resulting from the changing nature and scope of air and environmental quality (Institute of Medicine 2011). The extent to which conventional green building and renovation practices contribute to potentially harmful environmental conditions that exacerbate or mitigate health conditions is an important question. With increasing public investment in green and energy-efficient housing improvements, it is important to assess the collateral benefit such improvements may have in enhancing health conditions of residents and indirectly deterring healthcare costs.

1.2 Research Questions

Two overarching research questions directed this study:

1. To what extent does indoor environmental quality of homes improve following housing renovations of the American Recovery and Reinvestment Act (ARRA) Green Retrofit Program?

2. To what extent do health outcomes of seniors improve following designated housing renovations of the ARRA Green Retrofit Program?

In addition to these, two ancillary research questions were addressed:

3. What is the cost-benefit of these environmental/building improvements in light of both renovation costs and anticipated healthcare costs and savings?

4. What is the use and effectiveness of age-specific educational materials developed for this particular resident sample in informing and motivating residents to maintain their renovated homes in a healthy manner?

1.3 The Green Apple Project (GAP)

The adage "an apple a day keeps the doctor away" was appropriated for "branding" this research study – the effects of a green apple (i.e. green housing practices) on health. Supported by a HUD Green and Healthy Homes Technical Studies grant (#AZLHH0200-09), a multi-disciplinary team of faculty, research professionals and graduate students conducted a panel study examining impacts on indoor environmental quality (IEQ) and reported behavior and health conditions of senior residents following the green renovation of their apartment complex in Phoenix, Arizona.

As part of the 2009 American Recovery and Reinvestment Act, a total of $250 million in grants and loans was awarded nationally to various HUD-assisted multifamily housing properties across the country for installing utility-saving and other retrofits that would result in utility savings and other environmental benefits to these properties. One of the recipients of this HUD Green Retrofit Program for Multifamily Housing was Sunnyslope Manor (SSM) in Phoenix, Arizona, the site of our study (further description following). The building retrofit interventions that were undertaken do not reflect those of leading green certification programs such as LEED, but rather those of the Green Retrofit Program wherein housing authorities incorporated energy efficiency and other related housing improvements for assisted housing developments. Detailed description of these building interventions is provided in Chapter 2.

The health conditions and indoor environmental quality metrics that were examined in this study reflect key health-related concerns of older adult populations that could be exacerbated, or enhanced, by housing conditions, and of climatic conditions of the Southwest – an area with very little precipitation and humidity; high counts of outdoor air pollutants; and extreme heat for several months of the year with rather temperate weather conditions for the remainder.

1.4 Brief Overview of Housing and Health Issues of Seniors

While there are currently 39 million Americans who are age 65 or older (in this report, this age group will be referred to as "seniors" or "older adults"), that number is estimated to increase to 72 million Americans by 2030, representing 20% of the U.S. population (Federal Interagecy Form on Aging Related Statistics, 2010). Compared to research on children and families, relatively little research has examined adverse health effects facing this population from potential environmental exposures and hazards in the residential environments where they live. Aging-related changes in behaviors and activities, in mind and body, and in financial and social assets, can magnify exposure and susceptibility to environmental threats, resulting in potential health risks.

Many seniors spend up to 80 to 90% of their times indoors, often at home (Simoni et al 2003), indicating greater exposure to potential home containments and hazards. Susceptible to arthritis, muscular atrophy, osteoporosis, and visual impairment, many older adults can find it difficult to maintain sufficient cleanliness standards of their homes, to visually identify residential fixtures and features correctly (e.g. thermostat control switches), or to sufficiently grasp objects and move throughout their home safely and without injury (Davis 2007).

As they age, older adults have smaller airways and are therefore more likely to experience bronchial hyper-responsiveness (Yeatts et al 2006) and other respiratory ailments, making them increasingly vulnerable to indoor air particulates and certain environmental toxins and contaminants. Diabetes is among the top leading causes of death in the U.S. for seniors. People living with diabetes are considered at high risk for adverse health effects from exposure to

harmful particles or air pollution found both indoors and outdoors. Likewise breathing in harmful particles from air pollutants may increase the risk of heart attack and stroke (National Center for Healthy Housing 2008; Dominici et al 2006).

Mold growth in high concentrates can cause severe health effects in the elderly. Seniors are particularly susceptible to influence of mold spores as the immune system weakens as people age, and the respiratory system loses strength as lung tissue atrophies. This is a particular problem in damp, humid indoor environments. Seniors are less capable of fighting off unwanted airborne contaminants because the systems that help to prevent infections – the cough reflex, mucus lining, and antibodies – lose their strength with age (Indoor Restore 2012; Lippmann 2002). Too, thermal stress is increasingly problematic as the body's thermoregulatory processes diminish with age (Gomolin, Aung, Wolf-Klein & Auerbach 2005; Havenith 2001; Novieto & Zhang 2010; Tochihara et al 1993).

Both excessively high and excessively low relative humidity levels can exacerbate skin and respiratory conditions. Low levels can produce dry noses and throats that make people more susceptible to upper respiratory illnesses; low levels can also facilitate skin dryness and irritation. While recommended levels of relative humidity have been established by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), various researchers consider the recommended range too large (e.g. Arundel, Sterling, Biggin & Sterling 1986; Sterling, Arundel & Sterling 1985). The Mayo Clinic, for example, on their website recommends RH levels between 30 and 50%, a smaller range than ASHRAE standards.

Being at higher risk for residential injuries especially falls (Sleet, Moffett & Stevens 2008), seniors are vulnerable to mishaps on steps and stairs, smooth and slick floor materials, and wet surfaces in the home (USDHUD OHHLHC 2009). Each year over one-third of adults 65 years and older fall at least once. Every 18 seconds an older adult is treated in an emergency department for a fall, and every 35 minutes a senior dies as a result of their injuries. It is estimated that falls account for 33% of injury-related medical expenditures and cost Americans more than $38 billion annually (USDHUD OHHLHC 2009).

The American Association of Geriatric Psychiatry (2008) estimates that nearly 25% of people age 55 years and older experience some type of mental health concern, including anxiety, severe cognitive impairment and mood disorders. Dark, noisy, damp and dense living spaces can aggravate depression and dementia in elders (Guite, Clark & Ackrill 2004; Day, Carreon, & Stump 2000).

All of these conditions will grow in increasing prominence and medical expense as the number of people older than 65 years of age is expected to double between 2005 and 2030 (CDC & Merck 2007), and most of them will want to live in non-institutionalized homes (AARP 2000). As Selgrade and colleagues (2006) point out, the increase in the senior population living and aging in homes outside nursing homes and other institutionalized care facilities underscores the importance of addressing hazards and unique risk factors for housing-related illnesses and injuries among older adults.

1.5 The Research Site: Sunnyslope Manor, Phoenix, Arizona

Sunnyslope Manor (SSM) is a project-based Section 8 apartment complex in Phoenix, Arizona, owned and operated by the City of Phoenix Housing Department. The project consists of a single three-story, 116-unit building constructed circa 1970. All the apartment units within the building are of identical size and internal configuration. Half the units face northwest and half face south-east. Residents are required to meet the requirements of the HUD Section 8 housing assistance program including the limitation on family gross income.

Sunnyslope Manor was selected as the site for this research because the timing of a $1.7 million grant from the U.S. Department of Housing and Urban Development for a green retrofit made it possible to perform a panel (i.e. longitudinal) study of the effect of the green remodel on the indoor environmental quality of residents' homes and on residents' reported health and residential quality assessments. Further, Sunnyslope Manor represents the building age and scale of many federally assisted residential complexes retrofitted in HUD's ARRA Green Retrofit Program.

Figure 1.1 shows an arial view of the project (labeled A on the map) located in north central Phoenix. SSM is proximate to major health care facilities, shopping, churches, and bus transit facilities. A nearby irrigation canal affords paved walking path opportunities, as does a gravel equestrian trail extending from Ruth Street south on the east side of Central Avenue.

Figure 1.1 Aerial View of the Project

Figure 1.2 depicts details of the overall vicinity, site, and building configuration. The SSM building is situated on the south side of Ruth Street. The primary adjacent land uses include multi-family buildings to the north and single family residences to the south. Vehicular and pedestrian access to SSM is from Ruth Street. Covered parking, an important climate adaptation in the desert south-west, is provided for residents in the northwest and southeast quadrants of the site.

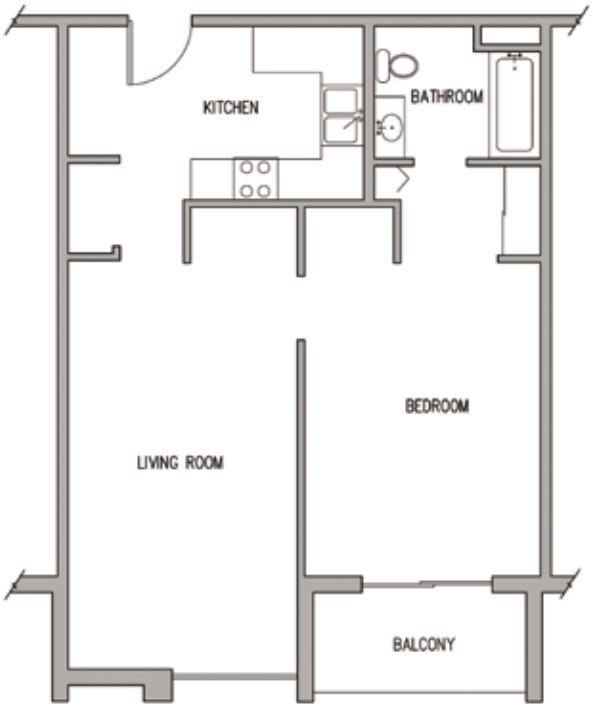
A circular drive and drop-off is located near the middle entry of the SSM building on its north side, providing access to important common areas including the main entry, offices, elevators, public restrooms, day room, library, arts and crafts room, and a multi-purpose room. The multi-purpose area is the small wing of the building extending toward the south. Garden plots for resident use are located to the east of the multi-purpose room and a recreation area is located to the west.

Figure 1.2 Overall Vicinity, Site, and Building Configuration

Figure 1.3 shows a view of the development from Ruth Street. The building is constructed of deformed concrete block load bearing walls (commonly known in the Southwest as “slump block”) with wood framed floor, roof, and interior partitions. The building has a flat roof with a metal mansard-type fascia around the perimeter. All but two units have balconies accessed by sliding doors and secured by metal railings. Vertical access within the building is by three stair towers and two elevators. Common area laundry facilities are located on the second and third floors near the center of the building’s north side. Access to individual apartment units is via double loaded corridors that run the length of the building.

Figure 1.3 View of the Development from Ruth Street

Figure 1.4 Typical SSM Apartment Floor Plan



All units are the same size and configuration (sometimes the layout orientation is flipped). Figure 1.4 depicts the typical SSM apartment floor plan prior to the green retrofit. Total livable area within each unit is 619 SF. The kitchen, bath, and closet areas of the unit are situated along the corridor side and the living and bedroom are adjacent to the exterior wall. Each unit has a 3’-0” accessible entry door opening into a 122 square foot (SF) kitchen. The living room and dining areas total 233 SF. The bedroom and closet areas total 197 SF, and the bathroom is 66 SF. All units (except two) have a balcony off the bedroom which is accessed by a 6’-0” wide arcadia-type sliding door. The living rooms have a 6’-0” wide by 4’-0” high sliding window equipped with an insect screen. Ceilings are flat at 8’-0” above the floor.

Chapter 2

Methodology


SUNNYSLOPE MANOR
205 E RUTH

2.1 Research Aim and Hypotheses

The overall aim of the research project was to assess the extent to which an array of building changes of the ARRA Green Retrofit Program resulted in improved indoor environmental quality and health of elderly residents living in an assisted housing development in Phoenix, Arizona. In so doing, several hypotheses and sub-hypotheses were proposed and tested; these are listed in Table 2.1. We also assembled a master table that lists each of these hypotheses with corresponding variables, measurements, instruments, covariates, and statistical analyses; this is located in Appendix 2.1.

Table 2.1 Study Hypotheses

1. **Indoor environmental quality (IEQ) of climatic conditions – *temperature, relative humidity and air infiltration* –** will improve following ARRA Green Retrofit housing renovations.
   These changes will be immediate (first post-test) and sustaining (second post-test) for most IEQ indicators.
   - These changes will meet thresholds of ASHRAE and other industry standards.
   - IEQ changes will be less in homes with certain resident characteristics/behaviors (i.e. resident moderating conditions) and building/design characteristics (i.e. building moderating characteristics) than without these characteristics.
   - Tighter air infiltration levels after the retrofit will also result in greater changes in temperature and relative humidity.

2. **Indoor environmental quality of air conditions – as measured by *particulate matter and aldehydes*** (formaldehyde, acetone, and acetaldehyde) concentrations – will change following ARRA Green Retrofit housing renovations, both immediate and sustaining for most IAQ indicators.
   - PM levels are expected to increase immediately following retrofit due to the construction process. PM levels are expected to improve over time.
   - Aldehyde levels are expected to improve both immediately and sustaining; and acetaldehyde and formaldehyde levels following retrofit will meet thresholds of health/safety standards.
   - IEQ changes will be less in homes with certain resident characteristics/behaviors and building/design characteristics than without these characteristics.
   - Tighter air infiltration levels after the retrofit will also result in greater changes in PM and aldehydes concentration.

3. Residents will **perceive and assess improved housing and IEQ conditions** following ARRA Green Retrofit housing renovations.

4. **Seniors' reported health** at Sunnyslope Manor will improve following ARRA Green Retrofit housing renovations.
   - These changes will be immediate and sustaining for many health indicators, primarily of: (1) overall health status and life satisfaction; (2) respiratory-related conditions; (3) mental health related conditions; (4) sleep; (5) functional limitations. Other health conditions that may be affected include: skin-related conditions; joint-related conditions; pain; heart-related conditions; neurological or brain-related conditions; diabetes; vision; and hearing.
   - Changes in health conditions at Sunnyslope will be greater than changes in health conditions in the general elderly, low-income population, as measured by national and state health surveys.

5. **Integrative model**: Changes that do occur in seniors' health conditions (hypothesis 4) will positively correlate or correspond with IEQ changes (hypotheses 1 and 2); but may be moderated by resident and building characteristics.

In addition to these hypotheses, we also examined the following research questions:

- To what extent can improved indoor environmental quality result in healthcare cost savings?
- Will an educational booklet, designed and developed for this particular resident group, be used by residents to maintain their renovated homes in a healthy fashion?

2.2 Research Design

While randomized experiments represent the gold standard of scientific research, they are generally not feasible in studies of occupied residential developments. Rather, this research utilized a research design that Campbell and Stanley (1963) refer to as "pre-experimental": the one-group pre-test, post-test design. We collected data of the same residents and apartment units once before the renovation and twice after the renovation was completed. Lacking a control or comparison group, we did compare our findings to what we call proxy and threshold measures: (1) health data of the same questionnaire items from national and Arizona samples of lower-income older adults during the same years of our data collection (2010, 2011, 2012); and (2) standards and thresholds of indoor environmental and air conditions. These proxy and threshold methods are described further in Section 2.10.

For this study, three data collection periods, or panels, were undertaken: one prior to the intervention (i.e. green retrofit) and two after renovation was completed. Data collection in each panel consisted of interview of residents and IEQ testing of residents' apartment units. Data collection panels in this report are referred to as:

Panel 1 (P1): Pre-intervention baseline test, occurred between June 10 and July 7 2010

Intervention: Renovation of all units, occurred between February and July 2011 (renovation on exterior, and common and non-unit areas continued through August)

Panel 2 (P3): First post-intervention test. This was scheduled to occur between one and three months after the resident's unit was renovated. Because the renovation process was staggered (see section 2.5 on "Intervention"), this took place between April 26 and September 23 2011

Panel 3 (P3): Second post-intervention test. This was scheduled to occur when a resident had occupied the renovated unit for at least 10 months, and in most cases over one year. This data collection took place between May 30 and August 3, 2012.

2.3 Recruitment and Description of Study Participants

Sunnyslope Manor consists of 116 one-bedroom apartment units, and as this research project began, all units were occupied. Working with the property manager of the site, we established a multi-pronged recruitment procedure.

- We held a social/informational event in the large community room, with refreshments, door prizes and a nurse who provided free blood pressure measuring. All GAP research team members attended, and made a 20-minute presentation describing the intent of the study, demonstrating the different air and temperature sampling equipment, and answering questions. Residents knew that their units and the building were going to be renovated to "green" standards. The social/informational event particularly attracted those residents who wanted to learn more about the intended renovations, the work schedule on their units, and the process of packing their belongings and furnishings during the renovation. Sign-up sheets for the study were distributed to residents who expressed interest in participating in the study.

- One GAP research member attended the weekly SSM resident council meetings and "coffee klatches" during May and June 2010 to field questions and better inform these residents of the scope and intent of the study. The resident council members

became informal “ambassadors” to other SSM residents who wanted more information or assurance about the study. Three GAP members were also in regular contact with the property manager to field questions that residents may have asked her.

- A sign-up sheet was pinned to the bulletin board outside each resident’s door. If a resident wanted to participate, s/he provided name and a phone number; and left the sheet in a large envelope pinned outside the office of the property manager. A GAP researcher collected these from the property manager every few days.

- Two GAP researchers went door-to-door of each unit in Sunnyslope Manor and talked with residents about the study, encouraging their participation and fielding any questions or concerns. If the resident did not speak English, a translator (Russian, Farsi, Romanian, Spanish) contacted them at a later date to discuss the project and encourage their participation. This was a time-consuming process but proved to be an effective recruitment technique.

In this manner, 77 residents from 74 units agreed to participate in the study at the time of Panel 1 (i.e. pre-renovation). Attrition occurred by panel 2. Being a panel study, residents who did not participate in Panel 1 were ineligible to participate in subsequent panels. The sample in Panel 2 consisted of 55 units, and 59 residents who had participated in panel 1. Of those no longer participating in Panel 2, eight had moved from Sunnyslope Manor, three had died, and seven said they were no longer interested in participating.

At the time of Panel 3, some of the residents who had participated in P1 but not P2 had a change of mind, and wanted to participate again. While we recognized that this would make the statistical analyses more challenging, our decision was to include them since it would boost our sample size in comparing pre-renovation and P3 data, where we expected to see noticeable improvement in IEQ. The Panel 3 sample included 57 residents and 53 units. Of those not participating in P3 but who had previously participated in Panels 1 and 2, only one resident refused, the others had moved from Sunnyslope Manor. Table 2.2 lists the sample size of each panel. It also identifies the number of residents and units participating in the combination of panels — which correspond to sample sizes in the statistical analyses comparing short-term (P1 to P2) and longer-term (P1 to P3) changes.

Table 2.2 Sample Sizes at Each Data Collection Panel, and Combination of Panels

Panels	# of Residents	# of Units
P1 only	77	73*
P2 only	59	55**
P3 only	57	53
P1 and P2	59	55
P1 and P3	57	53
P1, P2, P3	51	47

* One resident withdrew in Panel 1 before completing all IEQ sampling; consequently leaving only 72 units with all IEQ factors collected, and 1 unit with only PM and aldehyde data (i.e. no temperature, RH or CFM50 data)

** Three units in panel 2 had problems with PM sampling. PM data for these units are coded as missing in panel 2.

Many of the demographic questions were asked only at panel 1 since they were invariant (e.g. gender, prior employment and occupation before retirement, race/ethnicity). A demographic profile of residents participating in the final panel is provided in Table 2.3. Profiles of different panel samples are available upon request.

Table 2.3 Demographic Profile of Participating Residents,* As Measured at Panel 1

Gender	26% Male, 74% Female
Age	Mean = 73 (sd = 8.123); Range from 62 to 92 years
Race and ethnicity	83% White; 4% Black/African American; 5% American Indian; 2% Asian Indian; 14% Some Other Race; 14% Hispanic or Latino
Retired from working	90%
Have pets	19%
Smokes	21%
Lives alone in apartment	88%
General health, as rated on 5-point scale, with "1" being excellent and "5" being poor	Mean = 3.14 (sd = 0.953)
Number of days in past 30 days when health not good	Mean = 7.09 (sd = 9.503) (n=55)
Reports at least one respiratory health problem	65%

* This includes those residents who participated in at least Panel 1 and Panel 3, n = 57

While the homes were all the same size, layout, and with the same lighting, appliance and system fixtures, they were in different locations of the building. Because sun load could contribute to some of the IEQ and perception conditions in the study, we also identified each unit along these building location characteristics: (1) north or south facing unit (orientation); (2) east or west wing; (3) floor level. Table 2.4 profiles these characteristics of the units involved in the last panel.

Table 2.4 Building Location of Residential Units at Panel 3 (n=55)

Orientation:	49% facing north, 51% facing south
Wing:	47% in east, 53% in west
Floor level:	29% on first, 42% on second, 29% on third

2.4 Procedures for Data Collection

Residents who indicated their willingness to participate were contacted by phone or in person to set up a time for the interview, environmental sampling, and blower door testing of their residences. Prior to data collection, all GAP research members, including those not directly involved in contact with the residents but nonetheless were handling data or information, completed NIH or CITI Human Subjects training and certification. A Human Subjects application was submitted to and approved by Arizona State University's Institutional Review Board (IRB); the project received approval in May 2010 before any contact with residents. Renewal applications were submitted in April 2011 and April 2012; and approved by the IRB in May 2011 and May 2012.

The scheduling of the in-home interviews and most of the air sampling tests was combined to minimize disturbance of the resident. At the scheduled appointment time, two GAP research assistants would meet the resident in his or her apartment. One technician would set up

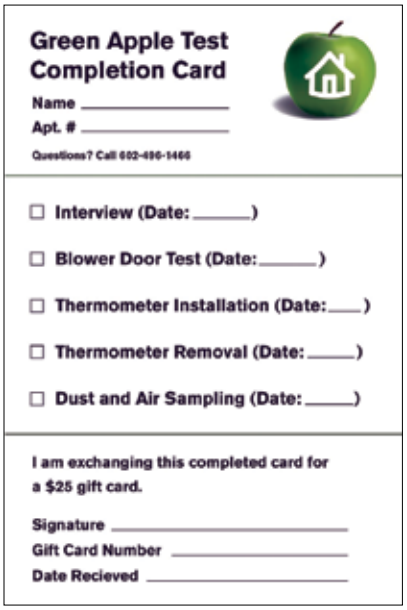
and operate the air sampling equipment (for aldehydes, particulate matter) in the unit for an hour. S/he would also set up the temperature/RH sensors in the unit that would remain there for 5 days of data recording. The other team member, a trained interviewer of ASU's Institute of Social Science Research (ISSR), sat with the resident and conducted the health interview; this generally took 30-45 minutes to complete. In those instances where the resident felt uncomfortable or unable to speak English, a translator accompanied the team. Translators were provided for those speaking Romanian, Spanish, Farsi, and Russian.

Before the interview began, the interviewer provided a written description of the study that also addressed measures to ensure confidentiality and anonymity; and also an information sheet about the air and temperature sampling equipment. A consent form was given to the resident, and signed by him or her, before the interview started. The study description and consent form were translated in Spanish, Romanian, Russian and Farsi, in accordance with IRB protocol. All participants signed the consent form.

Five days after the interview and air sampling, a GAP assistant arranged to stop by the unit to pick up the temperature/RH sensors. At this time or shortly thereafter, another technician visited the unit to conduct a blower-door test.

Once the interview was complete, the resident was given a "menu" card (see Figure 2.1 for an example). When a test listed on that card was completed, the GAP researcher checked off the corresponding test. When all tests had been completed, a GAP research member stopped by the resident's home, picked up the completed menu card, and gave the resident a gift card for a local grocery store in appreciation for participation. For panels 1 and 2, gift cards were in the amount of $25. To maintain participation at the final panel, $50 gift cards were distributed. The resident signed the menu card indicating receipt of the gift card, as required by ASU's Accounting Office. The signed consent forms and menu cards – as well as all other printed identifying information about the name or apartment number of the resident – were kept in locked file cabinets in a secure room location at the university.

Figure 2.1 Menu Card



2.5 Intervention: Green Retrofit of Sunnyslope Manor

As mentioned previously, the renovation of the residents' units began in February 2011 and continued through July 2011. Renovation on exterior elements (e.g. roof) and common areas in the interior (e.g. hallways, lounge) continued through August 2011.

The City of Phoenix did not move residents and their belongings from Sunnyslope Manor during the renovation, believing it would be too disruptive for residents. Instead, the renovation scheduling procedure involved having each resident box up his/her possessions for 5-7 days; most of these boxes and furnishings were stored elsewhere on the property where residents could access them when necessary. During the renovation of their unit, the resident would spend daytime hours in "The Green Room" (an unoccupied apartment unit in the building that was renovated and furnished), and return to their "under-construction" apartment each evening to sleep on their bed that was re-installed each day. Renovation of a unit was typically completed in 5 days.

Table 2.5 lists the changes made to the residents' units. Detailed description of changes and replacements is provided in the following sub-sections.

Table 2.5 Renovation Specifications of Sunnyslope Manor Green Retrofit

Item	Manufacturer/Model #:
Refrigerator	GE GTH16BB- Energy Star
Electric Range	GE Model JBP15DM Electric
Microwave/Range Hood	GE JVM1540 Microwave- Energy Star
Garbage Disposal	GE GFC520F 1/2 HP - Energy Star
Sealant: Disposal Flange to Sink	Plumbers Putty
PVC Pipe/Glue under Sink	Oatey PVC Glue
Kitchen Cabinets	Custom cabinets with natural Oak product
Kitchen Countertops	Kiln dried sold hardwood doors and frames. Engineered wood shelving with No or low VOC adhesive. Used Collins FSC certified Forest Product in the manufacturing of the cabinetry. Pionite Laminate Countertop -Low VOC
Adhesive: Counter to Base Cabs	adhesives Greenguard Indoor Quality Certified Liquid Nails Construction Adhesive
Adhesive: Backsplash to Wall	None
Caulking: Backsplash to Wall	GE Clear Silicone
Cleaning Solvents used by GC	Acetone
Kitchen Sink	Dayton Elite Double Bowl DSEMR23322 Stainless
Caulking: Sink to Countertop	GE Clear Silicone
Kitchen Faucet	Olympia Faucet K5030 1.5 gpm
Bathroom Sink	Mansfield Maverick II oval Vitreous China Sink
Caulking: Sink to Countertop	Model 267-4 GE Clear Silicone
Bathroom Faucet	Olympia Faucet L-6160
Bathroom Exhaust Fan	Broan Ceiling/Wall Fan Model 784 - Energy Star
Caulking: Bath Fan Grill to Ceiling	None
Showerhead	Niagra Conservation 1.5 GPM Massage
Aerators	Chrome Showerhead Model N2915CH 1.5 gpm Niagara Aerator Model N3210N 1.0 gpm
Toilet	Mansfield Alto Model 4137-3121 1.28 GpF/4.86 low flow water consumption
Caulking: Toilet to Flooring	GE Clear Silicone
Vinyl Flooring	Congoleum Air Steps- Autumn Glow
Floor Leveling Compounds	Ardex
Vinyl Flooring Adhesive	Low VOC
Solvent Seam Sealers	Acetone
Base at Vinyl Flooring	Roppe
Caulking: Rubber Base to Wall	DAP Acrylic
Carpet	Mohawk Towncenter 30 (Alladin)
Carpet Pad	Mohawk Commercial Lifeloc Pre-attached to carpet
Carpet Pad Adhesive	None (factory attached to carpet)
Carpet Adhesive	Henry 176 Bulldog

Item	Manufacturer/Model #:
Base at Carpeted Areas	MDF Molding
Adhesive: Base to Wall	Liquid Nails Construction Adhesive
Caulking: Base to Wall	DAP Acrylic
Interior Paint	Sherwin Williams Zero VOC - Harmony
Interior Paint on Metal Door Jambs	Sherwin Williams Zero VOC - Harmony
Interior Primers	Harmony Primer B11W900
Interior CMU Block Filler	PrepRite Block Filler
Kitchen Light Fixture	NULITE #WAP2285T5-UNV 4ft. Surface Mounted 2 bulb T5
Bedroom Fan/Light Fixture	Royal Pacific Ceiling Fan-Model 1051-L-ES Energy Star
Bedroom Light Fixture	Repurposed light fixtures from another property
HVAC Filter	Standard Type
Exterior Paint	Sherwin Williams Zero VOC - Summit Acrylic and Solo Metal Finish
Smoke seals at Entry Doors	Existing
Windows	Paramount Titan Series sliders, aluminum framed, double pane, low e coat with green cool tint.
Blinds/Drapes	Existing
Foam Sealants Around Windows	Great Stuff Expanding Foam
Caulking Around Windows	DAP Acrylic
Slider Doors (units)	Paramount Energy Star rated aluminum framed sliding glass door with double pane, Low E glass, with green cool tint.
Foam Sealants Around Door Unit	Great Stuff Expanding Foam
Mastic at Threshold	Liquid Nails Construction Adhesive
Caulking Around Door Unit	DAP Acrylic
Balcony Deck Waterproof Coating	None
Balcony Rail Primer/Paint	None

2.5.1 Systems

The HVAC system for each apartment includes 5 components: (1) a through-wall package terminal air conditioner package (PTAC) unit, (2) a bathroom exhaust fan, (3) a range hood exhaust fan, (4) a bedroom ceiling fan, and the (5) doors and windows. Of these, the front door and PTAC unit were scheduled to remain the same with no changes; replacements were made for both exhaust fans and the exterior windows and door; and a new ceiling fan was added.

While the ARRA Green Retrofit did not specify replacement of PTAC units, the City of Phoenix used other financial resources to replace many, but not all, of these units. New units were installed in seventy-seven (or 66%) of the apartments over a period of several months which coincided with the time between the second and final data collection periods of this study. Of the 53 units in Panel 3 of this study, 68% (or 36) had received these new PTAC systems. The older units are AMANA PTH153D50AR, a line that was discontinued by the manufacturer several years ago. Their EER (Energy Efficiency Ratio) was 9.3, which is quite high for this type of system. The new Frigidaire FRP15PTT2R units have a EER rating of 9.7, only slightly higher than the older units.

Package terminal air conditioner units (PTAC) are common in the hospitality industry. In the case of the Sunnyslope Manor, they are installed in the living room/balcony wall. Unlike the typical hotel room installation, the PTAC units at Sunnyslope Manor are connected to a short duct system in order to deliver tempered air to both the bedroom and living rooms. No conditioned air from the unit is delivered to the kitchen, closet or bathroom. Conditioned air to these spaces is essentially pushed through by the blower fan of the PTAC and also pulled through by the

bathroom and range hood exhaust fans, which vent to the roof via vertical ducts common to other units. Figure 2.2 depicts a typical PTAC unit.

Figure 2.2 Typical PTAC Unit in Resident's Home

The Frigidaire PTAC units are controlled by a simple, non-programmable thermostat on the living room wall near the door to the bedroom, at the approximate center of the unit. The PTAC units in Sunnyslope Manor are of varying ages given that units are replaced on an as-needed basis. No apartment unit specific data was made available to the research team whereby the exact age of a PTAC unit in a specific apartment unit might be determined. Moreover, the GAP research team has not been able to determine if/when the PTAC filters were changed during the course of the green remodel and/or what type of filter is currently installed. Thermostats for the PTAC units have 3 simple controls: a sliding temperature setting, cool/heat, and fan on/auto.

The **bathroom exhaust** fan is of the typical residential variety and is operated by a wall switch just inside the bathroom door. The bathroom exhaust fans were replaced with a Broan Ceiling/Wall Fan Model 784 -Energy Star unit specified to fit the existing duct size.

Three to six apartment units shared a common vertical exhaust duct that extends vertically through the roof where the air is exhausted. Accordingly, variances in an apartment's positive and negative air pressure can cause air to communicate between apartment units, rather than always being exhausted to the roof.

The **kitchen range hoods** are very similar. They are standard residential units exhausted to common vertical ducts extending up through the roof. Like the bathroom exhausts, the kitchen range hood exhaust air can also communicate between units depending on positive and negative air pressure differentials between units and floors.

Each **bedroom ceiling fan unit** is equipped with a junction box at the approximate center of the bedroom ceiling fed by a single hot, neutral and ground conductor from a single gang wall switch located near the inside of the bedroom door. The scope of the remodel included the provision of Royal Pacific Model 1051-L-ES Energy Star ceiling fans with light kits. Ceiling fans with light kits that are connected to a single hot wire require the resident to operate the fan speed and light kit on/off by means of pull chains hanging from the ceiling fan itself. They are distinguished by their length: 4" for fan, 6" for light. In most cases observed, the residents place their bed under the ceiling fan.

The final component of the HVAC system is **doors and windows**. In the course of the remodel, each apartment unit was equipped with a new arcadia-style sliding balcony door with sliding screen and a new living room sliding window. In both cases, the extant units were replaced with new Paramount Titan Series sliders, aluminum framed, double pane, low-E coat with green cool tint units in thermally broken sash and frames. The arcadia sliding doors are operated by a handle with a toggle finger lock and the windows are operated by a sash pull with a toggle lock.

2.5.2 Kitchens

The kitchens of each apartment unit were entirely remodeled with new cabinets, countertops, appliances, flooring, sink/faucets, light fixtures, and paint. The fixtures, cabinetry and appliances removed from the units were of unknown age and specification. Figure 2.3a depicts a typical kitchen in its original state. Figures 2.3b through 2.3g depict a kitchen in its remodeled state.

Figures 2.3a through 2.3f Kitchen Before (a) and After (b-e) Retrofit

a

In the renovation, the appliance locations remained approximately the same to minimize the expense of relocating utilities. The primary difference in the remodeled version was the inclusion of a large shallow vertical cabinet for dry goods storage and the provision of a desk in the short hallway leading from the kitchen to the living room. A small hallway closet was eliminated to make room for the desk.

b

c

d

e

The Energy Star and/or SEER rating of the former appliances is unknown. Appliances installed during the remodel were Energy Star compliant, including:

Range: GE Model JBP15DM – Energy Star
Microwave Range Hood: GE JVM1540 - Energy Star
Refrigerator: GE GTH16BB - Energy Star
Disposal: GE GFC520F 1/2 HP - Energy Star

Cabinets installed during the remodel were specified to be of low VOC materials and construction technique. The cabinets were of typical face frame residential grade featuring natural oak product kiln dried, solid hardwood doors and frames with engineered wood boxes and shelving with melamine surfaces applied with a low VOC adhesive. Hardwoods used in the manufacture of the cabinetry were Collins FSC certified forest products.

Countertops installed over the base cabinets were also specified to be of low VOC materials and construction technique. The countertops installed were residential grade Pionite laminate post-formed over particle board with integral splash and bullnose front edge using low VOC adhesives that were Greenguard Indoor Quality Certified.

Plumbing fixtures installed in the kitchen incorporated low-flow controls as follows:

Kitchen Faucet/Aerator: Olympia Faucet K5030 1.5 gpm
Kitchen Sink: Dayton Elite Double Bowl DSEMR23322 Stainless
Note: The prior kitchen sink was stainless as well

Flooring in the kitchen was specified to be low-VOC in manufactured and material. Congoleum Air Steps - Autumn Glow was installed over the existing subfloor using leveling compounds and the manufacturer's recommended flooring adhesive (Figure 2.4). Paint in the kitchen (as in all other rooms) was specified to be Sherwin Williams Zero VOC - Harmony and was roller and brush applied over existing gypsum wallboard.

Figure 2.4 New Flooring in Kitchen (left) and Living Room (right)

Light fixtures in the kitchen included a replacement of the ceiling fixture and the integral range hood fixture. The replacement ceiling light fixture was a surface mounted 4 foot NULITE #WAP2285T5-UNV with 2-T5 lamps providing approximately the same lumen output as the T8 prior fixture but with less energy consumption.

2.5.3. Bathroom

The remodel of the bathroom followed the same general scope of the kitchen remodel – the cabinetry, plumbing fixtures, and flooring were removed and replaced (see Figure 2.5). The cabinetry and countertop specifications and procurement were identical to the kitchen, as was the flooring. Plumbing fixtures were specified to be "low-flow" and included:

Shower head: Niagra Conservation 1.5 GPM Massage #N2915CH
Water Closet: Mansfield Alto Model 4137-3121 1.28 gpf
Lavatory Faucet: Olympia Faucet L-6160
Lavatory Aerator: Niagara Aerator Model N3210N 1.0 gpm

Figure 2.5 Remodeled Bathroom

The **flooring and baseboard** for the bathroom was the same as the kitchen and was applied with the same adhesives and technique.

2.5.4. Bedroom/Living Room

The bedroom and living/dining rooms received new **paint** and **carpet**. The paint was low-VOC acrylic and the carpet and pad were also specified to be low-VOC. The carpet was Mohawk Town-center 30 Alladin and the installation technique was the typical stretch method to perimeter tack trips over a Mohawk Commercial Lifeloc pre-attached pad (see Figure 2.4). **Baseboard** throughout the units was Roppe rubber base adhesive applied to the walls utilizing a Roppe product.

2.5.5. Miscellaneous Sealants and Adhesives

A variety of construction adhesives and sealants were used throughout each apartment unit, depending on application and location.

Trim Wood to Gypsum Wallboard (GWB): DAP Acrylic – Low VOC
Backsplash to GWB: GE Clear Silicone
Countertop to Base Cabinet Units: Liquid Nails Construction Adhesive
Sink to Countertop: GE Clear Silicone
Toilet to Floor: GE Clear Silicone
Tub Surround to Tub: GE White Silicone
Tub to Floor: GE White Silicone
Joints in Vinyl Flooring: Unknown
GWB to Window Frames: DAP Siliconized Acrylic
GWB to Door Frames: DAP Siliconized Acrylic
Aluminum Thresholds to Concrete Floor: Liquid Nails Construction Adhesive

2.5.6. ADA Units

Two apartment units at Sunnyslope Manor are designated as Type A accessible per the Americans with Disabilities Act. They received the same general scope of green remodeling. However, the configuration of the units was modified and certain features such as full ADA grab bars in the toilet and shower areas were incorporated (non-ADA units are equipped with a single vertical grab bar in the shower only). The **appliance package** was also modified, particularly the kitchen range. Figures 2.6a through 2.6d depict the ADA kitchen layout; Figures 2.7a through 2.7c depict the ADA bathroom layout.

Figures 2.6a through 2.6d ADA Kitchen

a

b

c

d

Figures 2.7a through 2.7c ADA Bathroom

a

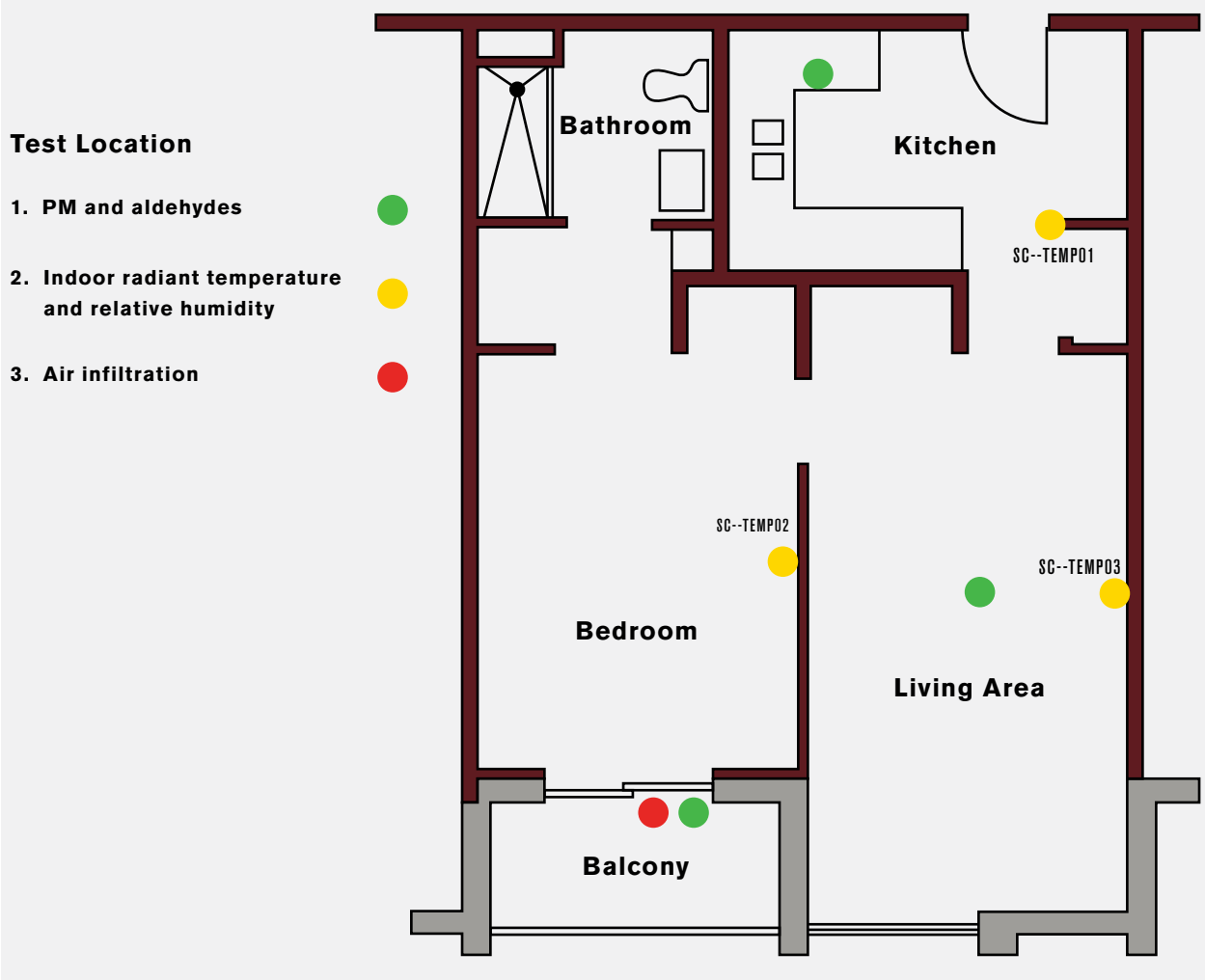
b

c

2.6 Measuring Environmental Quality

Temperature and Relative Humidity: Absolute air temperature was measured in three indoor locations as indicated in floor plan below in Figure 2.9.

Figure 2.9 Test Equipment Location Plan



Absolute air temperatures were monitored and recorded every 15 minutes in kitchen, bedroom and living area, utilizing mobile Onset HOBO data loggers. For the kitchen and bedroom, HOBO U-10-001 was used, and for the living room, a HOBO U-10-003 was used. This latter HOBO is capable of measuring absolute air temperature and relative humidity; the others in the bedroom and kitchen were capable of measuring absolute air temperatures only. Each HOBO was installed at approximately 4 feet or midway between floor and ceiling against the wall.

HOBO data loggers (see Figure 2.10) are small instruments manufactured by leading data logging company Onset. This small device can record absolute temperature and relative humidity every millisecond with an accuracy of ± 0.53 OC from 0° to 50°C (± 0.95°F from 32° to 122°F) and an operating range for logging of -20° to 70°C (-4° to 158°F); 0 to 95% RH (non-condensing). This logger has a memory of 64K bytes (52,000 10-bit measurements) and weighs 26 g (0.82 oz) with total dimensions of 45 x 60 x 20 mm (1.8 x 2.38 x 0.77 inches).

Figure 2.10 HOBO Logger for Measuring Temperature, RH

All HOBOs remained in place for 5 days, recording a total of 448 usable data points or more. Any additional points over 448 that may have been recorded because of delay in retrieval of the sensor equipment were disregarded.

From these data points, mean and standard deviation of absolute temperature and of relative humidity (RH) for each unit's room was calculated; as well as maximum and minimum temperature data points and RH data points of the 448. In addition, the number of temperature data points exceeding the ASHRAE-55 2010 standards was calculated for each unit's room: that is, number of data points at 81 degrees and higher (maximum summer allowable temperature) and number of data points at 68 degrees or below.

Air Infiltration: Ideal Energy, LLC (IEAZ) performed blower door tests at each data collection panel. IEAZ inspected each unit before testing began. All fenestrations of conditioned spaces were closed. All exhaust fans, vented dryers, air conditioners, ventilation system fans, and air handler fans were turned off. All interior doors to rooms that are conditioned were opened. The bathroom door was closed to prevent air infiltration through the exhaust fan to the roof. There was no practical means of closing the kitchen range hood exhaust fan to prevent the same occurrence. Appliances were not operating during the blower door test.

The blower door test equipment was set up on the back balcony door ensuring there was no obstruction of airflow to the fan during the test. Pressure tubing was run to the exterior to calibrate the equipment, followed by installation of the blower door test unit itself that was installed in the doorframe stabilizing it with the Velcro strap. After calibration, the fan was turned on and run until depressurization showed on the Blower Door manometer channel "A" a negative pressure of 50 pascals. Channel B yielded a reading indicating the unit's air infiltration at 50 CFM. The blower door test runs for a maximum of 3 minutes.

Test readings were recorded on a paper form. IEAZ reported on a weekly basis the progress and number of units tested per week to the research team.

Particulate Matter: Quantification of particulate matter used Dustrack 8533 Samplers that provide real-time measurement of suspended particles in different size ranges. This device was selected because it provides real-time measurement in a small, plug-in, low voltage device. The Dustrack 8533 samplers were used to collect air to determine particulate matter levels in three different locations (balcony, kitchen and living area) in all participating units (see Figure 2.5 above). The tracker uses minimal energy of the resident's unit for about 45 minutes total for each data collection period. While operating, the tracker makes a noise comparable to

that of a kitchen microwave; this is important as it allows simultaneous collection of indoor air quality and resident health information to minimize disruption to the resident.

Collected indoor air quality data reported particle levels including PM1 (referring to all particles with an aerodynamic diameter less than 1 micron), PM2.5, PM10 and total PM (representing all particles that pass through the sampling inlet; roughly equivalent to PM15). The US EPA has set National Ambient Air Quality Standards (NAAQS) for both PM2.5 and PM10. The NAAQS for PM10 is set at 150 micrograms per cubic meter over a 24-hr averaging period and the PM2.5 standard is set at 35 micrograms per cubic meter over a 24-hr averaging period. While sampling in the resident households only occurred for a period of one hour, there is no reason to expect significant temporal variability in the PM levels indoors, justifying the comparison of the one-hour average indoor PM levels to the NAAQS set over a 24-hour averaging period.

Aldehydes: Samples of indoor and immediate outdoor formaldehyde, acetone, and acetaldehyde were collected using commercial samplers containing dinitrophenyl hydrazine (DNPH)-coated silica gel (Waters XPoSure, Product number WAT047205). The cartridges were preceded by an ozone scrubber (Waters Sep-Pak, Product number WAT054420) to eliminate ozone from the incoming air, thus avoiding a common sampling artifact. The DNPH-coated cartridges were subsequently extracted with acetonitrile and analyzed by High Performance Liquid Chromatography (HPLC) with UV detection.

Residents were asked to avoid cooking, burning incense, smoking or doing any other activities during sampling that could alter the results of the sampling tests. Samples were collected over a 1-hour period using SKC Low-Flow Gas Pumps. The SKC pumps measure 2 x 1 x 4 inches and make relatively little noise, comparable to a spinning fan. Three samples were collected simultaneously (see Figure 2.5 above) in the living room, kitchen and the balcony (to obtain a measure of outdoor air levels). The flow measured with the SKC pumps were calibrated in the laboratory twice in 2010 (June 9 and July 15), twice in 2011 (February 3 and April 7), and twice in 2012 (May 22 and August 10).

2.7 Measuring Residential Health

The *Health at Home* (*HAH*) survey created and used in this study contained 108 fixed-response questions at Panel 1; 148 questions (including open-ended ones) at Panel 2; and 185 questions at Panel 3. Not all questions were pertinent to each study participant. Applicable questions from the National Health Interview Survey (NHIS) and from the Behavioral Risk Factor Surveillance System (BRFSS) for Arizona provided the basis for the bulk of the health-related questions in the *HAH* questionnaire. Questions from these surveys were determined to be applicable if they were consistent with the goals and hypotheses of the GAP study.

The NHIS is the principal source of information on the health of the civilian population of the United States that is not institutionalized. The survey results have been collected from over half a million US residents and children from all 50 states and territories each year since 1957. The results are tabulated every year and published in June on the Center for Disease Control's website (http://www.cdc.gov/NCHS/nhis/quest_data_related_1997_forward.htm). The questions in the NHIS survey are updated to reflect current concerns and trends every ten to fifteen years; however, many core questions do not change. NHIS data are used widely throughout the Department of Health and Human Services to monitor trends in illness and disability and to track progress toward achieving national health objectives.

The BRFSS is a state-based yearly survey that was established in 1984. More than 350,000 adults (over 18 years of age) are interviewed by telephone each year. Survey results provide timely accurate data on health-related behaviors such as risk, prevention, and access to healthcare for chronic disease and injury.

The NHIS is composed of seven questionnaires that contain family, adult and child components that survey all aspects of health. The BRFSS questionnaire includes core components, optional CDC modules and state-added questions. The goal of the GAP project was to

examine the influence of the environmental changes of the housing renovation on the health of elderly residents. Based on these goals, only relevant questions from the adult component of the NHIS 2010 and emotional risk components of the BRFSS were included in the HAH interview. The majority of the questions remain the same in the NHIS and BRFSS from year to year. However, since our study occurred in three separate calendar years (2010, 2011, 2012), we referenced questionnaire items from each annual state/national source. In order to maintain the reliability and validity of the GAP questions and subscales, if the NHIS or BRFSS question was altered or dropped in subsequent years, the question was also dropped from the HAH questionnaire.

For Panels 2 and 3 interviews, we eliminated questions from the P1 interview that had no prevalence, and added questions that would provide more information about the relationship of the environment to prevalent health conditions.

For health questions in Panel 1 *HAH* questionnaire, the **time frame** for recalling health ailments was primarily 30 days but on occasion 12 months or open (i.e. "have you been diagnosed with cancer?"), to be consistent with the time frames as those in the national surveys (NHIS, BFRSS) from which the specific questionnaire item derived. In Panel 2, health questionnaire items were rephrased to replace the 3-month, 12-month, and open time frames with "since the renovation" to ensure that residents' responses reflected health conditions post-renovation ("30-days" items were left intact since no resident was interviewed sooner than 30 days post-renovation). At Panel 3, the time frame of 30-day, 3-months and 12-months returned, consistent with the wording of Panel 1 interview. However, for those questions with open time frames at P1, "since the renovation" was again used. More information about the exact wording of the time frame for these questions is described in Chapter 7.

Additional open-ended and fixed-response questions were added in Panel 3 to further clarify some of the health, falls/trips, smoking behavior, and functional assessments.

The *Health at Home* questionnaire was pilot tested with residents of similar age to those in SSM. The items were easily understood and no questions were considered objectionable. Validity was not evaluated in the pilot because most of the questionnaire items were taken from standardized surveys of National Institute of Health (NHIS) and Centers for Disease Control (BFRSS) that have been undertaken on an annual basis for several years. Appendix 2.3 provides a list of all Health at Home health-related questionnaire items and their sources.

2.8 Measuring Environmental Perceptions

In addition to health questions, the Health at Home interview also addressed residents' assessments of the environmental quality of their apartments as well as household activities relevant to environmental quality (see Appendix 2.4). These items were derived from two sources.

The University of California Berkeley's Center for the Built Environment (CBE) has developed the *Occupant IEQ Survey* for multiple building types. This web-based survey instrument quantifies a building's environmental performance from the perspective of its occupants. It has been implemented in over 475 buildings and with 51,000 occupants as of October 2009. Survey items from the Residential version of the IEQ survey, pertaining to dormitories and multi-unit residential buildings, was used in this study.

The second source of residents' assessments was *The Healthy Housing Inspection Manual* (HHIM), developed by the CDC and HUD. The HHIM is also a useful reference tool for nurses, outreach workers, and others who are interested in preventing illness and injury due to residential health and safety hazards. Questionnaire items pertaining to relevant housing conditions (e.g. pests, moisture in home) were included in the survey of this study.

We also added fixed-response and open-ended questions about household cleaning activity and products. After the renovation, open-ended questions were included to target resident perceptions and use of particular fixtures in the retrofit (e.g. new ceiling fan) or of qualities/changes they particularly liked or disliked. In addition, prior to P3 data collection,

residents were to have received a handbook of cleaning activities that would assist them in keeping their homes healthy; questions were asked at Panel 3 about the usefulness of the book.

2.9 Moderating and Mediating Factors

Prior research indicated behavioral, physiological, and social factors that may mediate or moderate the impact of housing conditions on residents' health and indoor air quality; data on such factors was collected in the *HAH* interview. As mentioned previously, there are also key building conditions that may differentially affect indoor environmental quality. In the statistical analyses, this study targeted variables listed in Table 2.6 as potentially mediating or moderating factors.

Table 2.6 Moderating and Mediating Variables Used in the Analyses

Behavioral/Personal Questions and Response Set
Do you smoke? Yes/No *Approximately how many cigarettes a day do you smoke? *Do you smoke inside your apartment? Yes/No *How much of your smoking is inside your apartment? (1) Nearly all (2) About half (3) Very little (4) Don't know/Refused *At what age did you start smoking? *Did you ever smoke? Yes/No *How many years ago did you stop? Do you have pets? Yes/No If you have a fan over the stove, how often is it used when someone cook? 5-point scale (+ No fan or fan not working) If you have a fan in the bathroom, how often is it used when someone takes a bath or shower? 5-point scale (+ No fan or fan not working) Do you use bug sprays? Yes/No Do you use anything to change the smell of the air in your home (more than once a week)? Yes/No What type of cleaning do you most frequently use? Vacuum, HEPA Vacuum, Sweep or dry mop, Wet mop How old are you? Number of years How long have you lived at SSM? Number of years

Building Characteristics	
Floor Level	1,2,3
Orientation	North, South
Wing	East, West
Compass	NE, NW, SE, SW

* Only asked in Panel 3 interview

We assessed collinearity between these mediating/moderating factors by conducting Pearson correlation, Chi-square, and independent sample t-tests. Statistically significant relationships are listed in Table 2.7. Of particular note is that smoking behavior is related to odor-masking behaviors. Also, non-smokers in our study tended to be older.

Table 2.7 Significant Relationships Between Person/Behavior/Building Characteristics Used as Mediating/Moderating Factors

Variables	Panels	P-value	Test Value	Notes
Age and Time at Sunnyslope	1	<.001	r=0.461	Positive correlation between age and length of time living at SSM
Gender and Anything To Change The Smell (ACS)	2	.026	χ^2=4.958	Women more likely to use ACS
Smoke and ACS	2	.002	Fisher's exact	Smokers use ACS and non-smokers are split between use and nonuse
Smoke Inside and Air Freshener	3	.071	Fisher's exact	Inside smokers more likely to use air freshener
Smoke and Air Purifier	2	.055	Fisher's exact	Non-smokers more likely not to use air purifiers
Smoke and Age	1	.003	t=-3.234	Non-smokers are older
Smoke and Age	2	.035	t=-2.158	Non-smokers are older
Smoke and Age	3	.001	t=-3.576	Non-smokers are older
Smoke and Pets	1	.067	Fisher's exact	Residents who smoke more likely to have pets
Pets and Window	1	.065	Fisher's exact	Residents who open windows less likely to have pets
Pets and Fan	1	.093	Fisher's exact	Residents with pets more likely to use fan
Pets and Air Purifier	1	.067	Fisher's exact	Residents with pets less likely to use air purifier
Self-cleaning Oven and Pets	3	.058	Fisher's exact	Residents who use self-cleaning feature less likely to have pets
Self-cleaning Oven and Age	1	.015	t=-2.525	Residents not using self-cleaning feature are older
Self-cleaning Oven and Time at Sunnyslope	1	.093	t=-1.712	Residents not using self-cleaning feature have longer time living at SS
Window and Orientation	2	.066	χ^2=3.374	Residents on south side are more likely to open their windows
Window and Wing	2	.082	χ^2=3.026	Residents on west side are more likely to open their windows
P2 and P3 Bedroom Fan	2;3	<.000	Fisher's exact	If resident used fan in P2 they still used fan in P3
Age and Building Orientation	1	.032	χ^2=6.883	South side has younger residents
Age and Building Orientation	2	.024	χ^2=7.498	South side has younger residents
Building Orientation and Time at Sunnyslope	1	.008	t=2.732	Residents on north side have lived longer time at SSM

2.10 Proxy Measures

An exemplary quasi-experimental research design would entail a non-randomized comparison group measured on the same outcome variables but not exposed to the same intervention. Because there was no "non-green" renovation being done on a low-income seniors housing development in Phoenix at the same time as this study, alternative proxy measures were used in comparing data trends of our sample.

For Health Outcomes, data of adults 62 years and older and of low-income (i.e. below $35,000 annually) from the national and Arizona samples of NHIS and BRFSS surveys respectively constitute the proxy comparison group. As described previously, questionnaire items from these instruments were used in the *HAH* interviews at Sunnyslope Manor. At the time of the writing of this report, only 2010 and 2011 data from NHIS and BRFSS datasets is available.

For IEQ Outcomes, air and environmental quality standards and thresholds are used for proxy comparisons.

ASHRAE 55-2010 thresholds/standards ("Thermal Environmental Conditions for Human Occupancy," ASHRAE 2010) and ASHRAE 62.2-2013 thresholds ("Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings," ASHRAE 2013) were compared with SSM's temperature measurements. Using the graphic simplified method for determining recommended temperature and humidity, we established absolute recommended threshold **temperatures** for all seasons as: (1) High - 81 degrees Fahrenheit; (2) Low - 68 degrees Fahrenheit. **Relative humidity** levels are recommended as 65% or less for mechanical systems with dehumidification capacity. There are no established lower humidity levels for thermal comfort. However, ASHRAE notes that non-thermal comfort factors, such as skin drying, irritation of mucus membranes, dryness of the eyes, and static electricity generation may place limits on the *acceptability* of very low humidity environments. Given the very dry climatic conditions of the Phoenix area as well as physiological conditions of many seniors where dry conditions may exacerbate respiratory and skin ailments, we were acutely attentive to any extreme dry conditions in the SSM data even though threshold levels have not been established by ASHRAE.

Recommended **CFM50** levels were established by referencing table 4.1a in ASHRAE Standard 62.2-2013. For a unit of 615 ft², single bedroom and assuming double occupancy, ASHRAE Standard 62.2-2013 outlines a 45 CFM to be used for units between 501-1000 ft.

For **particulate matter**, the US EPA has set National Ambient Air Quality Standards (NAAQS) for both PM2.5 and PM10. The NAAQS for PM10 is set at 150 micrograms per cubic meter over a 24-hour averaging period and the PM2.5 standard is set at 35 micrograms per cubic meter over a 24-hour averaging period.

For **formaldehyde**, several health-based exposure levels have been established by various regulatory agencies in the US and other countries. We chose as threshold criteria for formaldehyde the reference exposure level (REL) for chronic (8-h) exposure in California and Canada, 7 ppbv and 40 ppbv respectively (California EPA 2007, Health Canada 2006). We also used as an additional threshold criteria the REL for acute (1-h) exposure established by the State of California (California EPA 2007). **Acetaldehyde** REL for 8-h and 1-h exposures in California are 160 ppbv and 260 ppbv respectively (California EPA,2007).

2.11 Measuring for Cost-Benefit Analysis

A component of the Green Apple Project was a cost-benefit analysis. The renovation of SSM included potential reductions in risks associated with ergonomic attributes of the building such as lighting, handrails, floor coverings, and the design and location of appliances and controls. These changes can affect the quality of life and, in some instances, reduce the risks of injuries and improve the mobility of residents. The other important group of renovations is those that improve the environment in which the residents live, including heat and air pollution that affect both the quality of life and, in some instances, individual health conditions such as asthma, chronic

obstructive pulmonary disease, and other respiratory conditions that can also contribute to cardiac problems.

Information about the methodology and procedures of this analysis is included in Chapter 8.

2.12 Procedure for Development and Assessment of Resident Education Booklet

Researchers and housing providers acknowledge that resident behavior is a key component of healthy home practices as well as green practices such as energy efficiency (HUD 2001; Wener & Carmalt 2006). While a number of educational programs and brochures have been developed and implemented for promoting healthier and more efficient operation and maintenance of one's home, many of these lack age-appropriate communication strategy for the elderly. Further, there is little research evaluation of their effectiveness. It is our premise that resident engagement programs and communication materials that are specifically designed for and targeted to different populations groups may be more effective in informing and motivating residents to maintain and operate their homes in healthy-efficient ways.

When talking with the SSM residents during social and resident events, we recognized that, by and large, older residents were quite energy conscious even though they did not have to pay their utility expenses (except for phone and cable), many sharing stories of how they had changed incandescent light bulbs in their homes (and even in public areas of SSM) to CFL bulbs, or how they had encouraged property management to increase the recycling efforts and bins in the complex. This prevailing "green behavior" of SSM residents reflects similar survey findings of the marketing firm I-COM (Environment News Service 2008) that showed that consumers over the age of 55 were the greatest users of green products. Accordingly, the GAP team believed the educational materials should focus not on energy efficiency but on cleaning and maintenance efforts and products for maintaining the healthy nature of their renovated homes.

Third year undergraduate students in The Design School Visual Communication Design studio course at Arizona State University undertook a 6-week project in Spring 2011 to create educational materials for the residents. The students were supervised by their instructor Lisa Peña as well as members of the GAP team (Patel, Sinclair, Ahrentzen). Divided into ten teams of four students each, the students examined conventional healthy homes educational materials (e.g. "Help Yourself to a Healthy Home," HUD 2001) to familiarize themselves with existing products. They then visited SSM, saw the renovated homes, observed use of the space, and spoke to several residents and the property manager.

Each team developed a set of different materials (e.g. calendar, handbook, magnets, place mats, cleaning products, etc.) intended to inform residents of practices and products for maintaining the fixtures, furnishings, appliances, and other features of their renovated homes that would be healthy and green. The prototypes were also responsive to physiological, social and cognitive conditions of this older resident population. After these prototypes were developed, the student teams held a 2-hour meeting with approximately fifteen SSM residents, demonstrating the materials and getting feedback from residents. Each prototype was refined based on this feedback, and later presented to and reviewed by members of the GAP research team and the studio instructor. One prototype was selected for further development, which was carried out by four students in Fall 2011 (Figure 2.11). The document was printed and distributed to residents by the property manager approximately two weeks before Panel 3 data collection began. Resident use and feedback on the educational materials is described in Chapter 7.

Figure 2.11 Selections from Resident Education Booklet for Sunnyslope Manor

Recipe

1 cup of vinegar

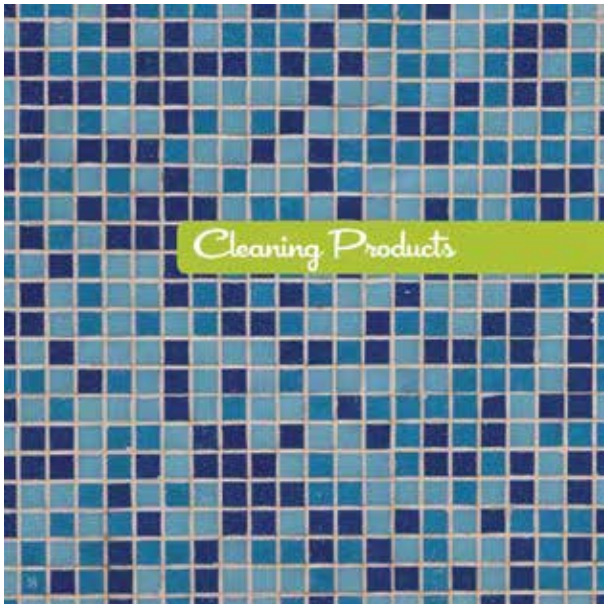
1/4 cup baking soda

juice from 2 oranges

Cleaning Tips

- Place the vinegar, baking soda and orange juice directly in your toilet bowl and let it sit for 15 minutes, scrub the bowl, and flush.
- Placing an orange peel at the bottom of your trash can before placing the liner bag will reduce odors and also help discourage insect infestation.
- Avoid harsh cleaning products containing ammonia, chlorine or petroleum-based chemicals.

Use It Here:



- **Green Works** Developed by the Clorox company, these are formulated to clean without leaving behind harsh chemicals and odors. Green Works can be purchased locally at Walgreens or Walmart.
- **Method** These products are nontoxic all-purpose naturally derived cleaners that can be used in almost any area of your home. They can be purchased at Sunflower Markets, Target, Lowes, and more.
- **Mrs. Meyers** These products are produced without using harmful chemicals such as ammonia, chlorine, formaldehyde, and artificial colorants. The chemicals used in the Meyers brand are completely biodegradable. These products can be purchased at Walmart, Sprouts and Target.
- **Seventh Generation** These cleaning products are chlorine-free and feature natural minerals and oils. Seventh Generation carries a line of recycled chlorine-free paper products such as tissue, paper towels, bathroom tissue and more. These products can be purchased at Sprouts, Fry's, Safeway and Target.

Cleaning Solution

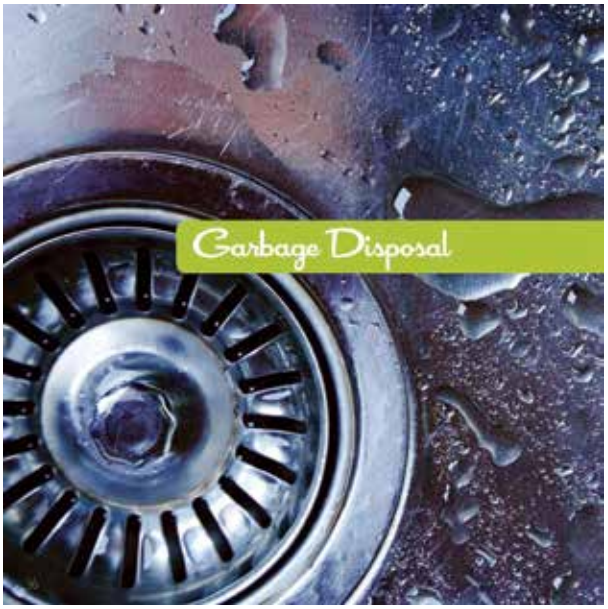
- Green store-bought solutions or hand-made one.

Oven Tips

- Always make sure your oven has cooled before reaching inside to clean.
- Never leave food being cooked unattended.
- Never leave wooden or plastic tools, dish towels or other items on the stove top.

Oven Cleaning

- Remove all items from oven before cleaning.
- Remove oven racks and place them in soapy water to soak.
- Turn oven to self-clean.
- Turn on fans and open windows/patio door when using self-cleaning features to eliminate toxic fumes.
- If your oven is not self-cleaning, follow the directions on the label of the product of your choice.
- After cleaning is complete, and the oven has cooled, wipe the interior of the oven with a damp sponge, rinsing frequently.
- Dry clean over with a soft cloth and replace clean and dried oven racks.



Garbage Disposal Tips

- Always run cold water when grinding. Running water through your disposal as you grind is a good way to make sure food particles are washed completely down the drain.
- Most food items can be put down the garbage disposal, but try to avoid high fiber items, like a corn husk.
- To get rid of smells and left-over food particles, grind ice and peels from citrus fruits like lemons or oranges. This helps keep the disposal smelling fresh and the natural acidity helps suppress bacterial growth associated with odors. This is a cheap and natural way to clean your garbage disposal.
- Don't put grease, fat or fibrous waste into the disposal. It will cause the drain line to become plugged. Dispose of those materials by placing them in the trash.

Avoid These in Disposal:

- asparagus
- avocado skins
- banana skins
- celery
- corn husks
- egg shells
- grease
- lettuce
- noodles
- potato skins
- rice

Baking Soda Tips

- Add a 1/2 cup of baking soda to the wash when you add your regular liquid detergent to naturally boost the cleaning power and assist in reducing smells.
- Quickly rinse acid spills and then sprinkle baking soda on your clothing to neutralize the acid and prevent damage.
- Instead of using fabric softener, try adding a 1/2 cup of baking soda to the rinse cycle.

Shared Laundry Courtesies

- Please empty all of the lint out of the dryer before putting in your next load of laundry.
- Be respectful of other residents by refraining from using bleach in the washer.
- Avoid overloading the dryer and leaving it operating unattended, as this can cause a fire.

Healthy Eating Tips

- Eat a variety of nutrient rich foods (whole grains, fruits, vegetables, nuts, dairy, poultry and fish).
- Try to maintain a healthy weight.
- Maintain a regular eating schedule.
- Try not to eat large portions or overeat.
- Try to reduce sugars and salt in your diet.

Helpful Supplements

- Probiotics can promote a healthy digestive by increasing beneficial bacteria in the digestive tract. They can be found in cultured foods such as yogurt, kefir milk, and sauerkraut, and can be purchased as supplements through most health food stores.
- Digestive enzymes are beneficial in helping the body break down food for better absorption. They can be found naturally in fruits and vegetables or can also be supplemented with a daily pill.
- Omega 3 and 6 can be taken to help aid in digestion and promote healthy brain functions.
- Fiber is a good supplement to take and can also aid in digestion by keeping bowel habits regular.

2.13 Other Meaningful Community Engagement

In addition to the development of the resident educational materials described above, other facets of this project fostered meaningful community engagement of the residents of Sunnyslope Manor. As noted previously, an initial kick-off meeting between GAP research members and SSM residents was held at the beginning of this project; and a final one was held after completion of P3 data collection. Figures 2.12a through 2.12d and Figures 2.13a through 2.13d show photos from these events, as well as do several of the chapter heading images of this report.

Figures 2.12a through 2.12d Kick-Off Event for Green Apple Project

a

b

c

d

Figures 2.13a through 2.13d Final Event for Green Apple Project

a

b

c

d

2.14 Quality Assurance

***Health at Home Survey* and Resident Interviews.** For the Health at Home survey, approximately 85% of questionnaire items were taken from standardized, national surveys that have undergone validity and reliability testing (e.g. NHIS, BRFSS, CEB's Occupant IEQ Survey). Many of the remaining questions come from HUD's Healthy Homes Inspection Manual that has undergone testing before public release. To minimize bias, we used trained interviewers, and interviews were given in the language of choice of the resident (i.e. English, Romanian, Spanish, Russian, Farsi). No resident was denied participation because of language restrictions. Only interviewers who held valid and current certification of successful completion of Human Subjects Training (CITI or NIH) interviewed residents in this study.

Research team members ensured that all interview data was collected and electronically recorded properly. Interviewers were trained by ASU's Institute of Social Survey Research (ISSR); and received additional information and explanation from Dr. Shea regarding particular issues of interviewing elderly residents and of the health terminology and conditions on the survey item. Two members of the GAP team (Ahrentzen, Shea) randomly attended 5% of the interviews at each panel to ensure that interviewing and data collection complied with study protocols (Quality Assurance Protocol, submitted June 2010). During resident interviews, interviewers entered resident responses into a computerized data capture system linked to an SPSS database, eliminating potential error in transferring data from paper forms to computerized dataset.

To ensure completeness, interview items contained "not applicable" and "don't know" options in the response set; such response options ensured that all questions have been asked and answered in a manner that allows for full response choices. For the interview data, at least 95% of the questions must contain a response (i.e. "don't know" is considered a valid response) or would be deemed incomplete and eliminated. All interviews met these thresholds.

All study participants were informed about the project in accordance with and pursuant to the approval from ASU's Institutional Review Board (IRB). The informed consent form was written in English, Romanian, Spanish, Farsi and Russian, and a translator was present when the resident read and signed the form to answer any questions. In addition to the consent form, an information statement (with graphics) of air and environmental sampling/testing equipment, briefly describing the IEQ tests, was given to the participant. The informed consent form explained the nature of the project and measures to protect confidential information. No unique personal identifiers of the study participants were included in any report, article or disseminated document; only aggregated data will be publicly disseminated.

As a safety concern to the participant, researchers were required to report health or home practices that may constitute a hazard. As of this writing, none were noticed.

IEQ Outcomes. For all air and environmental sampling measures, similar procedures were followed for quality assurance, while also developing unique procedures for the specific nature of the instrument.

For all instrument placement, a specific diagram was developed that indicated the exact location where each instrument was to be located and each test performed (see Figure 2.5 above). Multiple locations in each resident's unit were designated (except for blower-door testing) to ensure full range of environmental conditions at different locations in these relatively small homes, as well as comparison between indoor and outdoor air quality.

All field sampling personnel received training in the use of the same sampling instruments and protocols. Field audits periodically occurred to ensure that sampling personnel were following the prescribed protocols. At each data collection panel, IEQ sampling personnel were limited to three individuals, each assigned to perform his/her own procedure (i.e. one person collected air samples of aldehydes and PM; one person performed the blower door test; one person installed, de-installed, and downloaded data from HOBO sensors). In addition, all aldehyde samples across the three panels were submitted to the same laboratory (Lawrence Berkeley National Laboratory) for analyses by the same methods.

To enhance precision, in 5% of sample residences duplicate dust and formaldehyde samples from the same location in each home were collected, at each data collection panel. Except for HOBOs, all instruments collected readings or samples under a strict and controlled environment, and under the surveillance of a trained data collector, eliminating the possibility of tampering with instrument and altering sampling results. HOBOs were left in homes 5 days, in locations that were generally out of reach and/or notice of residents.

Dustrack sampler and SKC aldehyde pump were examined and serviced every week during data collection to ensure adequate performance. HOBOs were examined and serviced once a month, including battery check up. Blower door equipment was examined and serviced every 25 uses.

To assess instrument sensitivity, the laboratory (Lawrence Berkeley National Lab) assessing aldehydes included in their reports minimum detection limits (reporting limits) for each analyte as a measure of sensitivity.

Aldehyde Sampling. To ensure sample integrity throughout the collection and analysis process, the following sample handling and custody requirements was implemented. After each sample was collected with the SKC pump, the DNPH cartridge was removed from the pump, closed with its luer-type fittings and stored in the pouch provided by Waters for individual storage of these cartridges. Each pouch was labeled with the Study ID number and date. All samples were taken to ASU environmental laboratories and immediately stored at 4 degrees Celsius; DNPH samples should not be exposed to temperatures above 30 degree Celsius and should be refrigerated at the laboratories within 24 hours after they had been collected. Immediately after collection and during transportation from site to laboratory refrigerator, samples were stored in a cooler with ice packs. GAP personnel were responsible for keeping, properly coding with designated ID, and safeguarding all samples and transporting them to ASU laboratories in Tempe, Arizona. All samples had an identification label with designated Study ID number and date attached. After samples arrived at ASU laboratories, they were stored in the refrigerator for periods of one to two weeks prior to shipping to the Lawrence Berkeley National Laboratory (LBNL) for their analysis. At LBNL, samples were extracted and analyzed by HPLC.

Particulate Matter Sampling. Sampling devices were calibrated for flow accuracy before and after each sampling panel using an authentic flow device. Log sheets were kept, detailing the deployment of each sampler in each unit; data from each sampling day was downloaded and archived on a backed-up data server; quality assurance tests were performed including reviewing log sheets for sampler problems; screening collected data for outlying points; and review for consistency between the two indoor samplers at each unit.

In laboratory tests, scientists and engineers collected samples from pump card, injecting 2ml of acetonitride solution in one sample and 2 ml blank in another sample as a control sample. The blank sample results should always be zero while samples treated with acetonitride will yield a result higher than zero. All samples were kept at 4 degrees Celsius and stored for eighteen months for additional testing if needed.

For Panel 2, the PM data for three of the sampled units did not pass quality assurance review as described in the project Quality Assurance Plan. As a result, PM data for these three units for panel 2 was deemed “missing” in the database.

Blower Door Testing. The field technicians for the blower door tests made weekly reports indicating how many apartments were tested and how many readings were collected; and maintained up-to-date logs indicating Study ID number of residence, samples collected, date and time. A Minneapolis DG-700 Blower door and fan equipment was used to perform all infiltration and pressure tests. This equipment is calibrated every year per industry standards and recommendations. For all tests a field baseline pressure calibration occurs before each test is performed; this is conducted to ensure that air pressure is balanced between outdoor and indoor conditions.

For Temperature and Relative Humidity Sampling. Field personnel responsible for recording HOBO readings made weekly reports indicating how many apartments were equipped with HOBOs and how many readings collected. After the five days of sampling, data was downloaded from the sensor. If there was more than 5% incompleteness, HOBOs were reinstalled in the units for another 5 days of data collection. This occurred in only a few instances, primarily due to battery failure. Same standards and protocols were applied for all repeated thermal collections data. Before reinstallation, all faulty HOBOs were set aside for calibration or to be reset for future use.

2.15 Data Management and Archiving

All non-electronic data and forms, including signed informed consents and gift card receipts, are filed in a locked file cabinet in a locked office in ASU's School of Design.

While data from the individual IEQ tests and the *HAH* surveys are compiled in Excel or SPSS databases for each panel, we compiled and assembled this data in what we called "mega" datasets, extracting and then merging data along each case (i.e. resident). Cases in these mega datasets include only those residents participating in Panel 1 and subsequent Panels (either P2, P3 or both P2+P3): that is, those who participated in Panel 1 but not subsequent panels were dropped in the mega datasets since these were the ones we were using to compare changes over time.

The final "mega" dataset was analyzed for response frequencies to determine which variables would be used for statistical analyses. Those variables with extremely low or no frequencies were dropped from the final "mega" dataset for further statistical analysis. These datasets were assembled and verified by co-PI Ahrentzen and staff at University of Florida. Once assembled, they were uploaded upon a shared Dropbox system for GAP researchers to use. Procedures for data management for each of the individual datasets are described below.

Resident Interview Data. In keeping with IRB practices of anonymity and confidentiality, data collected from each resident and resident's home was coded with non-identifiable codes. Records of the assignment of these Study ID numbers to relevant resident, needed for subsequent post-intervention testing purposes, was kept in secure, locked physical storage at the ASU School of Design. Electronic records of participant's identity/contact information are stored in a designated drive/folder that is password-protected.

Aldehydes and Particle Data Forms. Air particle data is stored electronically in the internal data logger of the Dustrack sampler and on paper. Once SKC sample cartridges were sent to environmental laboratories, the data was recorded electronically. All data forms are stored at ASU laboratories. Data is electronically uploaded to ASU's server and computers under control of the co-investigators. This information is then added to the mega SPSS datasets described above.

HOBO Data Forms. This data was downloaded directly from each sensor into a laptop in the form of a Microsoft Excel file that was later transferred to files on the Stardust Center's server. This information was then added to the mega SPSS datasets described above.

Blower Door Data Forms. IEAZ collected all blower door test data on paper. These forms, marked by date and Study ID number, are stored at IEAZ offices. After testing all units in a panel period, copies of these forms were sent to GAP research staff who coded and entered this information into an Excel file. This information was then added to the mega SPSS datasets described above.

2.16 Data Analyses Procedures

Since this is a panel study examining the changes in each resident's unit over time, data from residents in P1 who did not participate in later panels was eliminated from analysis. While we tried to get residents to participate in all three panels, there were 6 residents who did not

participate in panel 2 but who later wanted to participate in panel 3. Because the sample size for this study is relatively small, we decided to allow these residents to participate.

While we originally intended to build statistical models to allow multivariate analyses across all three panels, upon consulting with a statistician we decided to instead simply compare P1 to P2 changes (i.e. immediate) and P1 to P3 change (i.e. sustaining) given the small sample size and number of outcome measures and covariates. Consequently, the sample sizes for the P1-P2 and P1-P3 analyses differ slightly (see Table 2.2) because of sample attrition and reinstatement as described previously.

Before any statistical testing, correlations and cross-tabulations were run on various outcome variables to assess collinearity, particularly for the IEQ data that was collected in multiple sites of the home. For example, while there were three sensors measuring air temperature in each unit, temperature data from the living room, kitchen and bedroom was correlated to assess potential collinearity. When correlations between these rooms were .70 or greater, a composite variable (i.e. mean) for the IEQ/IAQ variables was created. In nearly all cases (exception was acetone), correlations between rooms exceed .70; in the majority of cases, they exceeded .90. Because of the small sample size, we decided it inappropriate to use factor analysis to create composite variables on health factors. Instead, additional interval-level variables were constructed by counting the occurrence of similar health conditions (e.g. counting the number of different joint pains reported; the number of different respiratory conditions reported, etc.). These are described in more detail in Chapter 6.

When examining changes in IEQ or health from Panel 1 to Panel 2 (referred to as "P1P2") or from Panel 1 to Panel 3 ("P1P3"), we used a class of regression methods called fixed effects models. Since we did not have a control group but did have a longitudinal panel research design, these models were quite appropriate to the panel nature of our study, where each individual (or the individual's apartment) acts as his or her own control. In fixed effects models, the basis is to compare, for example, an apartment's formaldehyde concentration level before the renovation and after the renovation. Assuming nothing else changes (which can be a significant validity threat), the difference in formaldehyde levels between the two periods is an estimate of the retrofit effect for that individual unit. If the formaldehyde differences (e.g. P1P2) for all units are averaged, we then get an estimate of the average "treatment effect." This estimate controls for invariant characteristics of the resident or unit (e.g. age, gender, floor level). Although the technique does not control for time-varying factors (e.g. change in use of air freshener), these latter were handled by entering them into the regression model differently.

There are two basic data requirements for using fixed effects methods (Allison 2005). First, the dependent variable must be measured for each individual on at least two occasions; and those measurements must have the same meaning and metric. This is the case for all the IEQ data and most of our *HAH* data (exceptions discussed below). Second, the predictor variable must change in value across those two occasions for some substantial portion of the sample, which was again the case in our study for many of our variables. When it did not, we did not proceed with the analyses.

In cases where there was a change in the wording of the variable on the *HAH*, we did not undertake fixed effects models. This happened when we asked a question in P1 as "have you ever been diagnosed with emphysema," but in P2 asked, "since the renovation, have you been diagnosed with emphysema." In these cases, cross-tabulations or paired t-tests were used.


EXIT

Chapter 3

Energy and Water Efficiency at Sunnyslope Manor

Did the Retrofit Result in Decreased Utility Consumption? Energy and Water Efficiency at Sunnyslope Manor

Consultant retained by the City of Phoenix reported a reduction of 12.56% water and 19.41% in electricity consumption as a result of the renovation work, based on analysis of 39 months of metered electrical and water use data of Sunnyslope Manor between July 2009 and September 2012. Given the proprietary nature of the consultant's research methodology, we also examined the same 39 months of metered data to compare energy and water consumption rates before (July 2009 to January 2011), during (February 2011 to August 2011) and after the retrofit (September 2011 to October 2012).

Figure 3.1 Mean Monthly Temperature and Metered Energy Consumption

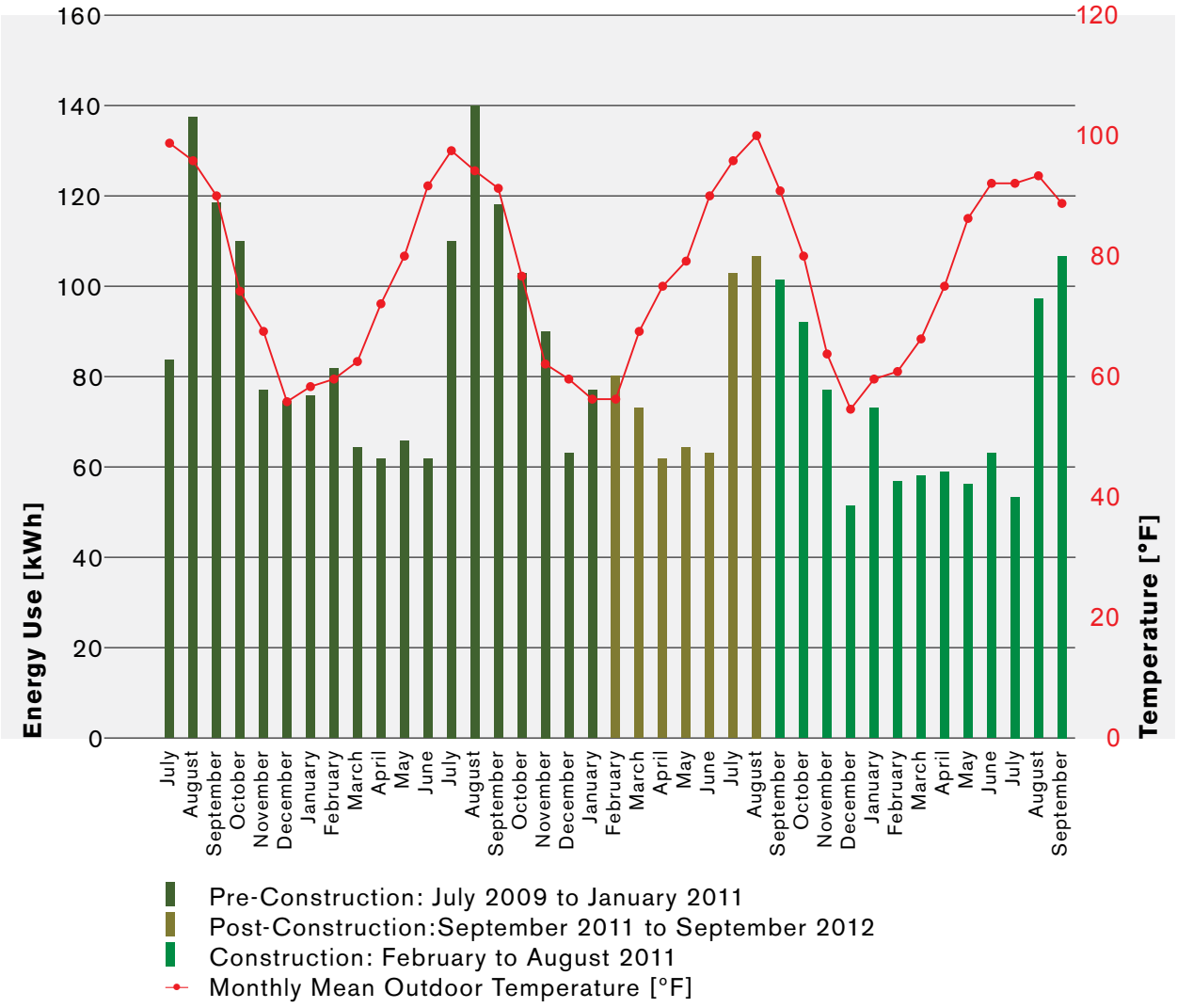
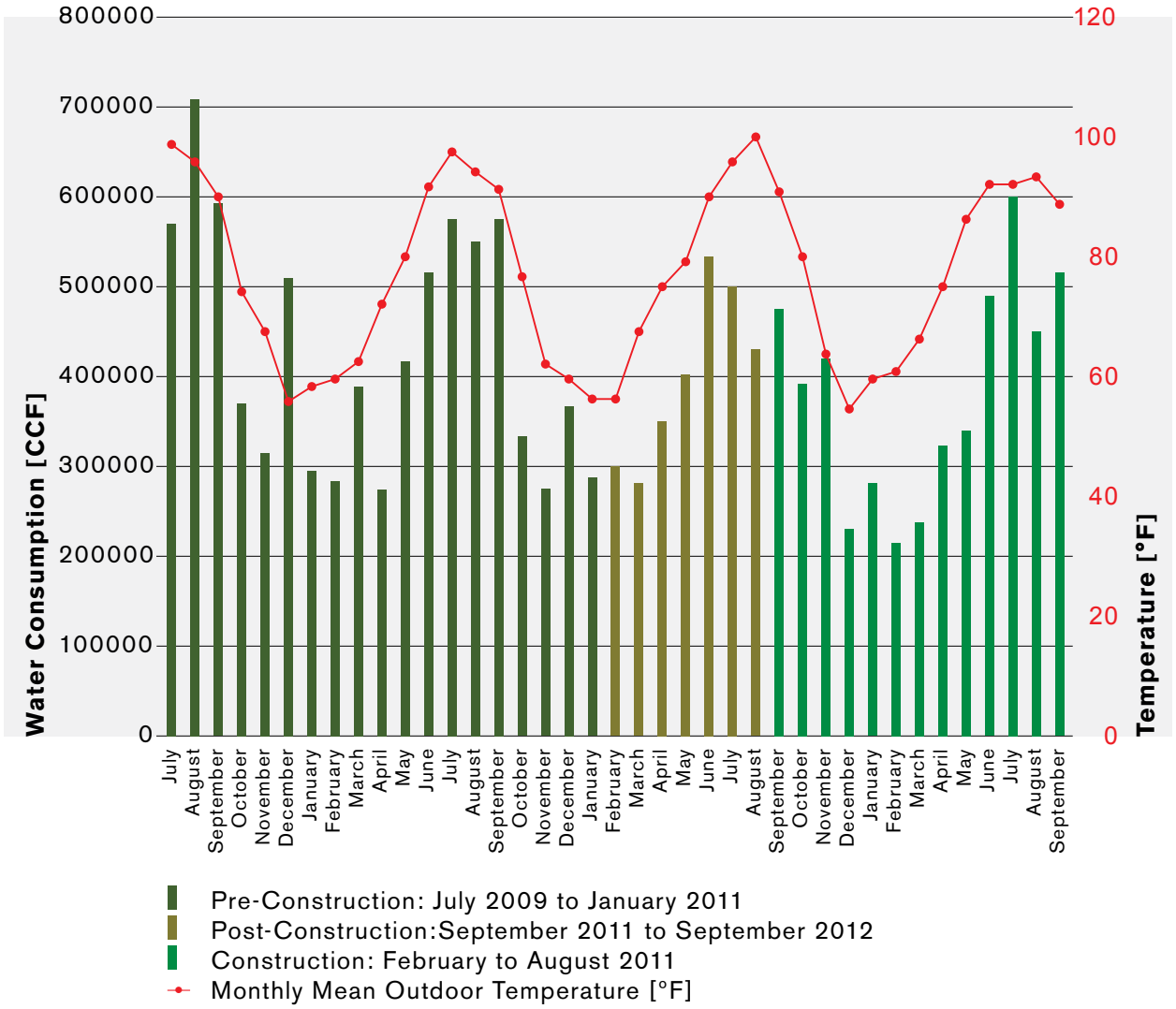


Figure 3.2 Mean Monthly Temperature and Metered Water Consumption



These metered data were first evaluated against corresponding monthly weather data obtained from the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center for Phoenix Sky Harbor Airport to note any significant variance in weather conditions over the 39 months that could substantially influence energy and water use during this short span of data. Notable differences were not observed in mean monthly temperatures, or in the number of reported Heating Degree Days or Cooling Degree Days between 2009 and 2012 (difference in total number of Degree Days reported between years is <1%). Consequently we concluded that changes observed in energy and water use are likely not due to variance in the weather.

A notable change in monthly energy (Figure 3.1) and water (Figure 3.2) use from pre-renovation levels occurred towards the end of the renovation phase (July 2011) and over the following months. Comparison of the pre- and post-renovation metered data shows energy consumption reduced from 1042 to 845 kWh annually, and water consumption from 5129000 to 4495000 CCF annually. These values amount to approximately 19% reduction in energy and 12% in water consumption, corresponding to the consultant's report.

Three summer months of peak cooling loads (i.e. July, August, September), where four years of metered data are available, shows that reductions in energy and water can fluctuate significantly between months. The difference between 2012 energy consumption values and the average consumption of years 2009, 2010, and 2011 may be as little as 5% or as great as 45% resulting in an average reduction of 24% in energy use (Figure 3.3). Water use varies between a 12% increase during the month of July to a reduction of 18% in the following month (Figure 3.4) with an average reduction of 3% over these three months.

Figure 3.3 Mean Monthly Temperature and Metered Energy Consumption for Four Years of Peak Summer Months July – September

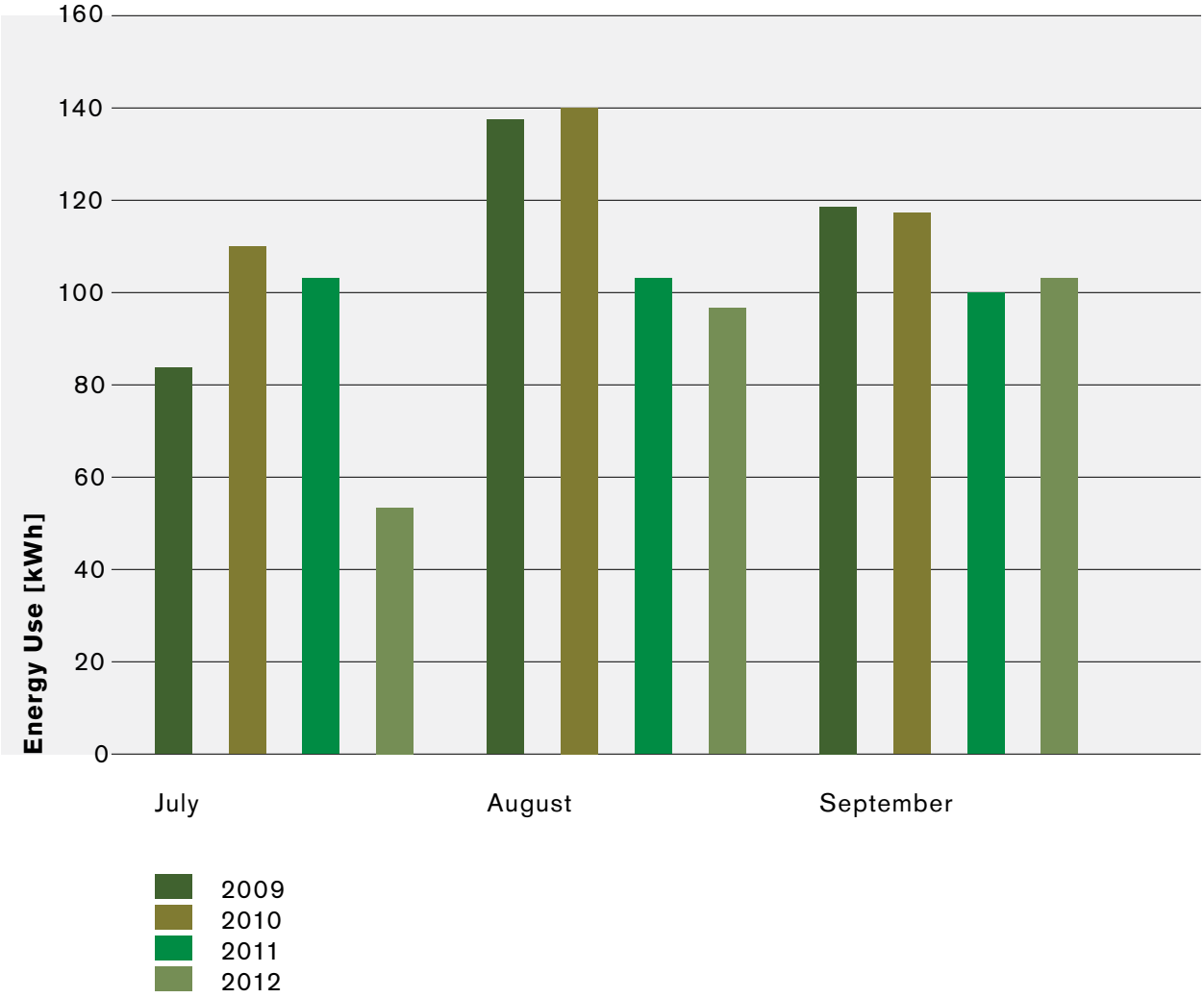
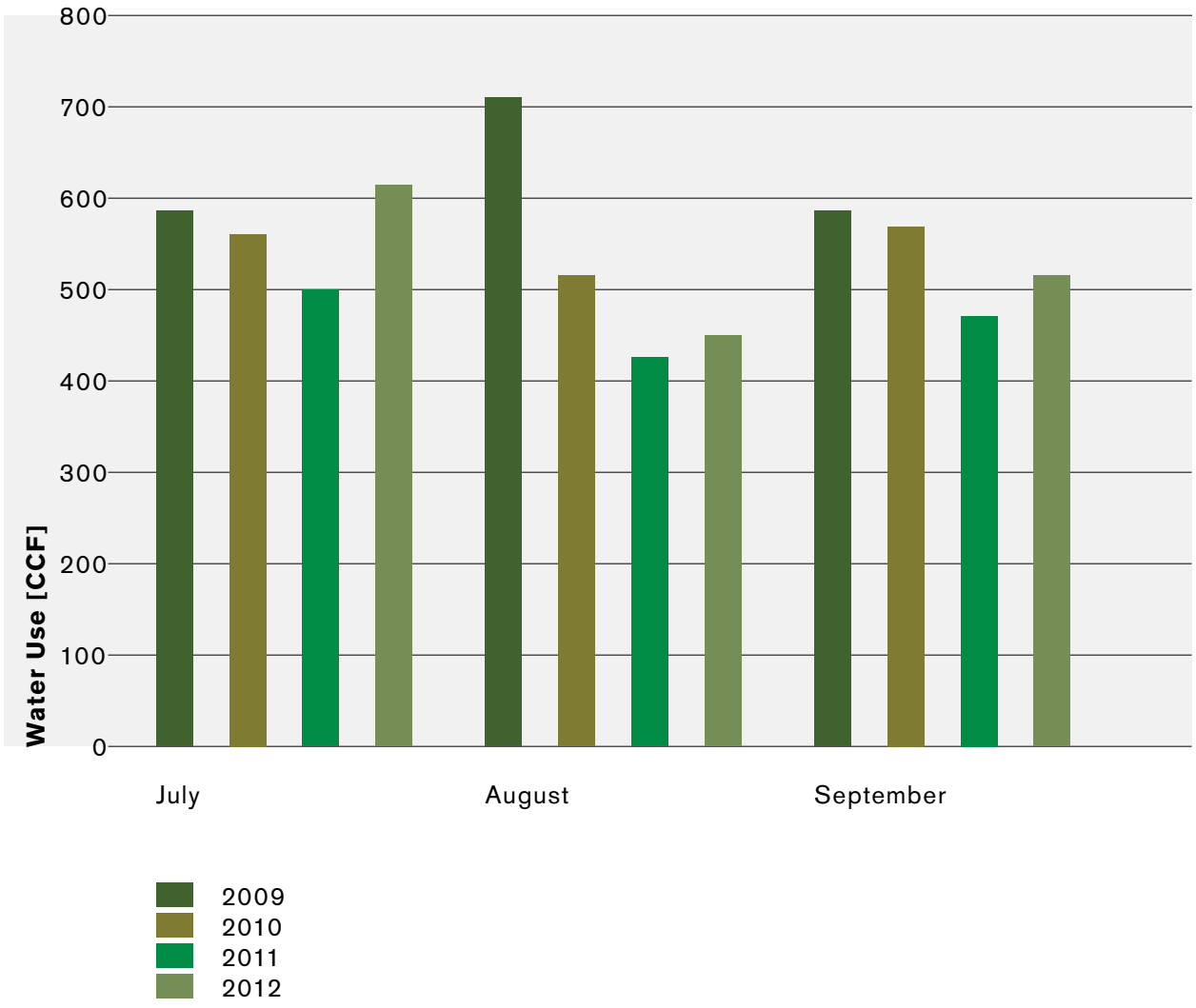


Figure 3.4 Mean Monthly Temperature and Metered Water Consumption for Four Years of Peak Summer Months July – September



Chapter 4

Did Indoor Air Quality Improve after the Retrofit?

Did Indoor Air Quality Improve after the Retrofit?

As described in Chapter 2, we sampled particulate matter (PM) and aldehydes of each resident's units in the kitchen, living room and balcony. Correlations between an apartment's kitchen and living room PM data were .90 or higher; this allowed us to combine measurements from these rooms into one composite measure (by averaging room-level data) to represent the unit. The same was done for acetone, acetaldehyde and formaldehyde data, which also had high correlations between kitchen and living room data.

For PM and the three aldehydes, we also created variables to represent the ratio of indoor to outdoor (I/O) levels: unit-level data divided by balcony data. Finally we also created two measures to represent the extent to which indoor formaldehyde levels of the kitchen and of the living room exceeded California 8-hr REL from 2005, or 27ppb. An exceedance ratio (i.e. room concentration divided by 27) less than 1 indicates the extent room formaldehyde concentration fell below this level; while greater than 1 shows the extent it exceeds this California standard.

In brief, the measures reported in this chapter are listed in Table 4.1.

Table 4.1 Particulate Matter and Aldehyde Measures Used in Analyses

$PM_{2.5}$:	$PM_{2.5}$ of Unit
PM_{10}:	PM_{10} of Unit
I/O $PM_{2.5}$:	Indoor/Outdoor Ratio (Unit/Balcony) $PM_{2.5}$
I/O PM_{10}:	Indoor/Outdoor Ratio (Unit/Balcony) PM_{10}
ACTN:	Unit Acetone Concentration
I/O ACTN:	Indoor/Outdoor Ratio (Unit/Balcony) of Acetone Concentration
AA:	Unit Acetaldehyde Concentration
I/O AA:	Indoor/Outdoor (Unit/Balcony) Acetaldehyde Concentration
FA:	Unit Formaldehyde Concentration
I/O FA:	Indoor/Outdoor (Unit/Balcony) Formaldehyde Concentration
FA EXC-K:	Exceedance Ratio Kitchen Formaldehyde Concentration Over or Under Cal 8-hr REL
FA EXC-L:	Exceedance Ratio Living Room Formaldehyde Concentration Over or Under Cal 8-hr REL

When considering possible mediating or moderating factors affecting indoor air quality, we examined three building characteristics (floor level, east-west wing, north-south orientation) as well as nine personal/behavioral factors (age, length of stay at SSM, whether occupant smokes, whether occupant smokes indoors, whether occupant has pets, use of bug spray, use of odor-changing/masking products, use of kitchen fan, and use of bathroom fan). These were treated as covariates in the fixed effects regression models.

4.1 Particulate Matter

Overall, there was no statistically significant change in PM levels before the renovation and afterwards (neither short nor long term post-retrofit). While mean PM counts did show changes over time, the variance was so sizeable that statistical significance was not achieved (see Table 4.2 for descriptive statistics of PM measures). However, when taking into account mediating factors, some changes occurred and these are discussed below.

Table 4.2 Descriptive Statistics for PM

	$PM_{2.5}$ Indoor Concentration (ppb)	$PM_{2.5}$ Indoor/ Outdoor Ratio	PM_{10} Indoor Concentration (ppb)	PM_{10} Indoor/ Outdoor Ratio
P1P2 (N=54)				
Panel 1 Mean + Standard Dev.	46 ± 91	2.5	50 ± 92	2.1
Panel 1 Median	13	1.1	17	1.0
Panel 2 Mean + Standard Dev.	91 ± 228	3.8	98 ± 228	3.9
Panel 2 Median	21	1.6	26	1.5
P1P3 (N=53)				
Panel 1 Mean + Standard Dev.	63 ± 139	3.4	67 ± 138	2.9
Panel 1 Median	13	1.1	17	1.0
Panel 3 Mean + Standard Dev.	37 ± 87	2.9	41 ± 87	2.2
Panel 3 Median	19	1.9	22	1.5

4.1.1 Short Term Effects

When the mediating factors were incorporated into the statistical tests as covariates, three were prominent: the resident's length of stay at Sunnyslope Manor, whether the resident smoked, and use of odor-masking products.

Between Panels 1 and 2, $PM_{2.5}$ and PM_{10} concentrations increased as the length of time residents lived at SSM increased ($PM_{2.5}$ $t = 3.063$, $p = .003$; PM_{10} $t = 3.041$, $p = .003$); while indoor/outdoor PM ratios decreased with length of time living there (I/O $PM_{2.5}$ $t = 3.721$, $p < .000$; I/O PM_{10} $t = 3.732$, $p < .000$).

The units of those residents who used odor-masking products showed increased levels of $PM_{2.5}$ and PM_{10} from Panel 1 to Panel 2 ($PM_{2.5}$ $t = 1.963$, $p = .052$; PM_{10} $t = 1.972$, $p = .051$), but there was no similar P1P2 change of indoor/outdoor PM ratios.

PM concentrations and Indoor/Outdoor PM ratios were significantly higher in homes of those residents who smoked than in the units of non-smokers ($PM_{2.5}$ $t = 3.717$, $p < .001$, PM_{10} $t = 3.96$, $p < .001$; I/O $PM_{2.5}$ $t = 6.592$, $p < .001$, I/O PM_{10} $t = 6.957$, $p < .001$); however, there was no significant change between P1 and P2 when smoking was added as a covariate. (In panels 1 and 2 residents were not asked whether they smoked indoors, so we did not consider this as a potential mediating factor in short-term effects.)

4.1.2 Long-Term Effects

Compared to short-term changes, some of the mediating factors of P1P3 change showed similar trends, while others did not; and a new one appeared to make a difference – resident's age.

Concentrations of both $PM_{2.5}$ and PM_{10} decreased between Panels 1 and 3 as the length of time a resident lived at Sunnyslope Manor increased ($PM_{2.5}$ $t = -1.865$, $p = .065$; PM_{10} $t = -1.897$, $p = .061$), but this pattern did not hold for indoor/outdoor ratios of these concentrations

With increasing age of the resident, PM concentrations between P1P3 decreased ($PM_{2.5}$ $t = -2.214$, $p = .029$; PM_{10} $t = -2.151$, $p = .034$) as well as indoor-outdoor ratios (I/O $PM_{2.5}$ $t = -2.151$, $p = .034$; I/O PM_{10} $t = -1.929$, $p = .057$).

The use of odor-masking products did not affect P1P3 change in any PM measures.

Regression models show that units occupied by individuals who smoke have statistically significant higher PM levels than units inhabited by non-smokers ($PM_{2.5}$ $t = 6.186$, $p < .000$; PM_{10} $t = 6.161$, $p < .000$). In P3, 6 of the 11 residents who smoked stated they smoke indoors. This covariate shows a different statistically significant PM relationship than units inhabited by the rest of the Sunnyslope sample population including both non-smoking and smokers who did not smoke in their units ($PM_{2.5}$ $t = 8.211$, $p < .000$; PM_{10} $t = 8.202$, $p < .000$). The higher PM concentrations measured in units with smokers is seen to decrease from P1 to P3 more than the decrease in PM levels measured in units of non-smokers ($PM_{2.5}$ $t = -3.078$, $p < .000$; PM_{10} $t = -3.059$, $p = .003$). Isolating the 6 units with indoor smokers shows a statistically significant decrease in PM levels different than the rest of the population ($PM_{2.5}$ $t = -3.780$, $p < .000$; PM_{10} $t = -3.771$, $p < .000$).

4.1.3 Conclusions of PM Results

Although we had expected a short term increase in PM concentrations after the retrofit, this was only statistically apparent with two covariates: length of stay for the occupant and the use of odor-masking products. In general, smokers had higher PM concentrations, but no short term change as a result of the renovation.

Over the long term (i.e. P1P3), units with residents who had lived longer at Sunnyslope Manor had a decrease in PM concentrations (but no effect on the indoor/outdoor ratio was noted), opposite that of the short term effect. Also, use of odor-masking products had no effect on changes in PM concentrations in the long term.

Long-term reductions in both indoor PM concentrations and indoor/outdoor PM ratios was apparent with increasing age of residents. One possible explanation for this result may be that older residents participate in fewer activities that re-suspend or release particles, such as walking, cleaning, and cooking. In both P1P2 and P1P3 data, units of residents who smoke were associated with higher indoor particle concentrations. However, units in which residents were smokers showed no change from Panel 1 to Panel 2 but a decrease in PM from Panel 1 to Panel 3.

4.2 Aldehydes

The aldehydes tested include formaldehyde, acetaldehyde, and acetone. To provide a general overview of aldehyde data of apartments in our sample, cumulative frequency plots were developed for unit concentrations of formaldehyde, acetone, and acetaldehyde at each panel (Figures 4.1, 4.2, and 4.3, respectively). Figure 4.1 also includes reference lines for the most recent California 8-h REL, the Health Canada 8-h REL, and the California acute REL.

Figure 4.1 Cumulative Frequency of Unit Formaldehyde Concentrations for Each Panel

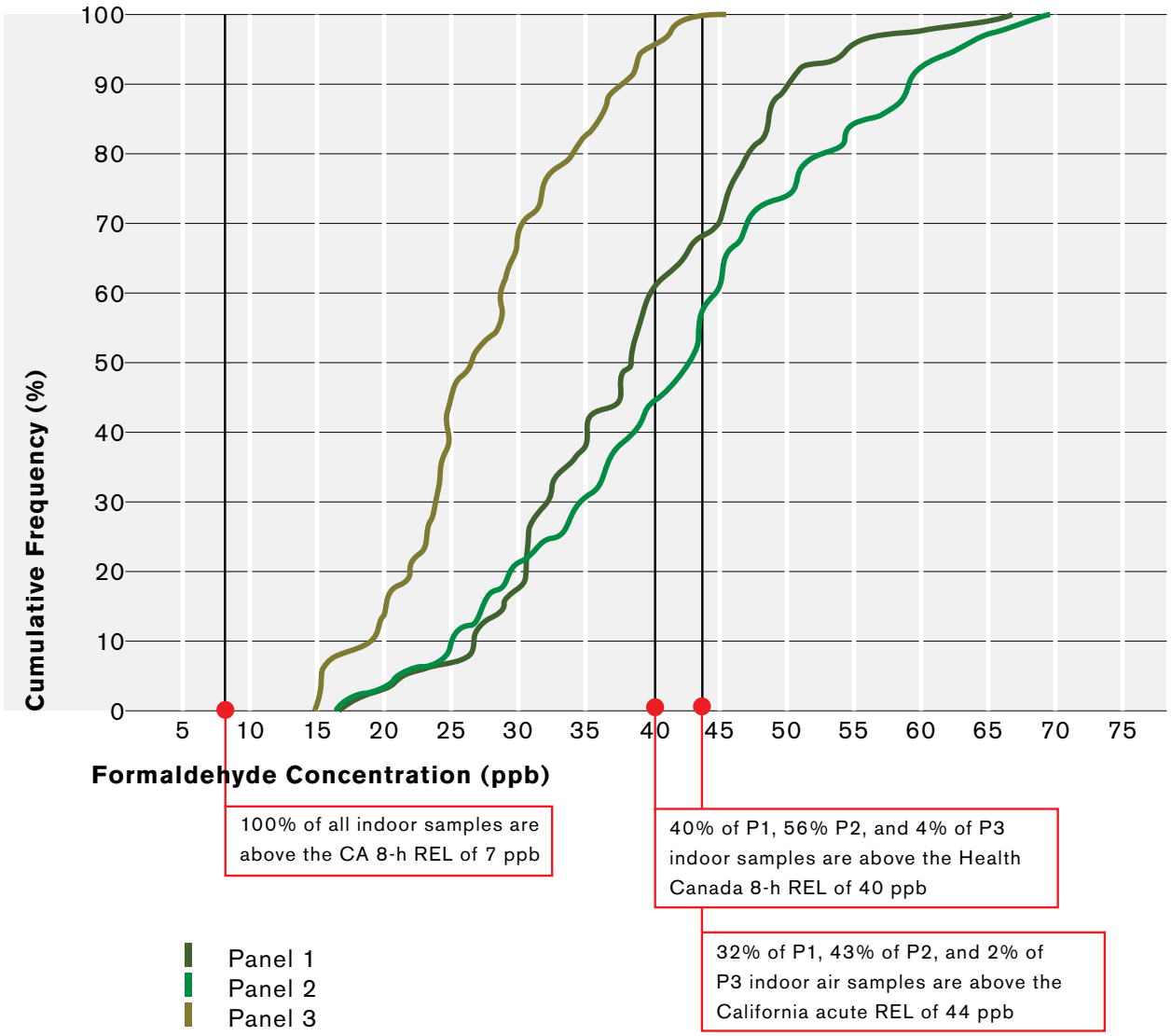


Figure 4.2 Cumulative Frequency of Unit Acetone Concentrations for Each Panel

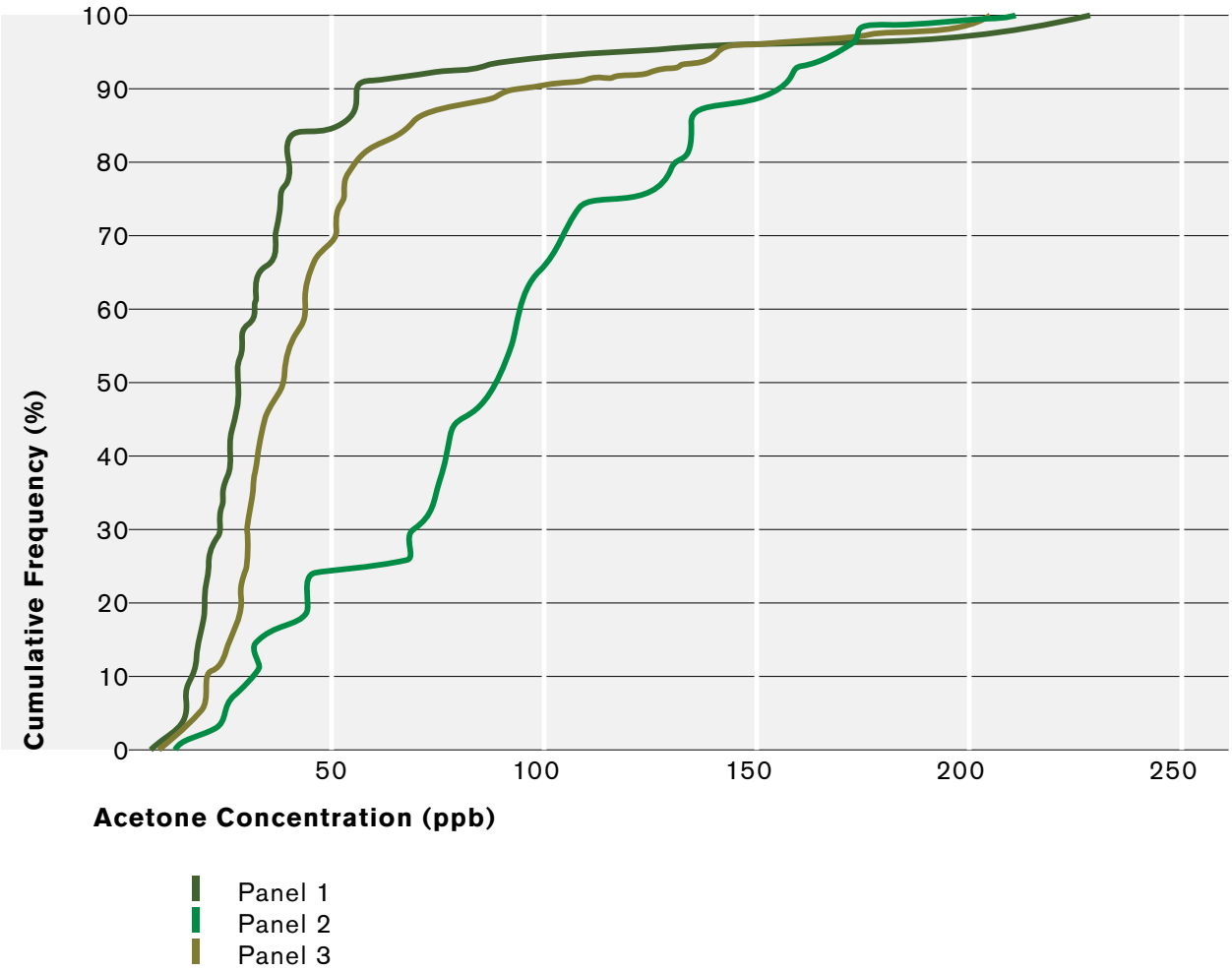


Figure 4.3 Cumulative Frequency of Unit Acetaldehyde Concentrations for Each Panel

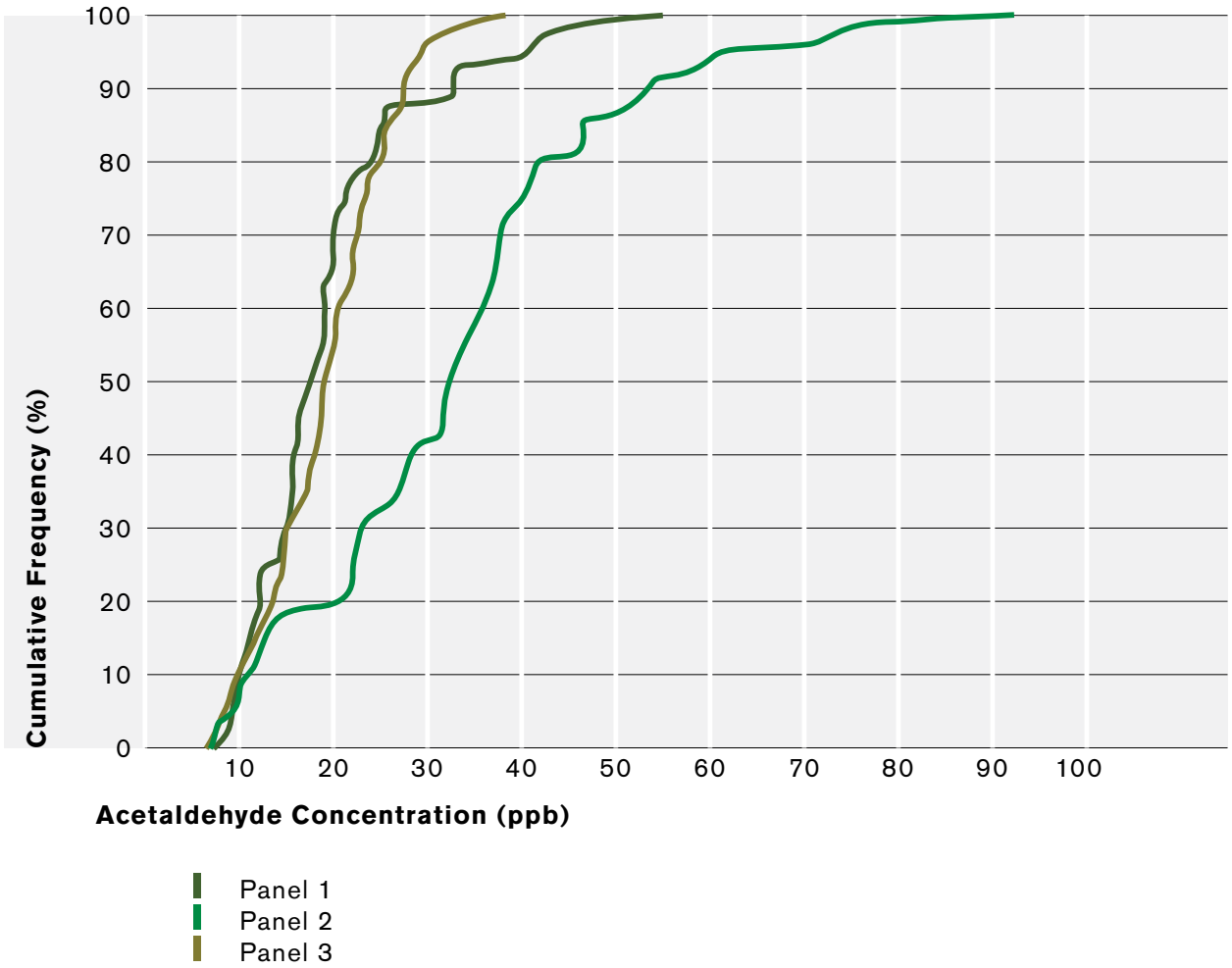


Table 4.3 shows the means and medians for these aldehyde concentrations and indoor/outdoor ratios.

Table 4.3 Descriptive Statistics for Aldehydes

	Acetone Indoor Concentration (ppb)	Indoor/ Outdoor Ratio	Acetaldehyde Indoor Concentration (ppb)	Indoor/ Outdoor Ratio	Formaldehyde Indoor Concentration (ppb)	Indoor/ Outdoor Ratio
P1P2 (N=54)						
Panel 1 Mean + Standard Dev.	40 ± 42	8.6	20 ± 9	11	39 ± 10	8.9
Panel 1 Median	28	8	18	10	38	7.9
Panel 2 Mean + Standard Dev.	91 ± 45	14	34 ± 17	13	42 ± 13	9.5
Panel 2 Median	90	11	33	10	43	7.1
P1P3 (N=53)						
Panel 1 Mean + Standard Dev.	42 ± 42	8.9	21 ± 10	11	40 ± 12	9.2
Panel 1 Median	28	8.2	19	11	38	8.0
Panel 3 Mean + Standard Dev.	52 ± 42	11	20 ± 7	10	27 ± 7	7.1
Panel 3 Median	39	9.7	20	9.1	26	6.8

4.2.1 Short-Term Effects

Between Panel 1 and Panel 2, there is a noticeable increase in two chemical pollutants, acetone and acetaldehyde, both in indoor concentrations and in indoor/outdoor ratios (see Tables 4.4 and 4.5).

Statistically significant increases in absolute **acetone** levels hold after controlling for a number of the mediating factors, including the three building factors and resident characteristics of length of stay, smoker, indoor smoker, and pet ownership (Table 4.4).

Table 4.4 P1P2 Changes in Indoor Acetone Concentrations, and After Controlling for Mediating Factors

	P1P2 Regression After Covariate		Relationship
	t-value	*p*-value	
Baseline	5.928	.000	Increased from Panel 1 to Panel 2
Floor Level	3.471	.001	Increased from Panel 1 to Panel 2 after controlling for floor level
Wing (East / West)	4.062	.000	Increased from Panel 1 to Panel 2 after controlling for wing
Orientation (North/South)	3.358	.001	Increased from Panel 1 to Panel 2 after controlling for orientation
Age of Occupant	-2.445 2.423	.016 .017	Older occupants have lower acetone and the increase is higher in units with older people
Length of Stay	3.316	.001	Increased from Panel 1 to Panel 2 after controlling for length of stay
Does the Occupant Smoke	5.472	.000	Increased from Panel 1 to Panel 2 after controlling for smoking pattern
Does the Occupant Smoke Indoors	5.877	.000	Increased from Panel 1 to Panel 2 after controlling for smoking pattern
Does the Occupant Have Pets	5.615	.000	Increased from Panel 1 to Panel 2 after controlling for pet ownership
Change in Bug Spray Usage	5.830	.000	Increase is lesser in units that stopped using bug spray from panel 1 to Panel 2
Change in Use of Products to Change Air Smell	3.500	.001	Increase is greater in units that started using products from panel 1 to Panel 2
Kitchen Fan Usage	4.684	.000	Increase is lesser in units which used kitchen fan in both panels 1 and 2
Bedroom Fan Usage	3.920	.000	Increased from Panel 1 to Panel 2 after controlling for bedroom fan
n = 53			

When controlling for resident age, analyses revealed lower initial acetone concentrations in units with older occupants, but their short term increase was higher than younger occupants (see Table 4.4).

When considering household behavior factors, the increase in acetone was less in units that stopped using insecticides from panel 1 to 2; but greater in units that started using odor-masking products. The increase was less for units where residents reported using their kitchen fan; yet still increased after controlling for bedroom fan use.

P1P2 increases in indoor/outdoor acetone ratios were statistically significant as well ($t = 3.433$, $p < .001$). After controlling for mediating variables, similar patterns occurred as those for indoor acetone reported above except for floor level, age, length of stay at SSM, and bedroom fan use.

Similar trends occurred when examining covariates in **acetaldehyde** data between panels 1 and 2 (see Table 4.5). The increase in concentrations between P1P2 is higher in those units where residents have lived longer at SSM. In addition, there was a larger concentration increase in units where residents began using odor-masking products between panels; but a decrease in units that stopped using indoor bug spray. The increase in concentration level is lower in units that used kitchen fan in both panels; but the increase remains after controlling for bedroom fan use.

Table 4.5 P1P2 Changes in Indoor Acetaldehyde Concentrations, and After Controlling for Mediating Factors

	Regression After Covariate		Relationship
	t-value	*p*-value	
Baseline	4.924	.000	Increased from Panel 1 to Panel 2
Floor Level	2.617	.010	Increased from Panel 1 to Panel 2 after controlling for floor level
Wing (East / West)	3.362	.001	Increased from Panel 1 to Panel 2 after controlling for wing
Orientation (North/South)	2.771	.007	Increased from Panel 1 to Panel 2 after controlling for orientation
Age of Occupant	-1.088	.279	Not significant
Length of Stay	2.180	.031	Increase is higher in units which have been occupied longer by the residents
Does the Occupant Smoke	4.061	.000	Increased from Panel 1 to Panel 2 after controlling for smoking behavior
Does the Occupant Smoke Indoors	5.083	.000	Increased from Panel 1 to Panel 2 after controlling for smoking behavior
Does the Occupant Have Pets	4.509	.000	Increased from Panel 1 to Panel 2 after controlling for pets
Change in Bug Spray Usage	-2.483 5.053	.015 .000	Decreased in units that stopped using bug spray; increased in others
Change in Use of Products to Change Air Smell	1.934	.056	Increase is higher in units that use products
Kitchen Fan Usage	3.910	.000	Increase is lower in units that used kitchen fan before and usage did not change
Bedroom Fan Usage	4.072	.000	Increased from Panel 1 to Panel 2 after controlling for bedroom fan

n = 53

While there was no short-term change in **formaldehyde** overall, the reported levels ranging from 17 to 69 ppb are particularly alarming due to the fact that the 2007 California EPA 8-h reference exposure level (REL) is 7 ppb, as mentioned in Chapter 2 (and see Figure 4.1). As seen in Figure 4.1, 100% of samples exceed the CA 8-hour REL. When compared to the CA acute REL standard of 44 ppb, 32% of Panel 1 and 43% of Panel 2 units are above the standard. Additionally, 40% of Panel 1 samples and 56% of Panel 2 samples exceed the Health Canada REL of 40 ppb. By contrast, all acetaldehyde levels were below the health-based exposure levels (see Figure 4.3) recommended by both agencies (the California EPA 8-h REL is 160 ppb and 1-h REL is 260 ppb for acetaldehyde). Acetone levels measured in this study do not pose any health hazards.

The indoor/outdoor ratios for formaldehyde revealed a few interesting relationships with the covariates. When evaluated by floor level, there was a marginally significant decrease between P1P2 in the bottom floor ($t = -1.724$, $p = .088$) and a statistically significant increase in the top floor ratios ($t = 2.025$, $p = .045$). In general, there were lower ratios in the north-facing units, but no change between Panels 1 and 2. Although very few residents indicated pet ownership (n = 9), there was a statistically significant increase in formaldehyde

levels in units with pets ($t = 2.514$, $p = .013$). There was also an increase in the units in which the kitchen fan was used in Panel 1 ($t = 1.758$, $p = .082$), and for those who changed their use of the kitchen fan between Panels 1 and 2 ($t = 1.758$, $p = .082$).

In the short term, there was no statistically significant P1P2 change in the exceedance ratios.

4.2.2 Long-Term Effects

Changes between P1 and P3 were notably different from those of P1P2. Panel 3 mean concentrations (n = 52) of formaldehyde, acetaldehyde, and acetone were 27 ($\sigma = 7$), 20 ($\sigma = 7$), 49 ($\sigma = 37$) ppb, respectively, which reveals a decrease in formaldehyde from Panel 1, where the means were 39 ($\sigma = 12$), 21 ($\sigma = 10$), and 42 ($\sigma = 43$) ppb (n = 52). The indoor/outdoor ratios were 9.2 ($\sigma = 4.0$), 11.0 ($\sigma = 4.7$), and 8.9 ($\sigma = 3.8$) in Panel 1 and changed to 7.0 ($\sigma = 2.4$), 0.3 ($\sigma = 4.5$), and 10.3 ($\sigma = 4.1$) in Panel 3.

Formaldehyde concentrations show a decrease from P1 to P3. This decrease held after controlling for most of the mediating building characteristics and personal/behavioral factors (see Table 4.6). In the Panel 3 survey, we asked additional questions about household cleaning products and use (use of self-cleaning oven; use of home-made cleaning solutions; use of commercial, non-green cleaning solutions; use of green solutions in kitchen; use of green cleaning solutions in bathroom; use of green cleaning solutions for furniture). P1P3 formaldehyde levels decreased even after controlling for these factors (Table 4.6).

Table 4.6 P1P3 Changes in Indoor Formaldehyde Concentrations, and After Controlling for Mediating Factors

	Regression After Covariate		**Relationship**
	t-value	*p*-value	
Baseline	-6.376	.000	Decrease
Floor Level	-2.042	.044	Decrease after controlling for floor
Wing (East / West)	-5.197	.000	Decrease after controlling for wing
Orientation (North/South)	-5.037	.000	Decrease after controlling for orientation
Age of Occupant	2.321	.022	Units with older people have higher FA but there is no change from one panel to another
Length of Stay	-4.796	.000	Decrease after controlling for length of stay
Does the Occupant Smoke	-5.290	.000	Decrease after controlling for smoking
Does the Occupant Smoke Indoors	-5.581	.000	Decrease after controlling for smoking
Does the Occupan Have Pets	-6.323 -2.033	.000 .045	Decrease after controlling for pets; also units with pets have lower FA
Change in Use of Products to Change Air Smell	-2.934	.004	Decrease after controlling for use
Kitchen Fan Usage	-4.237	.000	Decrease after controlling for use
Bedroom Fan Usage	-3.882	.000	Decrease after controlling for use
Use Self-Cleaning Oven	-5.377	.000	Decrease is more in units using the self-cleaning oven
Use Home-Made Solutions	-3.057	.003	Decrease after controlling for use
Use Store-Bought Non-Green Solutions	-5.471	.000	Decrease after controlling for use
Use Green Solutions in Kitchen	-4.268	.000	Decrease after controlling for use
Use green solutions in Bathroom	-4.948	.000	Decrease after controlling for use
Use green solutions in Furniture	-3.379	.001	Decrease after controlling for use
n = 53			

As seen in Table 4.6, older residents lived in units with higher levels of formaldehyde; however, there was no change in formaldehyde concentration in their homes between the first and third panels. Residents with pets had lower concentrations than those without pets (t = -2.033, p = .045); here, the change in formaldehyde concentrations decreased after controlling for pet ownership.

Between Panels 1 and 3, there also was an overall statistically significant decrease in the exceedance ratios for formaldehyde (for FA EXC-K, $t = -5.478$, $p > .000$; for FA EXC-L , $t = -6.974$, $p > .000$). Most building and personal/behavioral covariates followed similar patterns as those reported above for indoor formaldehyde concentrations changes.

Acetaldehyde concentrations did not change between P1 and P3. Although units with residents who smoke had higher concentrations ($t = -5.290$, $p < .000$), there was no difference between smokers and non-smokers in changed concentration levels in their units between panels. There were no P1P3 changes when controlling for age, length of stay or building characteristics. However, there was a decrease in acetaldehyde concentrations in units where occupants began using odor-masking products from P1 to P3 ($t = -2.934$, $p = .004$).

While there were increased levels of **acetone** in units over the short term, this difference dissipated by the third panel. However, indoor/outdoor ratios of acetone increased ($t = 1.703$, $p = .092$) – as they did for short-term changes. Units where residents stopped using odor-masking products over time showed reductions in indoor-outdoor acetone ratios, while other units showed a marked increase (Table 4.7). In addition, there is a marginally significant increase in indoor-outdoor ratios after controlling for building orientation and units with residents who smoke.

Table 4.7 P1P3 Changes in Indoor/Outdoor Ratio of Acetone, and After Controlling for Mediating Factors

	Regression After Covariate		Relationship
	t-value	*p*-value	
Baseline	1.702	.092	Increase
Orientation (North/South)	1.791	.076	Increased after controlling for orientation
Does the Occupant Smoke Indoors	1.188	.063	Increased after controlling for smoking
Change in Use of Products to Change Air Smell	-3.023 3.147	.003 .002	Decrease after controlling for use
n = 51			

4.2.3 Conclusions of Aldehyde Results

The most significant long-term changes are observed in the formaldehyde concentrations. As indoor formaldehyde concentrations typically originate from off-gassing from building materials, much of which were replaced during the renovation, this improvement is consistent with substitution of high-emitting materials with new low-emission products. Changes to acetone and acetaldehyde, commonly generated from use of cleaning products, smoking and cooking, were small compared to formaldehyde, and did not follow the same trends. This is consistent with the fact that sources for acetaldehyde and acetone are primarily associated with occupant activities and have not changed for the most part after the retrofit (see Chapter 7 for results of changes in household cleaning behaviors and products).

Chapter 5

Did Temperature, Relative Humidity and Air Infiltration Improve After the Retrofit?

Indoor Climate at Sunnyslope Manor

Did Temperature, Relative Humidity and Air Infiltration Improve After the Retrofit? Indoor Climate at Sunnyslope Manor

As described in Chapter 2, each panel's indoor thermal data was collected in 15-minute intervals for five days, totaling 448 data points per apartment unit. Temperature data was recorded in three locations throughout the unit: kitchen, bedroom, and living area. Relative humidity (RH) was recorded only in the living room. Air infiltration was measured at a single point in each panel, in the bedroom balcony door. As described in Chapter 2, comparisons between panels (P1P2 and P1P3) were made using fixed effects regression models. In addressing potential mediating variables, three building factors (floor level, wing, orientation) and two personal/demographic factors (length of stay at SSM, age) were considered in these models as well.

5.1 Temperature

Six unique temperature measures were created from each panel's 448 data points: mean temperature (MEAN TEMP); minimum temperature data point recorded (MIN TEMP); maximum temperature data point recorded (MAX TEMP); thermal variability, or THERM VRB (as measured by standard deviation of the 448 data points); and counts of 15-minute interval data points exceeding 81°F (EXCEED 81). Data was also calculated for the number of data points falling below 68°F. However, of the total 63,168 recorded data points for all units and all three panels, only 160 points, or approximately 0.25%, fell below 68°F. Because of this extremely low occurrence, this measure is not included in the following discussion.

A Cronbach's alpha reliability test was used to establish that the three recorded temperatures from each unit were similar, yielding results over $\sigma = 0.9$. This allowed the temperatures from the kitchen, bedroom, and living area to be combined into one composite temperature (representing an entire unit) without compromising the validity of the data. Variables used for analyses include values derived from using the average values between the three spaces.

5.1.1 Short Term Effects

Table 5.1 shows that while mean, maximum, and minimum temperatures decreased from Panel 1 (P1) to Panel 2 (P2), these changes were not statistically significant. Thermal variability is marginally significant, decreasing from P1 to P2.

Table 5.1 Descriptive Statistics of Four Temperature Measures, and P1P2 Regression

Temperature Measure	Descriptive Variable	Temperatures [°F]			P1P2 Regression	
		Panel 1	Panel 2	Δ Between Panels	*t*-value	*p*-value
MEAN TEMP	Mean	78.82	78.53	-0.29	-0.629	n.s.
	S.D.	2.41	2.36			
	Range	73.24 – 83.86	71.82 – 83.93			
MIN TEMP	Mean	75.55	74.61	-0.94	-1.346	n.s.
	S.D.	3.32	3.97			
	Range	66.65 – 81.86	61.46 – 80.27			
MAX TEMP	Mean	82.51	82.76	0.26	0.356	n.s.
	S.D.	3.14	4.3			
	Range	76.7 –92.14	75.49 – 100.77			
THERM VRB	Mean	2.43	5.95	3.52	1.686	0.095
	S.D.	2.78 15.25				
	Range	0.33 – 13.15	0.1 – 104.38			

$n = 55$

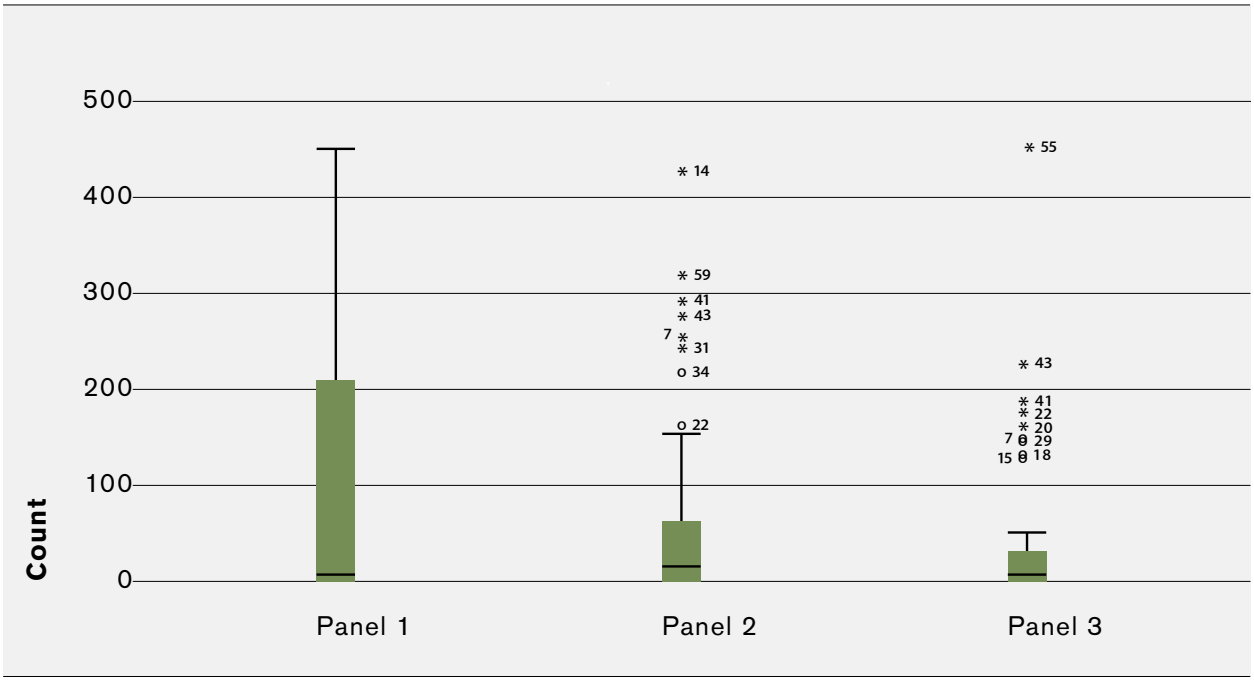
The mean (and standard deviation) of the number of times that apartment temperatures exceeded 81°F for P1 and P2 are shown in Table 5.2. While not statistically significant, we note that 23.81% of measured data points exceeded the ASHRAE threshold of 81°F in P1, and decreased to 18.31% in P2.

Table 5.2 EXCEED 81 at Panels 1 and 2

Descriptive Variable	Temperatures [°F]			% of Points Over 81°F per Unit		P1P2 Regression	
	Panel 1	Panel 2	Δ Between Panels	Panel 1	Panel 2	*t*-value	*p*-value
Mean	106.69	82.02	-24.67	23.81%	18.31%	-0.99	n.s.
S.D.	140.89	118.67	-22.22				
n = 55							

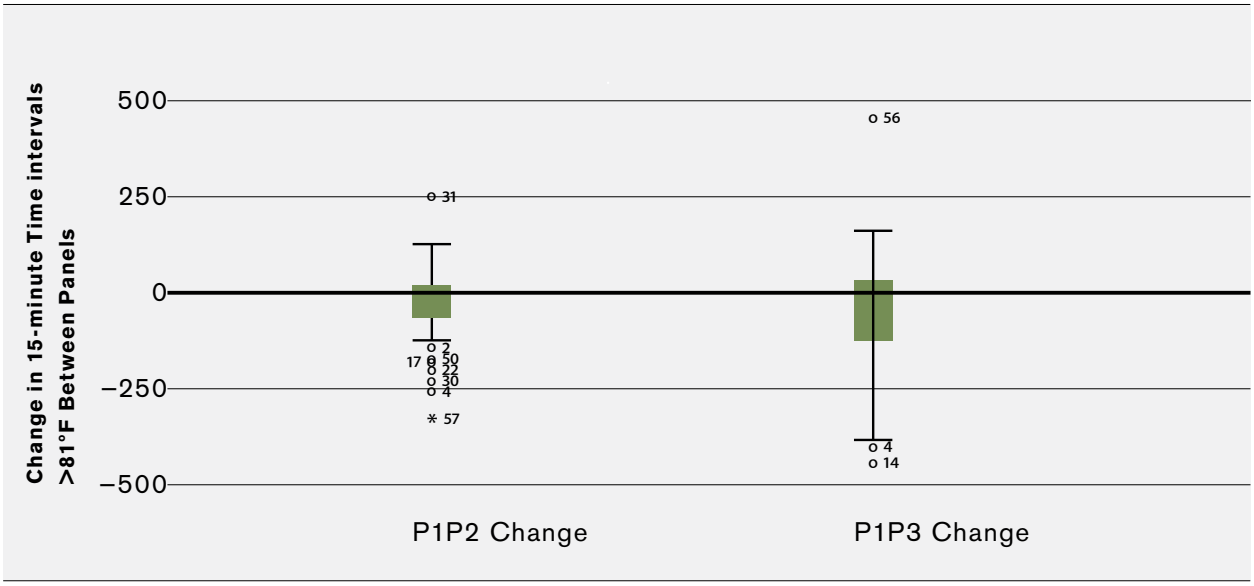
Figure 5.1 graphically depicts the changes between P1 and P2, using the sample of 47 units participating in all three panels. In Panel 1 the third quartile value is 209.8: that is, 75% of the units recorded less than 210 counts where the temperature exceeded 81°F. By Panel 2 the third quartile value had dropped to 60.8 counts or data points. In P2, eight units that exceed the fourth quartile value of 146 are noted as outliers.

Figure 5.1 Box Plot of EXCEED 81 Data in Each Panel (n = 47)



The magnitude of the changes of EXCEED 81 counts between panels is illustrated in Figure 5.2. Statistically between P1 and P2 there was no change, noted by the small distribution around the mean; however, there was a significant change observed in P1P3 (t = 2.36, p = .02), as can be seen by the wider distribution around the mean of P1P3.

Figure 5.2 Change Between Panels in Number of Temperature Data Points Exceeding 81°F (n = 47)



Building characteristics had a noticeable effect on temperature but little on P1P2 temperature change. MEAN TEMP is higher in upper floors (t = 2.068, p = 0.041) but did not affect P1P2 changes. Likewise, higher floors had more counts of EXCEED 81 ($t = 2.68$, $p = 0.009$), although no change from P1 to P2. However, when floor level was entered into the fixed effects model for P1P2, units in higher floors saw a greater reduction in MIN TEMP ($t = -2.282$, $p = 0.025$) and an increase in TEMP VRB ($t = 1.967$, $p = 0.052$). In addition, north-facing units had higher MAX TEMP and more EXCEED 81 counts than south-facing (MAX TEMP $t = 3.123$, $p = 0.036$; EXCEED 81 $t = 2.41$, $p = 0.018$) although there was no P1P2 change irrespective of N-S orientation. There were no temperature differences between east and west wing whatsoever.

In considering **resident characteristics**, there was no temperature difference for age. However, residents who had lived at SSM longer also had higher MEAN TEMP, MIN TEMP, MAX TEMP, and EXCEED 81 (Table 5.3). Interestingly, THERMAL VRB increased between P1 and P2 after controlling for resident's length of stay at SSM.

Table 5.3 Resident's Length of Stay at SSM on Temperature Variables

	MEAN TEMP		MIN TEMP		MAX TEMP		TERMAL VRB		EXCEED 81	
	t	*p*	*t*	*p*	*t*	*p*	*t*	*p*	*t*	*p*
Length of Stay	3.251	0.002	2.054	0.042	2.153	0.035	1.856	0.066	3.334	0.001

n = 55

5.1.1.1 Conclusions

With only thermal variability reporting a marginally statistically significant increase (see Table 5.1), indoor unit temperatures remain fairly constant between P1 and P2, suggesting that the renovation had little immediate effect on indoor temperatures. Yet when building characteristics are also considered in the P1P2 models as covariates, a few interesting patterns emerge. The data suggests localized thermal conditions are most prevalent in units located on the top floor and facing north where higher mean temperature and counts exceeding 81°F are more often recorded than in units elsewhere in the building.

Nevertheless, these patterns do not change between P1 and P2. Between P1 and P2, however, units located on higher floors experienced a larger drop in recorded minimum temperature as well as an increase in thermal variability than units located on lower floors.

These patterns might be explained by the increased exterior surface area of the roof that only top floor units have, as well as late afternoon direct solar gain that would only affect north-west-facing units. The third (top) floor units have nearly four times as much surface exposed to direct solar radiation than lower floor units, with the roof accounting for 76% of all exposed surface area on the third floor. The roof angle of solar incidence at solar noon during summer months is approximately 81° while south-facing walls receive solar radiation at only 19°. This greater incidence angle results in the roof being the most heat stressed surface of the building throughout the year. In addition to the stress placed on the roof by the sun, SSM is oriented at 21° NW which also exposes north-facing units to direct solar heat gains during the summer after 4:30 p.m. when the sun starts to set in the West. The combination of these elements may help explain why third floor units recorded higher temperatures, and in response the PTAC units may have cycled more frequently during the day to sustain preferred indoor temperatures, resulting in an increase of indoor thermal variability.

What is not clear is why temperatures in units occupied by residents who have lived at SSM longer than others have statistically significant higher mean, minimum, and maximum temperatures as well as recording more temperatures exceeding 81°F. Since thermal adaptability is a common occurrence among humans, it may be that residents who have lived in their SSM units for longer periods of time have reached a preferred thermal comfort level that is slightly higher than other residents. It may take years for some residents to find that level of adaptability, especially if they moved not only from a different apartment complex but also from a different geographic location and climate.

Finally, some of these observed relationships may be due in part to the renovation work that was continuing on other units and public spaces of SSM during Panel 2 data collection. How significant an impact this renovation work may have had on thermal conditions of the completed units in the short term is difficult to discern with the small sample size we have here.

5.1.2 Long Term Effects

Significant changes between Panel 1 and Panel 3 occurred for MEAN TEMP and MIN TEMP, and marginally so for THERMAL VRB (Table 5.4).

Table 5.4 Descriptive Statistics of Four Temperature Variables, and P1P3 Regression

Temperature Measure	Descriptive Variable	Temperatures [°F]			P1P3 Regression	
		Panel 1	Panel 3	Δ Between Panels	*t*-value	*p*-value
MEAN TEMP	Mean	78.66	77.67	0.99	-2.208	0.029
	S.D.	2.36	2.23			
	Range	73.24 – 83.86	72.94 – 83.37			
MIN TEMP	Mean	75.33	73.28	2.05	-1.952	0.054
	S.D.	3.31	6.83			
	Range	66.65 – 81.39	47.9 – 80.85			
MAX TEMP	Mean	82.19	82.86	-0.66	1.133	n.s.
	S.D.	2.7	3.25			
	Range	76.7 –89.02	78.1 – 91			
THERM VRB	Mean	2.4	3.55	-1.15	1.753	0.083
	S.D.	2.49	4.04			
	Range	0.33 – 13.15	0.08 – 16.67			

$n = 52$

Counts of 15-minute time intervals that exceeded ASHRAE Standard 55 threshold of 81°F (i.e. EXCEED 81) show a statistically significant decrease (Table 5.5). Examining the box plot of Figure 5.1, the third quartile value between P1 and P3 drops from 209.8 to 38.5. Nine apartment units show as outliers for P3, four of which were also outliers in P2. The mean decrease in EXCEED 81 counts between P1 and P3 equate to 13.7 fewer hours of apartment temperatures exceeding 81°F.

Table 5.5 EXCEED 81 at Panel 1 and Panel 3

Descriptive Variable	Temperatures [°F]			% of Points Over 81°F per Unit		P1P3 Regression	
	Panel 1	Panel 3	Δ Between Panels	Panel 1	Panel 3	*t*-value	*p*-value
Mean	95.35	43.18	52.17	21.28%	9.64%	-2.358	*0.020
S.D.	138.56	79.10		30.93%	17.66%		
$n = 52$							

When **Building Characteristics** were entered into the regression models, MEAN TEMP was significantly higher in units located on the upper floors ($t = 2.136$, $p = .035$); but these elevated temperatures did not significantly change the MEAN TEMP between panels at any floor level ($t = -1.518$, $p = .132$). MAX TEMP was also higher in upper floor units ($t = 2.187$, $p = .031$) than in units on lower floors, while the P1P3 decrease between panels in MAX TEMP was less in units located on higher floors ($t = -1.952$, $p = .054$). Fittingly, upper floors had more recordings where temperatures exceeded 81°F ($t = 2.806$, $p = .006$); and the decrease in EXCEED 81 values between Panel 1 and Panel 3 is larger on the upper floors ($t = -2.029$, $p = .045$).

North-south orientation made no difference in the P1P3 regression models, except for that of EXCEED 81. North-facing units not only had more counts of EXCEED 81 ($t = 1.891$, $p = .062$), but also a greater reduction from P1 to P3 ($t = -1.714$, $p = .09$).

The significant decreases in MEAN TEMP and in EXCEED 81 between P1P3 held after controlling for east-west wing.

In considering **Resident Characteristics**, resident age made no statistical difference. In contrast, MEAN TEMP and EXCEED 81 are significantly higher in units occupied by residents with longer stays at SSM ($t = 3.554$, $p = .001$; and $t = 4.729$, $p \leq .001$ respectively). A greater decrease in both of these temperature variables occurred between P1P3 in units with residents who have longer residency at SSM ($t = -2.903$, $p < .005$; and $t = -3.771$, $p < .001$ respectively). MIN TEMP is marginally higher in units occupied by people who have lived at SSM longer ($t = 1.694$, $p = .093$), but there is no change across P1P3 for length of stay. MAX TEMP is higher in units occupied by residents who have lived there longer ($t = 2.901$, $p < .005$), and also the P1P3 increase in MAX TEMP is marginally less for longer lengths of stay ($t = -1.676$, $p = .097$).

5.1.2.1 Conclusions

Between P1 and P3 several indicators suggest that indoor temperatures were positively influenced by the renovation work. The decreases noted in mean and minimum temperatures suggest that added roof insulation, roof primer, and Uni-Seal coat as well as increased air tightness of the building envelope may have contributed to improving control of indoor temperatures.

The number of instances where temperatures exceeded 81°F are also notably fewer than preceding panels, further indicating that renovations did have a positive impact on indoor temperatures by minimizing and stabilizing these temperature extremes (see Figures 5.1 and 5.2). The severity (i.e. distance from fourth quartile) of the outliers is smaller in Panel 3 compared to Panel 2. The outliers for Panel 3 might be partially explained by resident behavior: that is, some of the residents may have a personal preference for higher indoor temperatures, some may

change their thermostat settings as they leave their unit, or some residents may have left a door or window open for a prolonged period of time increasing air infiltration and indoor temperatures. The four apartments that were outliers in both P2 and P3 are more likely the result of resident behavior or preferences since relatively high counts of EXCEED 81 were recorded for these four units in all three panels. Unique outliers that occur in either panel but not both may more likely be explained by unique circumstances such as leaving a door open.

Curiously, thermal variability increased from Panel 1 to Panel 3; this pattern was marginally significant between P1 and P2. While the thermostat remained the same after the renovation, the new ceiling fan installed in the bedrooms, and new bathroom and kitchen exhaust fans, may have affected thermal variability, particularly as residents were becoming more accustomed to using them. At this time, we can not assess whether this thermal variability is either detrimental or desirable for the residents. As seen later in Chapter 7, residents are relatively satisfied with thermal comfort of their units at all three panels.

The localization of some higher temperature values observed in units on the top floor and those facing north-west is likely the result of additional surface area being exposed to the outdoor climate and fewer shading trees to protect the units from late afternoon solar gain, as discussed in Section 5.1.1. Units located on the ground and second floors only have one exposed surface to the summer heat (approximately 192ft^2), while third floor units have the added surface area from the roof, which in locations like Phoenix is the building surface that is the most stressed by solar heat gains.

5.2 Relative Humidity

Descriptive statistics for the two RH factors in our study (mean RH, RH variability) for units participating in both Panels 1 and 2, and for units participating in both Panel 1 and 3 are provided in Tables 5.6 and 5.7 respectively. Figure 5.3 displays data in box plots for those units participating in all three panels.

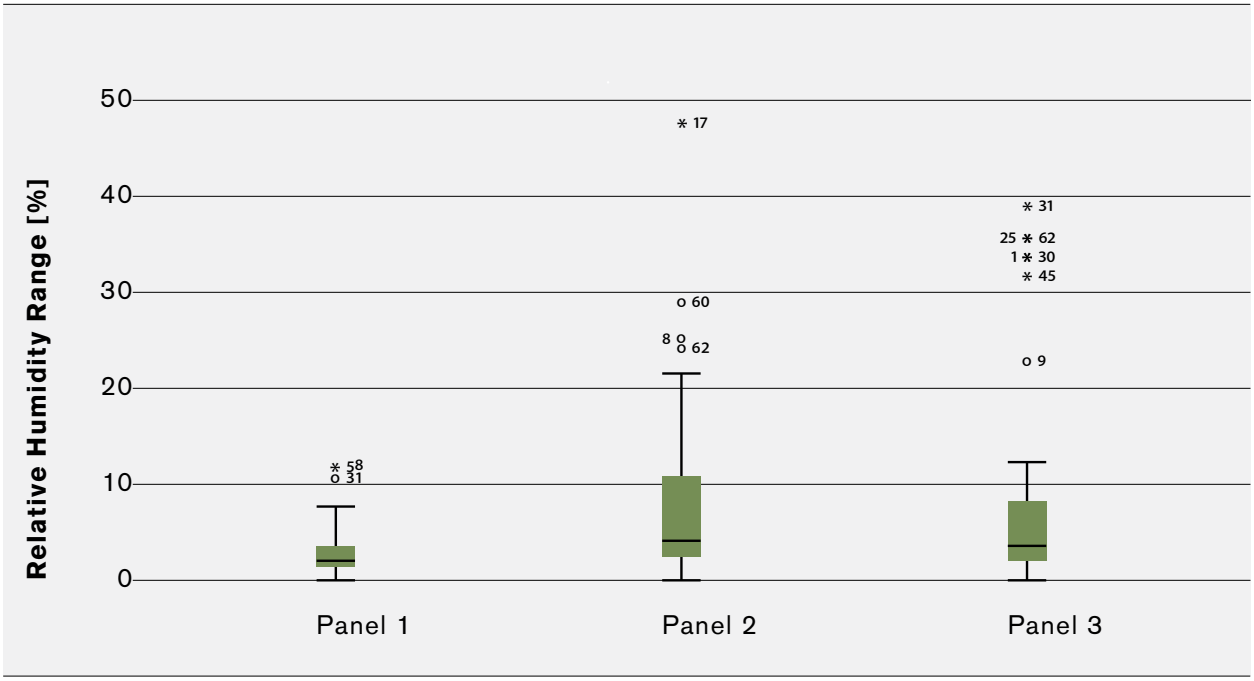
Table 5.6 RH Descriptives for Units Participating in Panels 1 and 2

Temperature Measure	Descriptive Variable	Panel 1	Panel 2	Δ Between Panels
MEAN TEMP	Mean	31.20	32.13	-0.93
	S.D.	3.86	7.91	
	Range	22.05 – 41.84	15.0 – 52.51	
MIN TEMP	Mean	3.87	8.36	-4.49
	S.D.	3.29	8.85	
	Range	0.62 – 20.96	0.00 – 45.47	
n = 55				

Table 5.7 RH Descriptives for Units Participating in Panels 1 and 3

Temperature Measure	Descriptive Variable	Panel 1	Panel 3	Δ Between Panels
MEAN TEMP	Mean	78.66	77.67	-0.99
	S.D.	2.36	2.23	
	Range	73.24 – 83.86	72.94 – 83.37	
MIN TEMP	Mean	2.4	3.55	-4.49
	S.D.	2.49	4.04	
	Range	0.33 – 13.15	0.08 – 16.67	
n = 52				

Figure 5.3 Box Plot of RH Data for Units Participating in All Three Panels (n = 47)



5.2.1 Short Term Effects

There was no change in mean RH between P1 and P2. However, with inclusion of building and personal covariates in the regression models, a statistically significant increase occurs for first floor units ($t = 3.672$, $p \leq 0.001$) while a statistically significant decrease occurs in third floor units ($t = -3.594$, $p = 0.000$).

Between the two panels, RH variability increases ($t = 3.528$, $p = 0.001$). This increase was significant even after controlling for building characteristics of Floor, Orientation, and Wing, as well as the personal characteristics of Age and Length of Stay at SSM.

5.2.2 Long Term Effects

Long term changes in relative humidity variability show similar results as those of short term effects described above. There was no change in mean RH, but there was a significant increase in RH variability between Panel 1 and Panel 3 ($t = 3.466$, $p = 0.001$). This increase in RH variability held after controlling for floor level ($t = 1.922$, $p = 0.058$) and wing ($t = 2.856$, $p = 0.005$), but not North-South orientation. The increase also held after controlling for resident's length of stay at SSM ($t = 2.153$, $p = 0.034$).

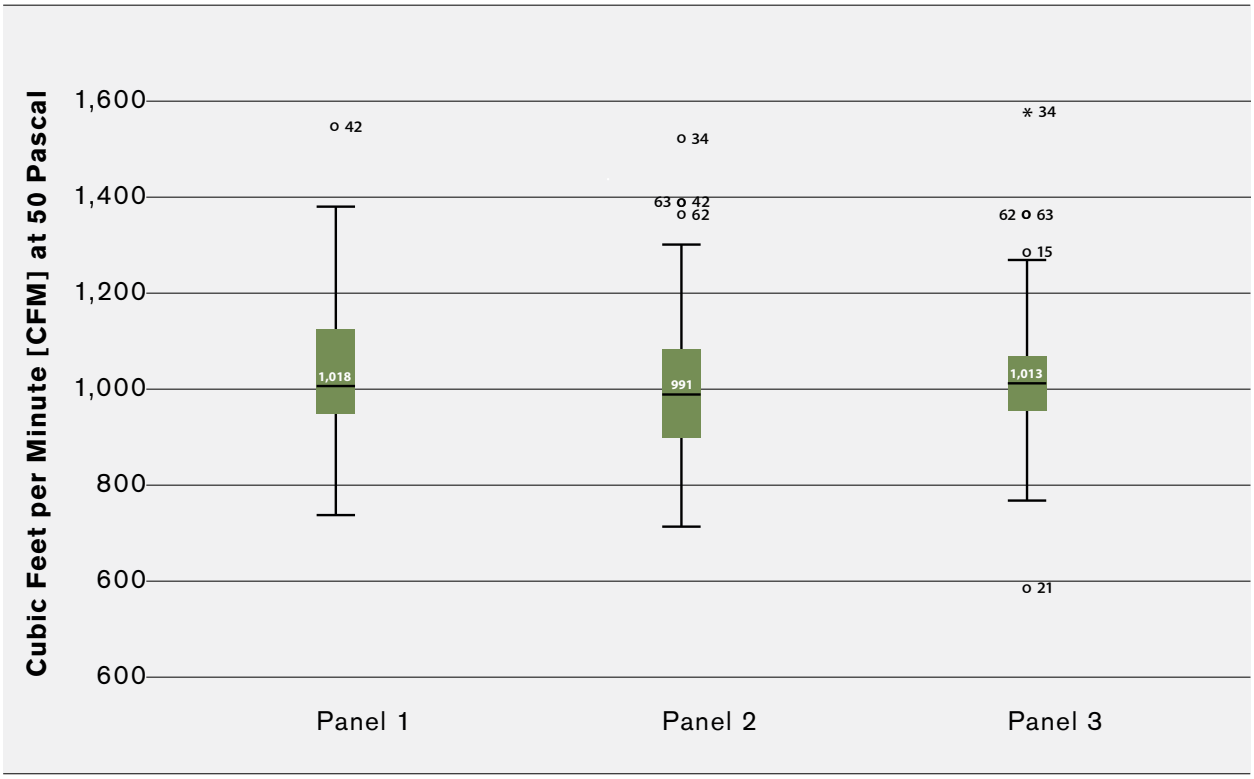
5.2.3 Conclusions

While mean relative humidity did not change in either Panel 2 or Panel 3, RH variability increased in both panels in relation to Panel 1. Why this occurs is unclear. However, as shown in Figure 5.3, the variability range within most units is not excessive and likely conducive to resident comfort and health (see Chapter 7 for further discussion on this).

5.3 Air Infiltration

Infiltration levels of each apartment unit were tested using a CFM50 blower door test (Cubic Feet per Minute force at 50 Pascals of pressure) to measure the airflow (in Cubic Feet per Minute) necessary in order to achieve an internal pressurize of 50 Pascals. Blower door equipment was located at the balcony door of the unit, while the apartment's door to the hallway was closed and the bathroom and kitchen fans covered. Results show a wide range of CFM50 levels in each panel (Figure 5.4).

Figure 5.4 Air Infiltration (CFM50) for Units Participating in All Three Panels (n = 47)



A level of 45 cfm under normal pressure is recommended by ASHRAE Standard-62.2 2013 for units between 501 ft² and 1000 ft². Units at Sunnyslope Manor are 619 ft². Calculated mean of all units' cfm levels for P1 were 49.01; for P2, 47.92; and for P3 45.81, the latter being the closest to ASHRAE recommended minimum infiltration level. However, although the mean CFM50 values from all three panels met minimum recommended infiltration standards, 23 units in P1, 24 units in P2, and 25 units in P3 recorded individual infiltration values below the minimum 984.50 CFM50 necessary for achieving an unpressurized 45cfm flow of outside air. These results show that just shy of half of the units tested have a flow of outside air that falls below ASHRAE recommended minimum levels indicating these envelopes may be too resistant to air infiltration.

5.3.1 Short and Long Term Effects

Surprisingly, there were no statistically significant changes in infiltration after the retrofit, either immediately (P1P2) or sustaining (P1P3). While units on the higher floors had greater air exchange than those on the lower ($t = 5.143$, $p < .001$ for P1P2 model; $t = 4.497$, $p < 001$ for P1P3), there was no effect of floor level on P1P2 or P1P3 changes. As with preceding results for temperature, a statistically significant relationship is noted between CFM50 and units occupied by residents who lived in SSM longer ($t = 2.952$, $p = .004$, and $t = 2.595$, $p = .011$ respectively); but again, no effects are noted on changes across panels.

5.3.2 Conclusions

Overall building air infiltration experienced no significant change after the retrofit, suggesting that renovation work had little or no impact on the air tightness of the building envelope, as measured by CFM50. This is not surprising considering that the existing windows and sliding doors that were in place prior to the retrofit were in relatively good condition and well sealed, so much so that the new windows and doors may show little effect on P2 and P3 CFM50 values. While the mean infiltration of all apartments met minimum ASHRAE 62.2 2013 standards of recommended infiltration of 45 cfm for units between 500 ft² to 1000 ft² at each panel, several units recorded infiltration levels below that value, indicating that those units are too tight by ASHRAE 62-2013 standards and could benefit from more outdoor air ventilation.

Since temperature is a primary driver of indoor environmental conditions, we would expect to see higher levels of infiltration occurring in units with wider temperature variability; in the case of SSM that would be units located on the upper floors where the units are more exposed to the elements due to larger surface area (roof) and reduced cover from trees and shrubs. When temperature increases, air infiltration likewise increases, as air gets thinner and more volatile, thus increasing air drafts.

Chapter 6

Did Reported Health Conditions Change After the Retrofit?

Did Reported Health Conditions Change After the Retrofit?

6. 1 A Note on Reformatting Health Questions Across Interview Panels

As described in Chapter 2, the GAP's Health at Home questionnaire was derived from questionnaire items on the 2010 NHIS and 2010 BRFSS surveys. Since these latter two are cross-sectional surveys and our study is a panel study with an intervention, several formatting changes were necessary. These changes were carefully crafted to ensure that the presence of chronic health conditions was not counted more than one time per resident; and that there was a clear indication of when diagnosis occurred in relation to the data collection periods.

Questions regarding presence/absence of chronic and specific health condition questions (e.g. heart condition, asthma) were asked in Panel 1 without a specific time frame (e.g. "Have you ever been told by a doctor or health professional that you had hypertension?"). For post-intervention interviews, these questions included time parameters, for example: "Since the renovation of your apartment, have you been newly diagnosed with any of the following illnesses, diseases, or other medical conditions?"

At Panel 1, general health conditions typically did not have a time frame or had a time frame of 30 days (e.g. "How would you say that your health is, in general?" and "How many days during the past 30 days was your physical health not good?"); and these were asked in the same form in subsequent panels.

While most of our health-related questions derived from the NHIS and BRFSS surveys, we added additional questions specific to the nature of our study that would help clarify residents' perceptions of home environmental influences on health conditions. For example, "Do you believe that your skin condition is probably related to something in your home?" was added as were others similar to this.

6.2 SSM Residents' Health Compared to State and National Samples

Before addressing our study hypotheses, we wanted to gauge how similar or dissimilar SSM residents' health conditions were to those of larger populations of low-income older adults. We compared the SSM health data to data from the same health items in the NHIS (national) and BFRSS (state of Arizona) surveys, using the same years of data collection (2010 and 2011) and selecting only those respondents who were at least 62 years of age and had individual annual incomes of less than $32,000 (which was the upper threshold for eligibility to live in Sunnyslope Manor) The sample sizes and gender distribution for the comparative populations are displayed in Table 6.1. Please note that in the BFRSS survey, some questions are asked of only a smaller sub-group; and this sub-group varies from question to question. Hence the sample size reported in the following tables for BRFSS typically reflects the sub-sample asked that question, not the total sample size reported in Table 6.1.

Table 6.1 Sample Size and Gender Counts of SSM, NHIS* and BRFSS* Survey Respondents

Survey	Sample Size	Male	Female
NHIS 2010	851	349	502
BRFSS 2010	18,722	5,897	12,825
SSM (P1, 2010)	65	20	45
NHIS 2011	1,053	432	621
BRFSS 2011	85,105	34,893	50,212
SSM (P2, 2011)	59	19	40
SSM (P3, 2012)	57	15	42

* Only for respondents over 62 years of age and under $32,000 annual individual income

Our original intent was to compare changes in health conditions between 2010 and 2012 – which correspond to Panel 1 and Panel 3 time periods – of our SSM residents with those of U.S. and Arizona low-income older adults. This would allow us to gauge whether the degree of change in health among SSM residents is reflective of the degree of change among low-income elderly at national and state levels. While not a valid proxy measure for assessing whether health changes among SSM residents are a result of the green retrofit, such comparisons can help identify whether something unique is happening to the SSM compared to Arizona or national samples over this time period that may warrant more systematic investigation for future research.

However, such statistical comparisons of health changes, or trends, over time are not possible here because 2012 NHIS and BFRSS survey results had not been released before the end of our study and final report deadline. We plan to undertake these analyses at a later time. At this time, we can simply gauge the extent to which SSM residents' reported health is reflective of state and national figures of low-income elderly at 2010 and 2011.

6.2.1 Chronic Health Conditions and General Health

Table 6.2 lists the chronic health conditions of SSM residents and NHIS and BRFSS subsamples for years 2010 and 2011. BRFSS does not measure all the same conditions as NHIS, but some core measures are the same. A look at the health conditions measured by both BRFSS and NHIS surveys suggests that for most of these healthy indicators, a larger proportion of Arizonans have chronic health conditions than Americans at large.

Table 6.2 Binominal Analysis of Percentage of Respondents Reporting Chronic Health Conditions, Between SSM Sample and NHIS/BRFSS Survey Respondents for 2010 and 2011

Chronic Condition	2010 SSM (P1)	BRFSS2010		NHIS2010		2011 SSM (P2)	BRFSS2011		NHIS2011		2012 SSM (P3)
	n = 65	*n* = 18,722		*n* = 851		*n* = 59	*n* = 85,105		*n* = 18,722		*n* = 57
		Proportion		Proportion			Proportion		Proportion		
			p-value		*p*-value			*p*-value		*p*-value	
	%	%		%		%	%		%		%
High blood pressure	70.3%			56.6%	.017	70.7%			56.1%	.016	66.7%
Coronary heart disease (CHD)	23.4%	13.9%	.029	10.0%	.001	20.7%	13.3%	.077	12.1%	.043	22.8%
Angina	7.8%	13.9%	.000	4.2%	.000	6.9%	13.3%	.000	5.5%	.000	8.8
Myocardial infarction (MI)	14.3%	14.2%	.000	5.8%	.000	13.8%	13.9%	.000	7.4%	.000	15.8%
Any heart condition	31.7%			15.3%	.001	36.2%			12.7%	.000	35.1%
Stroke	14.1%	9.7%	.000	3.4%	.000	10.3%	9.5%	.000	5.2%	.000	14.0%
Emphysema	7.7%			4.1%	.000	8.5%			2.7%	.000	7.0%
Asthma	9.2%	13.7%	.196	10.6%	.459	8.6%	13.1%	.212	10.8%	.393	10.5%
Diabetes	29.7%	23.5%	.000	17.5%	.000	28.8%	24.1%	.000	20.0%	.000	32.7%
Hay fever	25.0%			8.5%	.000	27.1%			7.9%	.000	24.6%
Sinusitis	38.7%			18.2%	.000	37.3%			16.4%	.000	42.1%
Chronic bronchitis	21.9%			7.5%	.000	23.7%			6.2%	.000	26.3%
Skin condition	33.8%			84.5%	.000	37.3%					33.3%
Anxiety disorder	21.9%	11.5%	.000			23.7%	13.2%	.000			23.2%
Depressive disorder	30.8%	16.1%	.002			30.5%	18.1%	.009			33.3%
Arthritis	64.6%	63.6%	.488	44.8%	.001	69.5%	55.8%	.022	44.1%	.000	70.2%
Headache	23.1%			9.6%	.000	28.8%			9.9%	.000	31.6%

Since the response sets for these questions were "yes/no," binominal analysis was undertaken in comparing SSM with Arizona and U.S. figures. As indicated in Table 6.2, the proportion of SSM residents reporting such conditions was significantly larger than expected for most health conditions in comparison with state or national figures; an exception is asthma in 2010. Noticeably large differences between SSM residents and state/national samples are for coronary heart disease, any heart condition, stroke, hay fever, sinusitis, chronic and bronchitis in both 2010 and 2011, for example.

SSM residents were asked about existing health conditions in Panel 1. Table 6.3 displays the number of residents who developed a chronic condition some time between the baseline data collection (i.e. P1) and Panel 3, or approximately one year following the renovation. While the increase is not statistically significant, some of the health conditions that increased may be influenced by reactions to airborne substances.

Table 6.3 Chronic Conditions That Developed During Study And Final Percentage Of SSM Residents With Condition At The Completion Of The Study

Chronic Condition	No. Residents who Acquired Condition Between P1 and P3 Data Collection	Percentage of SSM Residents With Condition at Completion of the Study
Any heart condition	2	32%
Sinusitis	2	42%
Chronic bronchitis	2	25%
Skin condition	3	42%
Anxiety disorder	1	23%
Arthritis	2	68%

6.2.2 Emotional Distress

Emotional distress is evaluated by questioning the prevalence of feeling. Six questions about the frequency of feelings (see Table 6.4) in the last 30 days were rated (all, most, some, little and none). The five-point response set was subsequently collapsed to three-point because few residents responded in the extreme. Table 6.4 displays the prevalence of emotional distress of SSM and national (NHIS) respondents in 2010 and 2011. For the most part, SSM residents experience symptoms of emotional distress more so than the national average; an exception is feeling worthless in 2011. (Statistics for Panel 3 SSM respondents are reported in Appendix 6.1.)

Table 6.4 Comparison of SSM and National (NHIS) Respondents on Prevalence of Feelings in Emotional Distress Subscales, for 2010 and 2011

Sample Source	*n*	Time Felt Feeling			X^2	*P*-value
		All / Most of the time	Some / Little of the time	None of the time		
So sad nothing could cheer you						
SSM2010 (P1)	65	9%	40%	51%		
NHIS 2010	850	2%	24%	74%	76.45	<.001
SSM2011 (P2)	59	5%	27%	68%		
NHIS 2011	1052	3%	24%	74%	108.97	<.001
Nervous						
SSM2010 (P1)	65	3%	55%	42%		
NHIS 2010	850	2%	29%	69%	7.49	.024
SSM2011(P2)	59	14%	29%	58%		
NHIS 2011	1052	4%	25%	72%	33.14	<.001
Restless and fidgety						
SSM2010 (P1)	65	9%	55%	35%		
NHIS 2010	850	4%	28%	68%	11.55	.003
SSM2011(P2)	58	16%	34%	50%		
NHIS 2011	1052	4%	25%	71%	38.56	<.001
Hopeless						
SSM2010 (P1)	65	11%	18%	71%		
NHIS 2010	850	1%	10%	89%	6.45	.040
SSM2011(P2)	58	16%	34%	50%		
NHIS 2011	1052	1%	9%	90%	8.21	.017
Everything is an effort						
SSM2010 (P1)	65	17%	40%	43%		
NHIS 2010	850	3%	18%	79%	9.29	.010
SSM2011(P2)	58	16%	45%	40%		
NHIS 2011	1052	4%	19%	77%	132.59	<.001
Worthless						
SSM2010 (P1)	65	8%	23%	69%		
NHIS 2010	850	1%	08%	91%	012.72	.002
SSM2011(P2)	57	4%	21%	75%		
NHIS 2011	1052	1%	8%	92%	3.09	.214

6.2.3 General Health and Sleep

The BRFSS asks several questions about general health; we used relevant questionnaire items from this survey. In most cases we grouped the response set into a smaller number of categories because of the low frequency of responses in the extremes. Treating these as ordinal scales, we conducted Mann Whitney U tests for comparing the Arizona and SSM samples; however, in displaying results in Tables 6.5 through 6.9 we show the descriptive statistics – such as relative frequency tables – as well as inferential statistics, such as Mann Whitney U, z value and p value. Data from the 2012 BRFSS was unavailable at the time of this report, so comparisons were only made for Panel 1 and Panel 2 time periods (2010, 2011). Statistics for SSM for 2012 are reported in Appendix 6.1.

On a five-point scale in response to a question about general health (see Table 6.5), there were no differences between Arizona and SSM respondents during the time periods of the first and second panels (2010, 2011).

Table 6.5 Comparison of SSM and Arizona (BFRSS) Respondents on Reported General Health, 2010, 2011

Sample	*n*	General Health					*U*-value	*Z*-value	*p*-value
		Excellent	Very Good	Good	Fair	Poor			
SSM 2010 (P1)	65	4.6%	16.9%	47.7%	23.1%	7.7%	2579781.5	-.332	.n.s
BRFSS (AZ) 2010	81,213	8.1%	22.7%	33.9%	23.3%	2%			
SSM 2011 (P2)	59	6.8%	22%	23.7%	37.3%	10.2%	2196036.5	-1.158	.n.s
BRFSS (AZ) 2011	84,624	8%	22.7%	34.1%	23.3%	11.8%			

However, in response to a more targeted question on how often they felt healthy and full of energy, significantly more Arizona (BRFSS) elderly respondents feel such "all" or "most of the time" than do SSM residents at the time of the first panel (Table 6.6). Similarly when asked about life satisfaction, SSM residents were generally less "very" satisfied than other low-income older adults in Arizona (Table 6.7). (Since the BRFSS did not ask these questions in 2011, we could not compare statewide figures with SSM ones for that year.)

Table 6.6 Comparison of SSM and Arizona (BFRSS) Respondents on Prevalence of Reported Feeling Healthy and Full of Energy, 2010 and 2011

Sample	*n*	Health and Full of Energy Responses			χ^2	*p*-value
		All / Most of the time	Some / Little of the time	None of the time		
SSM 2010 (P1)	65	43.1%	40%	16.9%	457.24	<.001
BRFSS (AZ) 2010	633	62.5%	16.2%	21.1%		
SSM 2011 (P2)	58	50%	44.8%	5.1%	n/a	n/a
BRFSS (AZ) 2011*	n/a	n/a	n/a	n/a		

*Question not asked in 2011 BRFSS survey

Table 6.7 Comparison of SSM and Arizona (BFRSS) Respondents for Satisfaction with Life, 2010 and 2011

	n	Satisfaction with Life				*U*-value	*Z*-value	*p*-value
		Very Satisfied	Satisfied	Dissatisfied	Very Dissatisfied			
SSM 2010 (P1)	65	18.5%	77%	4.6%	.002	2579781.5	-.332	.n.s
BRFSS (AZ) 2010	78,147	40%	54.5%	4.5%	1%			
SSM 2011 (P2)	59	32%	63%	3.5%	0%			
BRFSS (AZ) 2011*	–	n/avail	n/avail	n/avail	n/avail			

*Question not asked in 2011 BRFSS survey

Residents and BRFSS survey respondents reported the number of days in the last month when they were in poor physical health or fell asleep unintentionally. We grouped the responses to these questions that ranged from 0 to 30 days into four categories for comparison. For 2010 and 2011, SSM residents reported less days than Arizona respondents for these (Table 6.8).

Table 6.8 Comparison of SSM and Arizona (BFRSS) Respondents on Number of Days of Poor Physical Health in Last Month, and Number of Days of Unintentional Sleep in Last Month, for 2010 and 2011

			Reported Days						
		n size	0	1-7	8-23	24+	**U-value**	**Z-value**	**p-value**
Poor Physical Health	SSM 2010 (P1)	65	35.4%	32.3%	18.5%	10.8%	226672	-5.289	.000
	BRFSS (AZ) 2010	8,866	20.0%	37.6%	26.1%	16.4%			
	SSM 2011 (P2)	59	36.9%	24.6%	12.3%	13.8%	202551.5	-5.085	.000
	BRFSS (AZ) 2011	8,899	20.3%	38.0%	25.4%	16.2%			
Unintentional Sleep	SSM 2010 (P1)	65	46.2%	35.4%	12.3%	03.1%	030932	-6.431	.000
	BRFSS (AZ) 2010	1,529	17.9%	40.5%	25.2%	16.4%			
	SSM 2011 (P2)	59	23.1%	9.2%	12.3%	46.2%	012970.5	-4.943	.000
	BRFSS (AZ) 2011	609	21.8%	39.9%	21.2%	17.1%			

6.2.4 Functional Assessment and Pain

We also compared data from the functional assessment subscale of the NHIS 2010 survey with those of SSM residents (Table 6.9). (Because the response set in Panel 2 for SSM was different from the response set of NHIS, we do not make a comparison here with 2011 NHIS data.) SSM figures for 2011 and 2012 are reported in Appendix 6.1.

Table 6.9 Comparison of SSM and National (NHIS) Respondents on Functional Assessments, 2010

Variable /Data	*n*	Difficulty Level					*U*-value	*Z*-value	*p*-value
		No Difficulty	Little	Somewhat	Very	Don't Do Activity			
Walk 3 city blocks									
SSM 2010 (P1)	65	26%	18%	22%	14%	20%	12885	-8.638	.<001
NHIS 2010	825	74%	11%	7%	4%	4%			
Stand for 2 hours									
SSM2010 (P1)	65	18%	11%	17%	31%	23%	10691	-9.876	.<001
NHIS 2010	831	72%	10%	7%	4%	6%			
Sit for 2 hours									
SSM2010 (P1)	63	56%	19%	14%	8%	3%	18306.5	-6.490	.<001
NHIS 2010	842	86%	6%	4%	2%	1%			
Stoop, bend, kneel									
SSM2010 (P1)	63	24%	21%	32%	22%	2%	16853.5	-5.335	.<001
NHIS 2010	839	59%	15%	12%	7%	6%			
Reach over head									
SSM2010 (P1)	64	67%	8%	11%	13%	2%	21336.5	-4.606	.<001
NHIS 2010	844	87%	6%	3%	2%	1%			
Grasp handle small objects									
SSM2010 (P1)	65	72%	12%	9%	5%	2%	23515	-3.206	.001
NHIS 2010	847	87%	7%	5%	2%	%			
Carry 10 pounds									
SSM2010 (P1)	63	35%	16%	17%	24%	8%	12553.5	10.628	.<001
NHIS 2010	843	86%	4%	5%	3%	2%			
Push pull heavy objects									
SSM2010 (P1)	64	38%	13%	11%	23%	16%	14409	-8.329	.<001
NHIS 2010	834	80%	9%	5%	2%	5%			

In all eight aspects of functional limitations, SSM report more difficulty than the national sample of low-income older adults. Additional questions regarding pain in neck, lower back and limitations due to arthritis (see Table 6.10) suggest that pain in these areas may contribute to the greater limitations of SSM residents. The prevalence of low back pain is particularly high in Panels 1 and 2.

Table 6.10 Binomial Analysis Comparing SSM and National (NHIS) Samples on Reported Pain in Last 3 Months, in 2010 and 2011

Chronic Condition	2010 SSM (P1) *n= 65*	NHIS *n = 851*		2011 SSM (P2) *n = 59*	NHIS *n = 1053*		2012 SSM (P3) *n = 57*
	%	Test Proportion %	*p*-value	%	Test Proportion %	*p*-value	%
Arthritis Limits Activity	41.5	33.2	n.s.	44.1	29.9	0.015	35.1
Pain In Neck	32.3	15.5	<.001	18.6	17.9	<.001	15.8
Pain In Lower Back	65.6	29.2	<.001	64.6	30.3	<.001	39

6.2.5 Summary of Comparison

In summary, SSM residents were more likely that State or national samples of older, low-income adults to experience chronic health conditions (except asthma) and feelings that contribute to emotional distress. While SSM residents' reports of general health are similar to those of national respondents, their reports of healthy/energy, life satisfaction, and days of poor health and

unintentional sleep are significantly lower than their Arizona compatriots. Comparatively, SSM residents have more functional challenges with weight-bearing activities and have higher incidence of pain in the lower back and neck than the national older adult respondents. Unfortunately at the time of this report, we were unable to undertake our major purpose for comparing our sample's health conditions with those of national and state survey respondents – to examine whether health changes over time (2 years) among SSM residents follow similar patterns of health change of national and Arizona survey respondents. We intend to do so in future reports.

6.3 Key Health Conditions

After comparing the prevalence of health conditions of residents at SSM with those in the BRFSS and NHIS surveys, we focused our analyses on those health conditions most susceptible or responsive to the green retrofit changes, namely: **respiratory conditions, emotional distress, general quality of health/life,** and **fall incidence**. We also considered functional limitations important, given the extensive remodel of the kitchen and bathroom that might facilitate reaching, grasping, kneeling and other movement difficulties. However, analyses for changes in functional limitations between panels were not available at the time of this report.

Given that each of these health conditions encompasses several questionnaire items, we initially considered performing a factor analysis to group them into factors. However, since our sample size was too small for factor analysis technique, we used subscales and compilation of related variables from the *Health at Home* questionnaire items. Table 6.11 displays health measures that were constructed from the compilation of key health condition items in the questionnaire. Given the measurement nature of the questionnaire item (i.e. nominal, ordinal, interval), compilations were made either by counting the number of positive occurrences (e.g. counting the number of "yes" responses) or by summing the responses. Subsequently, either ordinal regression or binary logistic regression was used in assessing changes between Panels 1 and 2 (i.e. P1P2), and Panels 1 and 3 (i.e. P1P3). Given the exploratory nature of this study and small sample size, we use $p < .10$ as an indicator of potential statistical significance.

Table 6.11 Key Health Measures Constructed from Individual Questionnaire Items

Health Measure	Method of Construction and Individual Health Items	Health at Home Survey Questionnaire Item of Panel 3
Emotional Distress* (3)	sad, nervous, restless/fidgety, hopeless, everything is an effort, and worthless (response set 1-5)*	49-54
Low Life	Sum individual scores on above 6 measures (interval scale)	
Count Low Life	Count number of instances where response is 1, 2 or 3 on each six measure above (Interval scale)	
Any Low Life	If score is >0 on any of the six measures (dichotomous)	
Respiratory Conditions	snore, asthma, emphysema, hay fever, sinusitis, bronchitis (response set: yes/no)	19, 32, 33, 36-38
	If positive response on any of the above measures (dichotomous)	
Quality of Health/Life	general health, satisfaction, feel healthy and full of energy (response set 1-5)	12, 15, 48
	Sum of scores of above 3 measures (interval)	
Falls	Falls in home , falls at Sunnyslope Manor	73
	If positive response of any of the above measures (dichotomous)	
Functional Limitations^ (3)	Walk a quarter of a mile, walk up 10 steps, stand or be on your feet for 2 hours, sit for 2 hours, stoop, bend or kneel, reach up over your head, grasp small objects, lift or carry 10 pounds, push or pull large objects (response set 1-4)	60-68
Activity Problems	Sum individual scores on all above measures	
Activity is Difficult	Count number of instances where response is 4 on scale	
Activity At Least Somewhat Difficult	Count number of instances where responses are 2, 3, or 4 on scale	

* Valid and reliable Emotional Distress subscale, also used by NHIS, is from Pilkonis and colleagues, 2011

^ Valid and reliable Functional Assessment subscale, also used by NHIS, is from Rose and colleagues, 2008

In this section of the report, data was examined for: (1) changes in key health conditions between P1P2 and P1P3; (2) intercorrelations of emotional distress with other health conditions, given that emotional distress was noticeably high in the SSM sample (particularly at the baseline panel) and because it was the one health condition with significant changes over time; and (3) relationship between health measures and residents' perceptions of their home environment, at each panel.

6.3.1. Short Term Changes

In analyzing ***P1P2 changes in the health variables*** listed in Table 6.11, only AnyLowLife (a binary measure of presence of any emotional distress) showed a change, and this was marginally so (Wald = 2.606, p = .10) and reflected an increase.

When we examined ***inter-relationships between emotional distress and other health measures*** at Panel 1, we did find emotional distress (as measured by LowLife, see Table 6.12) significantly correlated with all functional limitations ($r^{=}$.35, p = .004) and quality of health/life ($r^{=}$**–.48** p<0.001). In Panel 2, LowLife was correlated once again with quality of health/life ($r^{=}$.39, p = .002) but not functional limitations. There were no significant relationships between emotional distress and any of the respiratory measures.

We also asked residents if they thought their ***home environment may have contributed to their health conditions***. An ordinal regression was performed on a survey item that asked, "How much did the home environment contribute to emotional distress feelings (sadness, nervousness, restlessness, hopelessness, worthlessness and that everything was an effort)?" The residents reported significant increase (Wald = 11.918, p = .001; -1.627 to -.557 95% CI) in the contribution of the home to feelings of emotional distress, from P1 to P2 .

We also analyzed the relationship between the ***health measures and residents' environmental perceptions of their home***. At Panel 1, correlations between LowLife emotional distress score and environmental perceptions indicated an emerging relationship, particularly that of satisfaction with kitchen air quality ($r^{=}$.33, p = .008) and satisfaction with visual comfort ($r^{=}$.30, p = .018); but not satisfaction with kitchen lighting, satisfaction with kitchen temperature, or extent to which lighting affected comfort. At Panel 2, none of these reached statistical significance.

When asked if they had ***fallen*** within the last three months (at Panel 1 and Panel 3) or since the renovation (at Panel 2), sixteen residents at P1, five at P2, and twelve at P3 reported falling. Some of these residents reported falling multiple times within the same time period. The total number of falls was 21 at Panel 1, 11 at Panel 2, and 20 at Panel 3. When asked whether the fall resulted in an injury that limited regular activities for at least a day or the resident had to see the doctor, 31% of those reporting a fall at P1 said it had resulted in such an injury, 40% at Panel 2, and 50% at Panel 3.

While the time frame for this question about falls differed at Panel 2, we considered it compatible with that asked at P1 and P3 since the typical time from renovation of one's unit to P2 data collection was three months. Falls are described in more detail in the following section on long-term changes and in Chapter 8.

6.3.2 Long Term Changes

Between Panel 1 and Panel 3, no ***key health conditions*** changed except for emotional distress; and for this, reductions occurred in all three measures as shown in Table 6.12.

Table 6.12 Descriptive Statistics of Emotional Distress, and P1P3 Regression

Emotional Measure	Descriptive Variable	Value		P1P3 Regression	
		Panel 1	Panel 3	*t*-value	*p*-value
LowLife	Mean	11.28	9.28	-2.540	0.012
	S.D.	4.25	3.90		
CountLowLife	Mean	1.74	0.89	-2.717	0.007
	S. D.	1.80	1.57		
AnyLowLife	Mean	0.66	0.35	Wald	<0.001
	S.D.	0.48	0.481	15.284	

n=57

Questions in Panel 3 also asked residents if any of the following conditions had improved or worsened since the renovation: sleep, hypertension, coronary heart disease, angina, heart attack, other heart condition, stroke, emphysema, asthma, diabetes, hay fever, sinusitis, allergy, chronic bronchitis, other respiratory conditions cancer depressive disorders, arthritis. Of these 18% of residents noticed an improvement in their sleep following the renovation and 16% believed their allergies to be worse since the renovation. However, there were no significant P1P3 statistical results to support these residents' beliefs at panel 3.

In examining ***relationships between emotional distress and other key health conditions*** at Panel 3, emotional distress (as measured by LowLife) was correlated significantly with times fallen ($r^{=}=0.362$, $p<0.001$), all functional limitations ($r^{=}.401$, $p = .002$) and quality of health/life ($r^{=}.0551$, $p < .001$). There were no significant relationships between emotional distress and any of the respiratory measures.

As we did in Panel 2 interview, we also asked residents if they thought their ***home environment may have contributed to their health conditions***. Residents reported a decrease (Wald = 16.155, $p<.001$; 1.0275 to 2.451 95% CI) in the contribution of the home environment to emotional distress.

We did discover significant inverse correlations between ***emotional distress and perceptions of the environment*** in Panel 3 (Table 6.13). In Panel 3, residents continued to demonstrate a significant positive relationship between emotional distress (LowLife) and functional limitations ($r^{=}.40$, $p<0.01$) as they did in Panel 1. Emotional distress also continued to have significant inverse relationships with perceptions of their home environment; however satisfaction with kitchen lighting ($r^{=}-.33$, $p<0.01$) and extent to which lighting interfered/enhanced with their comfort ($r^{=}-.34$, $p<0.01$) were not significant in Panel 1, were significant in Panel 3.

Table 6.13 Correlations of Emotional Distress (LowLife) with Functional Limitations and Environmental Perceptions in Panel 3

	Functional Limitations		Satisfaction with Kitchen lighting		Satisfaction with Kitchen Temperature		Satisfaction with Kitchen Air Quality		Lighting Interferes or Enhances		Satisfaction with Visual Comfort		Quality of Life	
	r	p	r	p	r	p	r	p	r	p	r	p	r	p
Emotional Distress	0.40	<0.01	-0.33	0.01	-0.33	0.01	-0.41	<0.01	-0.34	0.01	-0.46	<0.01	-0.55	<0.01

To further examine these simple correlations between lighting and emotional distress, we used a linear regression model (see Table 6.14) to analyze the predictability of lighting perceptions on Emotional Distress (LowLife) at each panel. Four variables (satisfaction with light in unit; satisfaction with visual comfort in unit; lighting quality interfere or enhance comfort; satisfaction with kitchen lighting) were entered into the model. The predictability of lighting was significant in Panel 1 ($p=.032$) and Panel 3 ($p<.001$). The beta values for each independent variable in the model in P1 and P3 had a similar relationship with the dependent variable, Emotional Distress, except for one item (How satisfied are you with the amount of light in your unit?). The model in P2 was different and not significant.

Table 6.14 Linear Regression of Four Perceived Lighting Items on Resident's Emotional Distress, at Each Panel

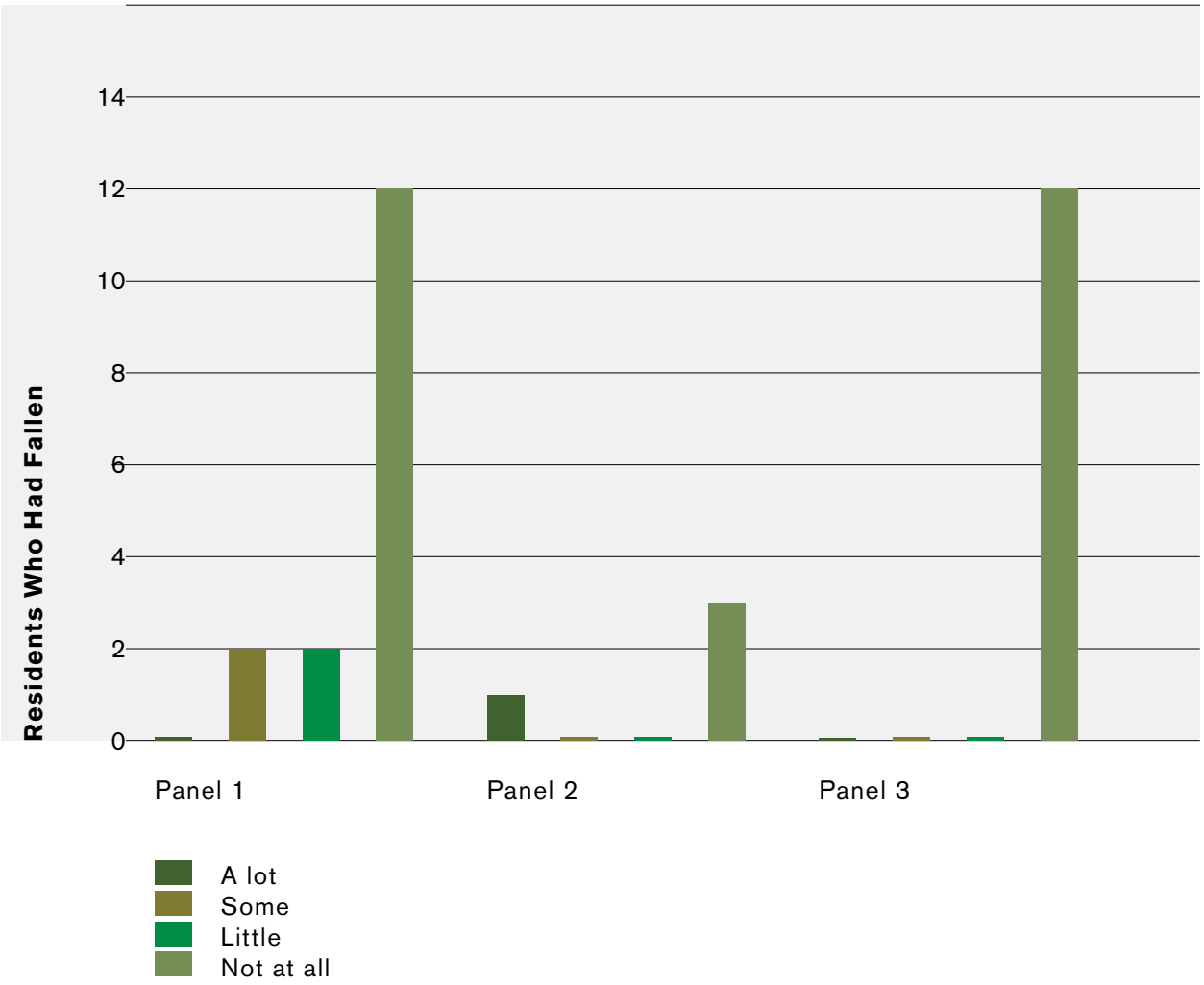
Predictive Items		**P1**	**P2**	**P3**
How satisfied are you with the amount of light in your unit?	ß	.223	-.234	-.304
How satisfied are you with the visual comfort of the lighting (glare, reflections, contrast)?	ß	-.591	.144	-.411
Overall, does the lighting quality in your unit enhance or interfere with your comfort?	ß	.133	-.077	.186
How satisfied are you with the following aspects of your kitchen? Lighting	ß	-.109	.018	-.197
	Model significance	.032	.749	<.001
	F value	2.841	.481	8.187

Note: Response set for all lighting perception items range from 1 to 7

In examining **falls** across panels, we first looked to see if specific individuals had a tendency of falling repeatedly across the two years of our study. One resident reported a fall at each panel. Nine residents reported falls at two panel interviews (two at both P1 and P2; four at both P1 and P3; three at both P2 and P3). Twenty-six residents reported a fall at only one panel interview.

We asked individuals who had reported the extent to which they believed that their home environment contributed to their fall (see Figure 6.1). In general, very few believe that something in their home led to the fall.

Figure 6.1 Extent Home Environment Contributed to Fall, as Reported by Residents Who Had Fallen in Home at Panel 3



In Panel 3 we asked additional questions about the location of the fall. Of the 20 falls reported at Panel 3, twelve were in their apartment. Table 6.15 lists the most common rooms where falls occurred in the home. Other areas at Sunnyslope Manor where falls occurred included back door from the lounge to the patio, the parking lot, the terrace, and the west gate to the property.

Table 6.15 Rooms Where Falls Occurred, as Reported at Panel 3

Room in Apartment	# of Falls
Bedroom	5
Living Room	3
Bathroom	2
Kitchen	2

6.4. Correspondence Between Changed Health and Changed IEQ

Chapters 4 and 5 identified indoor environmental quality measures that demonstrated significant changes between baseline (P1) and subsequent measures after the retrofit, both short-term (i.e. approximately 3 months after the retrofit, or P2), and longer-term (i.e. approximately a year after the retrofit, or P3). The question arose whether significant IEQ improvements in a unit also resulted in significant reported health changes.

In pursuing this question, we chose two IEQ measures that demonstrated some of the most dramatic changes: formaldehyde in the unit, and how often unit temperatures exceeded ASHRAE standard of 81°F. Using fixed effect regression, we examined whether the changes between P1 and P2, and between P1 and P3, contributed to resident changes in reported health (over the same time period). For the latter we chose to examine a general health indicator (quality of life/health) and emotional distress which showed changes over time P1P2 and particularly P1P3, as described in earlier sections of this chapter. We also examined the average number of hours of sleep (per day) that residents reported. Table 6.16 reports these results.

Table 6.16 Regression of IEQ Change on Change in Reported Health, for P1P2 and P1P3

	Between P1 and P2						**Between P1 and P3**					
	Quality of Health/Life		**Emotional Distress**		**# Hours Sleep**		**Quality of Health/Life**		**Emotional Distress**		**# Hours Sleep**	
	t	p value	t	p value	t	p value	t	p value	t	p value	t	p value
Exceed 81	.019	n.s.	-.036	n.s.	-.515	n.s.	3.179	.002	-2.085	.039	2.150	.034
Formaldehyde in Unit	2.624	.014	-3.912	<.001	.696	n.s.	1.275	n.s.	-1.781	.078	.410	n.s.

Changes in how often the apartment was quite hot (i.e. over 81°F) had no effect on these reported health conditions in the short term. On the other hand, over the longer term (i.e. between P1 and P3) the changes in a unit's degree of extensive temperatures also resulted in reports of improved quality health/life, reduced emotional distress, and increased number of hours sleeping.

Changes in the apartment's formaldehyde concentrations also contributed to changed health conditions, but more so in the short term than long term. Between Panels 1 and 2, changes in formaldehyde concentrations contributed to resident's reported quality of life/health and reduction in emotional distress. Between Panel 1 and 3, this formaldehyde change contributed only to reduction in emotional distress score.

6.5 Summary and Explanation of Results

The small sample size and relatively short study period presented challenges for detecting changes in chronic health conditions. However, our results show that SSM residents reported less emotional distress between Panels 1 and 3, one year after the renovation. What might be the source of this change, and why did this not appear between Panels 1 and 2? One explanation may be the lighting. At Panel 3 we found several significant correlations between emotional distress and residents' perceptions of the lighting of their apartments. In the renovation, lighting fixtures and light bulbs in the bedroom, kitchen and bathroom were replaced, as well as windows (although same size). Also, approximately three feet of the wall separating the kitchen and living room was removed to install a desk system with overhead cabinetry. Walls were repainted in the same neutral white hue, and new flooring installed (the kitchen flooring was darker in the renovation). It may be that the apartments were brighter (or at least appeared to be to the residents) and allowed more natural lighting to permeate into the living space, particularly part of the kitchen. At each panel, all lighting perception variables are shown to be significant predictors of emotional distress. As perceived lighting quality rises, so does the emotional status of the residents.

Since we did not take objective lighting measures, we cannot be sure that these patterns between perceptions and emotional status are the result of lighting levels per se. Nor do we know the actual basis for residents' perceptions of lighting quality: it may correspond to actual higher levels of natural or artificial light. But it may also be a reflection of having a cleaner or cleaner-looking apartment, or the quality of the reflective surfaces. Some of these issues are explored further in Chapter 7 particularly as they pertain to perceived air quality.

Three months following the renovation of their units (Panel 2), a significant number of residents reported that they believed the home contributed to their emotional distress feelings. Once the residents were settled in (Panel 3), the environment was perceived to be less of a contribution to those feelings. Emotional distress from disruptions related to the construction and upheaval of renovations is likely. The nature of the renovation "move" process, as described in Chapter 2 where residents were shuffled back-and-forth into their apartment each night while their unit was being renovated, may have contributed to heightened feelings of emotional distress as suggested in several residents' responses during Panel 2 interviews when asked what features of their newly renovated apartment they were particularly displeased with.

However, we also found that changes in formaldehyde concentrations and excessive temperatures in a resident's apartment also contributed to reports of reduced emotional distress over time. A better gauge of the relative contribution of these IEQ changes to residents' emotional distress requires more sophisticated models with relevant covariates. Because of the small size of our sample, we were unable to develop these more sophisticated models. However, the results here suggest viable avenues for future research with larger sample sizes.

We recognize that finding significant health changes as a result of the retrofit in this study were limited because of the short time frame of the study as well as the nature of many of the questions posed. Our decision to extract questions from national surveys was made so as to compare health changes of Sunnyslope Manor residents with those of national and state populations. However, many of these questions asked simply whether or not the respondent had the condition (dichotomous response set). Questions asking the extent of the condition (on ordinal or interval-level scales) may have been more relevant in examining changed conditions of individuals (e.g. a resident may still have had a respiratory condition at Panel 1 and Panel 3, but the severity of the condition could have changed, which could have been assessed with a scaled response set instead of a dichotomous one).

Nonetheless it is important to note that there was a larger rate of health problems among Sunnyslope Manor residents than witnessed in the national or state surveys. We could not undertake comparative analyses on changes in health conditions over time until the 2012 national and state figures are released. This type of analysis – which we plan for the future – will enable us to assess whether trends or patterns in health changes over a two-year period of SSM residents are consistent or not with those noted in national and Arizona samples of low-income older adults.

Chapter 7

Did Resident Perceptions and Behaviors Change After the Retrofit?

Did Resident Perceptions and Behaviors Change After the Retrofit?

We asked Sunnyslope Manor (SSM) residents several questions about their perceptions and assessments of their apartments (Appendix 2.4). Some of these were general, open-ended questions (e.g. *Overall, what features or changes in your new renovated home are you most pleased with*?); others were scale items targeting specific environmental quality or physical features (e.g. *Does the air quality in your unit enhance or interfere with your sleep*? with a 7-point response set). We also asked about household behaviors relevant to maintaining cleanliness in the home (e.g. *I'd like to know what kind of cleaning solutions you use to clean the kitchen*?); these were both open-ended and scale items.

During the interview, responses to the open-ended questions were entered into the CATI system. Afterwards, two research assistants individually examined the responses to each open-ended question and categorized them. Category schemes of each assistant were quite similar (in part because of limited variation in residents' responses). For most open-ended questions, two levels of categories were created to characterize responses: (1) item-level features or aspects (e.g. kitchen knobs, refrigerator, new ceiling fan), that could be clustered into (2) room or environmental quality level (e.g. kitchen-based changes, lighting quality improvements). Some responses were directly of the latter type itself (e.g. "everything about the kitchen," or "the whole place is brighter"). Frequencies were calculated on the latter type, based on the number of residents who made a response that reflected that type; word clouds were created to reflect relative responses of the item-level features.

This chapter reports residents' statements about the features most liked and disliked in their renovated apartments. It also examines short-term and long-term changes in perceptions, and in household cleaning and climate-control behaviors. Finally, it examines the correspondence of actual changes in indoor air quality – as reported in Chapters 4 and 5 – with residents' perceptions.

7.1 Liked and Disliked Features of the Renovated Apartments

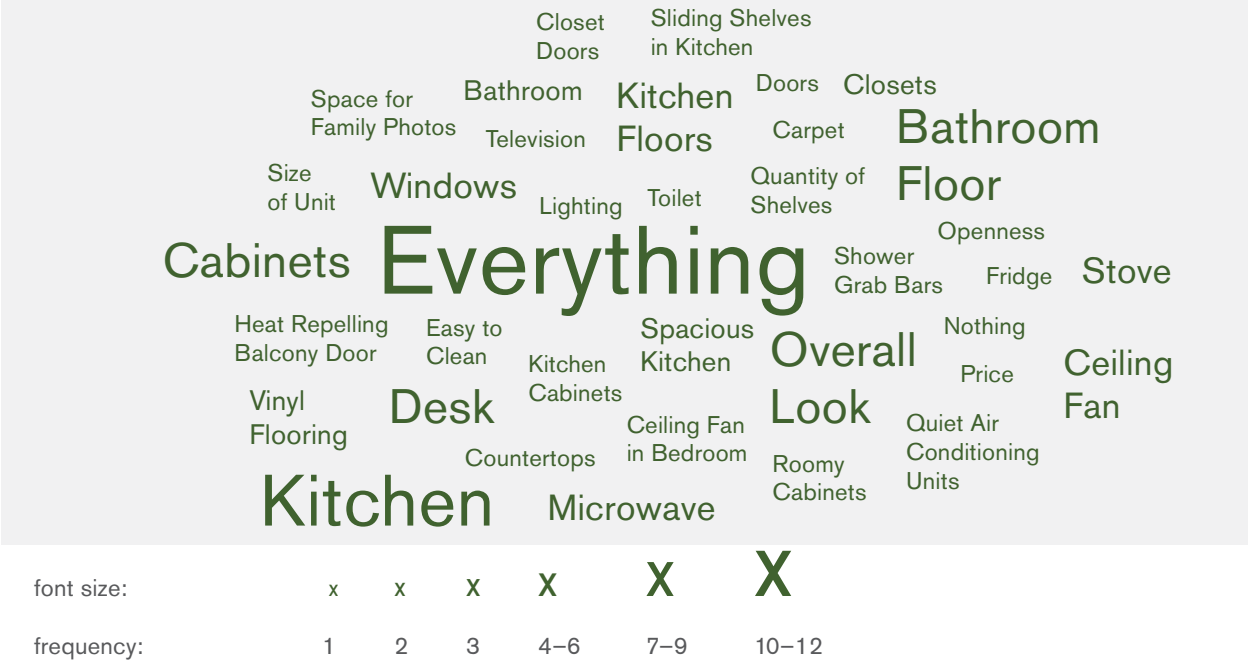
As mentioned in Chapter 6, we asked residents, "***To what extent did the renovation of your home affect your emotions overall?*** *Would you say your feelings and emotions are (1) much better, (2) somewhat better, (3) the same, (4) somewhat worse, or (5) much worse."* We then asked them, ***"What aspects or features of the renovation made you feel that way?"***

In Panel 3, 75% answered "much better" or "somewhat better" when asked how the renovation affected their emotions. In the follow-up question, residents could name as many features as they wanted. Of those who said the renovation affected their emotions much or somewhat better, nearly half (51%) of the respondents mentioned specific features of the renovation such as cabinets, stove, desk, and the like. Over a third (37%) mentioned ambient qualities, such as the renovation made the unit cleaner, brighter, or more open. There were also many (23%) who responded favorably to the kitchen renovation in its entirety as making them feel better. One-fifth (21%) of respondents mentioned the floors, and the same percentage also mentioned a general "Overall" or "Everything" response.

Among the six people who said the renovation made them feel worse or somewhat worse, they responded that the cause was: more bugs, noisier, carpeting, and the kitchen as a whole.

We also residents, ***"Overall, what features in your home are you MOST pleased with?*** *Please name as many as you want*." In Panel 3, nearly all (97%) respondents mentioned at least one feature. Over half (56%) of the residents mentioned individual features. One-quarter of the residents said they were pleased with the renovation overall. One-fifth mentioned the unit being cleaner, brighter, or feeling more open. Thirteen percent said they were pleased with the kitchen as a whole. The word cloud in Figure 7.1 illustrates specific responses to this question; the size of the word (i.e feature or quality) represents the relative proportion of residents stating this as an aspect of the renovation that pleased them.

Figure 7.1 Word Cloud of Home Features Most Liked



When asked in Panel 3, ***"Overall what features in your home are you DISPLEASED with?*** *Please name as many as you want,"* 91% of residents mentioned at least one thing. Most prominently, 40% mentioned specific features of the kitchen. Several residents (17%) mentioned something that was lacking: no knobs on kitchen cabinetry; no bathtub, only a shower; lack of lights in certain areas. One respondent was displeased with the kitchen as a whole. The word cloud in Figure 7.2 illustrates the various responses to this question; the size of the word represents the relative proportion of residents stating this as an aspect of the renovation that displeased them.

Figure 7.2 Word Cloud of Home Features Most Disliked

For both the displeased and pleased open-ended responses, the kitchen — overall or specific features — represented a large proportion of the responses. This was perhaps not surprising since the kitchen was the site of most major changes to the apartment.

7.2 Changed Perceptions of Environmental Quality

In examining changed perceptions of the environmental quality of their homes between Panels 1 and 2 (P1P2), and between Panels 1 and 3 (P1P3), three specific aspects were considered: (1) temperature; (2) air quality; (3) lighting.

Four questions addressed different aspects of perceived temperature or thermal comfort of their homes: (1) satisfaction with temperature in the unit; (2) satisfaction with temperature conditions in the kitchen; (3) satisfaction with effectiveness of the thermostats; (4) extent to which thermal condition in the unit enhances or interferes with one's comfort. All of these (as well as those regarding air quality and lighting) were seven-point response sets and treated as ordinal scale. Ordinal regression analysis was used to examine changes in a resident's response between the panels. Because of lack of response on lower end of the response sets, the 7-point scales were converted into four-point scales (1, 2 and 3; 4 and 5; 6; 7). The link function used is logit so the models are ordered logit models.

There were no changes in residents' perceptions of thermal comfort on any of the four items between Panels 1 and 2. Residents did report greater satisfaction with the effectiveness of the thermostats between Panels 1 and 3 (Wald = 2.950, p=.001), but that was the only noted perception change of the temperature measures.

We asked residents *"How difficult is it to use the thermostat?"* In Panel 3, 23% (n=13) said it was "somewhat difficult" or "very difficult." We followed by asking, *"Can you tell me how it is difficult?"* Of those saying it was somewhat or very difficult, subsequent responses clustered in two categories: (1) 69% said the problem was with themselves (e.g. their eyesight was bad so they couldn't read the numbers on the thermostat display, or they were too short so they couldn't read the display); and (2) 23% said the problem was with the device, primarily because of the visual display or the device had been installed too high on the wall.

Of the four questions pertaining to **perceived lighting** (satisfaction with the amount of light in the unit; satisfaction with visual comfort of the lighting, e.g. glare, reflections, contrast; satisfaction with the lighting in the kitchen; extent to which lighting quality in the unit enhanced or interfered with comfort), there were no changes, short-term (P1P2) nor long-term (P1P3).

Three questions asked about **perceived air quality** in all three panels. Also, three questions were added in Panels 2 and 3 that asked about perceived air quality as it related to their health. Notably, we found several significant changes here (see Table 7.1 and Table 7.2).

Table 7.1 Short-term (P1P2) and Long-term (P1P3) Changes in Residents' Perceptions of Air Quality of Their Apartments

	P1P2 Change		P1P3 Change	
	Wald	***p*-value**	**Wald**	***p*-value**
Satisfaction with air quality in unit (i.e. stuffy/stale air, cleanliness, odors)	1.423	n.s.	5.325	.021
Satisfaction with air quality in kitchen	.785	n.s.	4.282	.039
Air quality enhances or interferes with one's comfort	3.456	.06	8.728	.003

Table 7.2 Changes in Resident Beliefs of Effect of Air Quality on Health Following Renovation (P2P3)

After the Renovation	**Wald**	***p*-value**
Air quality in unit enhances or interferes with any breathing or respiratory ailments	4.620	.032
Air quality in unit enhances or interferes with one's sleep	14.502	<.001
Air quality in unit enhances or interferes with feelings of dizziness, headaches or feelings of nausea	0	n.s.

7.3 Changes in Cleaning Behaviors and Use of Cleaning Products

Individuals may use household cleaning products that contribute environmental toxins to the air while they are cleaning their homes. Accordingly, we asked several questions about their cleaning behaviors and the products they used.

We asked residents **how easy or hard it was to clean their apartment**, using a three-point scale. At Panel 1 (n= 57, using only residents who remained in the study through P3), 54% of the residents said it was easy; 18% hard; and 28% said it was neither easy nor hard. Of the 10 residents who said it was hard at P3, three of them still maintained it was hard at Panel 3 but the other seven said it was now easy or neither easy nor hard. We were unable to test the significance of the association since a Chi-square test of this data would result in four of the 9 cells with expected counts less than 5.

Examining cleaning behaviors across panels, we found significant changes in **use of any odor-masking products** (such as candles, incense, air fresheners) between P1P2 and P1P3 (for P1P2, $\chi^2 = 13.237$, $p < .001$; for P1P3, $\chi^2 = 8.071$, $p = .004$) but the changes did not follow a set pattern. For example, of the 37 residents who did use such products at Panel 1, 24% (or 9 residents) no longer used these products at Panel 2. But of the 22 residents who did not use such products at Panel 1, 27% (6 residents) used them at Panel 2.

The retrofit included a **self-cleaning oven**. When asked about their use of the self-cleaning feature in Panel 3, 75% said that they had not used that feature, 25% had. Of those who had (n = 14), half had used the feature only once since the renovation, 29% had used it twice, and the remainder used it between three and five times.

When asked why they had not used the self-cleaning features (n= 39), 72% said they did not need to clean their ovens; 18% preferred having it cleaned by hand rather than using the mechanical function; 5% did not use it because of the odor it produced; and 5% said they did not know that there was a self-cleaning feature.

During our Panel 3 interviews with the residents, we asked them about the **type of cleaning products** they used for the kitchen, for the bathroom and for the furniture. In those instances when asked about commercial products they used or when they responded that they used "other" products than those we had listed for them, we asked to see the particular product (since we were in their homes) or asked them for the brand name. In cases where the product did reflect one of our categories (e.g. a resident mentioned Ajax powder cleaner as "other," but it did fall into "commercial or store-bought products that are not green or natural"), we recoded the response into prior appropriate category.

Table 7.3 shows the percentage of residents using each of the cleaning solutions; clearly, home-made products are very common among this senior population.

Table 7.3 Percentage of Residents Using Type of Products When Cleaning Their Homes, Asked at Panel 3

	In Cleaning Kitchen	In Cleaning Bathroom	In Cleaning Furniture	In Cleaning of Home
Homemade Solutions from Water, Lemon, Unscented Soap, Borax, Vinegar, Cornstarch or other Common Household Products	69.2%	52.3%	50.8%	80.7%
Store-bought Commercial Cleaning Solutions that are labeled "Green" or "Natural"	1.5%	1.5%	0%	3.5%
Store-bought Commercial Cleaning Solutions that are not labeled "Green"	29.2%	46.2%	24.6%	49.1%
Bleach	7.7%	10.8%	0%	14.0%
Ammonia	0%	0%	0%	0%

As mentioned in Chapter 2, we also produced and distributed to residents prior to Panel 3 data collection a booklet describing and illustrating ways to keep their homes healthy, including specific formulas for producing home-made cleaning solutions. When asked about the booklet at Panel 3, 63% said they had received a copy of the booklet (if they said they did not receive a copy, we gave them one then). Of those who said they had received a copy, 88% said they had looked at it; and 70% said they had read of a recommendation that was new to them. Most of these included home-made cleaning solutions (e.g. "use of baking soda and vinegar to clean"; "white vinegar to remove hard water spots on faucets") and a few pertained to use of appliances or equipment (e.g. "it is okay to put lettuce down the disposal").

7.4 Correspondence between Resident Perceptions of and Objective IEQ Changes

Chapters 4 and 5 described significant IEQ changes after the retrofit for thermal variability (THERM VAR), relative humidity variability (RH VAR), indoor temperature counts exceeding 81°F (EXCEED 81), and for aldehyde concentrations, particularly formaldehyde. We examined the extent to which these particular IEQ measures corresponded to residents' perceptions of temperature and thermal comfort and to perceptions of indoor air quality. We examined whether the perception was not only dependent on the actual IEQ condition at that panel, but also on the change in IEQ condition from panel 1 to the subsequent panel. The statistical models used were specified as follows (for Panel 3, substituting Panel 3 for Panel 2 dummy):

Perception (t) = B0 + [B1 *IAQ/IEQ conditions (t)] + [B2 * Panel 2 Dummy]
+ [B3 * Panel 2 Dummy * Change in IAQ/IEQ]

B1 indicates whether the perception at any panel is correlated to the prevailing IAQ/IEQ conditions; B3 indicates whether the magnitude of change of IAQ/IEQ affects perception change.

7.4.1 Correspondence Between Thermal Measures and Resident Perceptions

As mentioned in Section 7.2, there were 4 measures of thermal perceptions. In examining P1P2 data, THERM VAR significantly contributed to only one of these perception measures: satisfaction with effectiveness of thermostats. On the other hand, EXCEED 81 positively contributed to each of the four temperature perception items at Panel 2 (Table 7.4). We did not find that any P1P2 changes contributed to thermal perceptions. We found no significant relationships between RH VAR and any of the four temperature perceptions.

Table 7.4 Effects of Temperature Conditions on Resident Thermal Perceptions, at P1P2

	Satisfaction with Unit's Temperature		Thermal Conditions Enhance/ Interfere with Comfort		Satisfaction with Kitchen's Temperature		Satisfaction with Effectiveness of Thermostat	
Temperature Measure and Panel Test	Wald	p	Wald	p	Wald	p	Wald	p
THERM VAR								
at P2	.828	n.s.	1.376	n.s.	.199	n.s.	10.820	.001
between P1P2	.318	n.s.	.065	n.s.	.343	n.s.	.677	n.s.
EXCEED81								
at P2	4.146	.042	4.752	.029	5.285	.022	2.864	.091
between P1P2	1.121	n.s.	.099	n.s.	n.s.	.65	1.749	n.s.

When examining changes in THERM VAR and EXCEED 81 between Panels 1 and 3, there were no significant relationships with any of the four perception measures. However, resident's satisfaction with kitchen temperature was related to RH VAR at Panel 2. Satisfaction with kitchen temperature and satisfaction with the thermostat effectiveness was also related to P1P2 changes in RH VAR (see Table 7.5)

Table 7.5 Effects of RH Variability on Resident Thermal Perceptions, at P1P3

	Satisfaction with Unit's Temperature		Thermal Conditions Enhance/ Interfere with Comfort		Satisfaction with Kitchen's Temperature		Satisfaction with Effectiveness of Thermostat	
RH Measure and Panel Test	Wald	p	Wald	p	Wald	p	Wald	p
RH VAR								
at P3	.828	n.s.	1.376	n.s.	.199	n.s.	10.820	.001
between P1P3	.318	n.s.	.065	n.s.	.343	n.s.	.677	n.s.

7.4.2 Correspondence Between PM and Aldehyde Measures and Resident Perceptions of Air Quality

In all panels, we asked two questions about residents' satisfaction with the unit's air quality (i.e. stuffy/stale air, cleanliness, odors) and the extent to which air quality in the unit enhanced or interfered with their comfort (7-point scales).

In addition, following six of the health questions (pertaining to asthma, skin conditions, joint stiffness, emotions, physical limitations, falls), we asked residents if either they or a health professional believed that their home environment contributed to that particular health condition. We tallied the "yes" responses of these dichotomous questions to create an interval variable that reflects the extent to which a resident believes the home environment contributed to their health. We refer to as HomeProb.

When examining the data from these perception items and aldehyde concentrations, we found no significant correspondence for acetone and acetaldehyde. However, the P1P2 changes in the unit's formaldehyde concentration as well as for the exceedance levels for the kitchen and living space (see Chapter 4 for descriptions of these measures) was significantly related to changes in the HomeProb score, but not to the other two air quality perceptions (see Table 7.6). However, these formaldehyde patterns diminished in P1P3, with only P1P3 changes in the exceedance level of the kitchen significantly related to HomeProb score

(Wald = 3.018, p = .082). There were no other significant relationships between aldehydes and air quality perceptions.

Table 7.6 Effects of Formaldehyde Concentrations on Resident Perceptions of Home Environment Contributing to Health Problems, at P1P2

	Extent Home Environment Contributes to Health Problems	
Formaldehyde Measure and Panel Test	**Wald**	**p**
FA in Unit		
at P2	1.096	n.s.
between P1P2	4.792	.029
FA Exceedance for Kitchen		
at P2	.968	n.s.
between P1P2	3.281	.07
FA Exceedance for Living Room		
at P2	.975	n.s.
between P1P2	5.863	.015

7.5 Conclusions

The significant changes in IEQ of residents' homes that were documented in Chapters 4 and 5 are not consistently perceived by residents in a similar fashion when asked about their perceptions of thermal and air quality conditions of their homes. While residents express greater satisfaction of their homes' air quality between Panels 1 and 3, the actual IEQ changes in a resident's unit – by the measures reported in this Chapter – do not, for the most part, correspond to similarly changed perceptions by that resident. This might be expected since most aldehydes and fine particulate matter are odorless and invisible to an older population. Yet still we see increased satisfaction in air quality, and stronger beliefs that air quality in their homes interferes or enhances one sleep, and with breathing or respiratory ailments.

While we cannot ascertain the basis for these changed perceptions, the findings of the open-ended questions may provide some clues for future investigation. In responding to what pleased them about the newly renovated apartments, over a third mention ambient qualities such as the apartment being brighter, cleaner, more spacious and the like. It may be that their perceptions of improved air quality correspond to these ambient qualities as a result of new paint on the walls, new carpeting on the floor, lighter-color cabinetry, and so on — more so than to specific air quality concentrations of formaldehyde, for example. A home without stains on the carpet, with a new ceiling fan, or with a fresh coat of paint may appear less stuffy, with less stale air and odors. Given our sample size and the nature of our open-ended questions, we cannot statistically examine this; but it is a hypothesis that could be explored in the future.

Residents do not appear to change their cleaning behaviors from before the retrofit; but then again we find that many of them are using homemade cleaning solutions, especially in the kitchen. While we did not inquire into the particular homemade solutions they concocted, it is likely that they do not contain toxic substances as do most commercially available cleaning products. If their household cleaning products and behaviors were relatively healthy ones to begin with, not changing their products may be beneficial. Again, a hypothesis for further investigation.

While there were some significant relationships between thermal perceptions and actual temperature conditions, these were difficult to interpret given that most of these significant relationships were found in Panel 2 where few significant temperature changes occurred from the baseline panel (see Chapter 5).


2012

Chapter 8

Benefit Cost Analysis


TV

The Sunnyslope Manor renovations include reductions in risks associated with ergonomic attributes of the building such as lighting, hand rails, floor coverings and the design and location of appliances. These changes improve the quality of life and, in some instances, reduce the risks of injuries and improve the mobility of residents. The other important group of renovations are those that improve the environment in which the residents live, including indoor thermal and air quality which affect both the quality of life and, in some instances, individual health conditions such as asthma, chronic obstructive pulmonary disease, and other respiratory conditions that can also contribute to cardiac problems. The health effects of the environmental changes on illnesses can only be realized over long periods of time while changes that reduce the risks of injuries are obtainable once the renovations are completed.

As identified in Chapter 1, the first three overarching research questions addressed by this project include:

1. To what extent does indoor environmental quality of homes improve following housing renovations of the American Recovery and Reinvestment Act (ARRA) Green Retrofit Program?

2. To what extent do health outcomes of seniors improve following designated housing renovations of the ARRA Green Retrofit Program?

3. What is the benefit cost of these building improvements in light of both renovation costs and anticipated healthcare costs and savings?

This section addresses the third question.

8.1 Research Design and Methodology

The analysis of alternative methods of improving the health individuals is typically accomplished using cost-effectiveness analysis (CEA). A cost-effectiveness analysis measures the added costs and health outcomes associated with an intervention. The added costs and health outcomes are used to calculate the incremental cost-effectiveness ratio relative to some alternative. Costs are measured in monetary values and benefits are measured in non-monetary terms.

The primary difference between benefit cost analysis (BCA) and CEA is the absence of monetary measures of the benefits. The predominance of CEA in most studies of health outcomes is the difficulty of assigning monetary values to outcomes that are not subject to market exchanges and the consequent absence of prices as measures of value.

Several hybrids of cost-effectiveness studies exist including Cost-Utility Analysis (CUA), a particular type of cost-effectiveness analysis that measures effectiveness in terms of quality-adjusted life years (QALYs). Utility is a subjective measurement of the well-being gained from a particular intervention and includes both qualitative and quantitative outcomes.

As indicated in the research questions, the primary objective of the economic evaluation of this project is the avoidance of health care costs associated with injuries or illnesses attributable to the built environment. Thus, the primary method is benefit cost analysis, although some mention will be made of potential improvements in individual well-being.

8.1.1 Perspective

The analysis is conducted from the perspective of society as a whole, comparing benefits and costs without regard to the identity of the payers or the beneficiaries.

8.1.2 Costs

The costs are measured as the accounting costs recorded in the construction budgets that are part of the contracts between the builders and the city of Phoenix. The costs of the study are not included in the cost estimates.

The challenge is how to best allocate the costs of an alteration among the multiple objectives to which it contributes. The detailed costs of the renovation are available. Strictly speaking, one would ideally measure the differences between the costs of the "green" renovations and the costs of less environmentally friendly methods. We will, however, be restricted to the costs of the green renovation, suggesting that the costs used in our comparisons are not the marginal costs of a green renovation, implying a somewhat overstated set of cost estimates relative to the ideal.

A more difficult issue with the cost estimates is the fact that none of the elements of the renovation have the improvement of health as their only product. The replacement of worn stair treads, worn floor coverings or depreciated appliances, for example, is simply a requirement to maintain the functioning of a residential space. To the extent that a joint product of the routine maintenance is the improvement of health because the replacement is more environmentally friendly than a conventional replacement, some portion of the cost is appropriately compared to the resulting improvements in health.

8.1.3 Duration

The renovations represent a capital investment that will yield service to the residents over several years. We assume a minimum period of fifteen years as a conservative estimate of the duration over which benefits will be realized. Ideally one could also add annual maintenance costs for the same period, making it possible to compare the original investment plus the present values of the maintenance costs to the present values of the benefits achieved during the fifteen-year period. The residents of Sunnyslope are older adults and there will be significant attrition and replacement of the current cohort of residents over the next fifteen years as residents die or are forced to move to assisted living or skilled nursing care environments because of ill health. We will assume that a cohort of 77 persons will reside at Sunnyslope in each of fifteen years, recognizing that the individuals within the cohort will change over time.

8.1.4 Discount Rate

The costs of the intervention are capital expenditures, invested in housing at a point in time but generating benefits over much longer periods. It is necessary, therefore, to compare the benefits measured during the period of the proposed project to the portion of the total investment that is distributed to the years in which the benefits are received. Otherwise the ratio of benefits to costs will be understated. Projections beyond the life of the proposed study in which benefits are measured must be converted to present values using a discount rate. One approach is to use a real discount rate of 2%, approximately the real rate of interest in the United States for nearly a century. The real rate of interest, in the simplest terms, is the difference between inflation rates and returns on risk adjusted securities. This approach does not attempt to increase, in this context, health care costs for inflation.

8.2 Benefits

This portion of the analysis focuses on the health or health-related benefits of the project and does not consider the other objectives of the project.

The potential benefits from the ergonomic alterations include:

- Increase in resident mobility, including the ability to perform activities of daily living is an important benefit, contributing to the quality of life among the residents. These benefits can be more important to the residents than our measures of avoided health care costs but they cannot be monetized and are not, therefore, included in our benefit cost analysis.

- Reduction in the risk of injuries with special emphasis on injuries related to falls and injuries typically classified as “struck by/against” (highlighting that many residents have poor eyesight).

- The avoidance of health care costs associated with illnesses or injuries that are attributable to the residential environment, including hazards that can lead to falls and environmental conditions, including air quality that can affect respiratory function.

The health of elderly persons is likely to depreciate at increasing rates with age. Human capital theory predicts, therefore, that increasing annual investments in the health of elderly individuals are required to simply offset part of the losses due to life cycle depreciation. The appropriate gauge of returns to investment in health is, therefore, the maintenance of an existing state of health rather than an absolute improvement.

Elderly persons typically experience multiple chronic diseases, such as arthritis, cardiovascular impairments and respiratory problems as well as limited vision and hearing. The combined effect of these multiple conditions on individual health is extremely difficult to measure for any age group and particularly difficult for elderly persons such as the residents of Sunnyslope. Absent an index that sums the effect of multiple diseases, observed changes in health during short periods of time are almost impossible to separate into the portion attributable to environmental changes and the portion attributable to age-related depreciation in health.

8.2.1 Falls

Falls are one very important exception to the limitations on the measurement of renovations on health care costs. Although the combined effects of multiple impairments, including limitations in vision and mobility, are one important reason for falls, the environment is also an important contributor. The risk factors for falls include (ADHS, 2010):

1 Advanced age
2 Physical frailty
3 Chronic diseases
4 Poor lower body strength
5 Difficulty climbing stairs
6 Difficulty rising from chairs
7 Medications
8 Safety hazards in the home
9 History of falls
10 Poor vision
11 Poor balance
12 Frequent dizziness

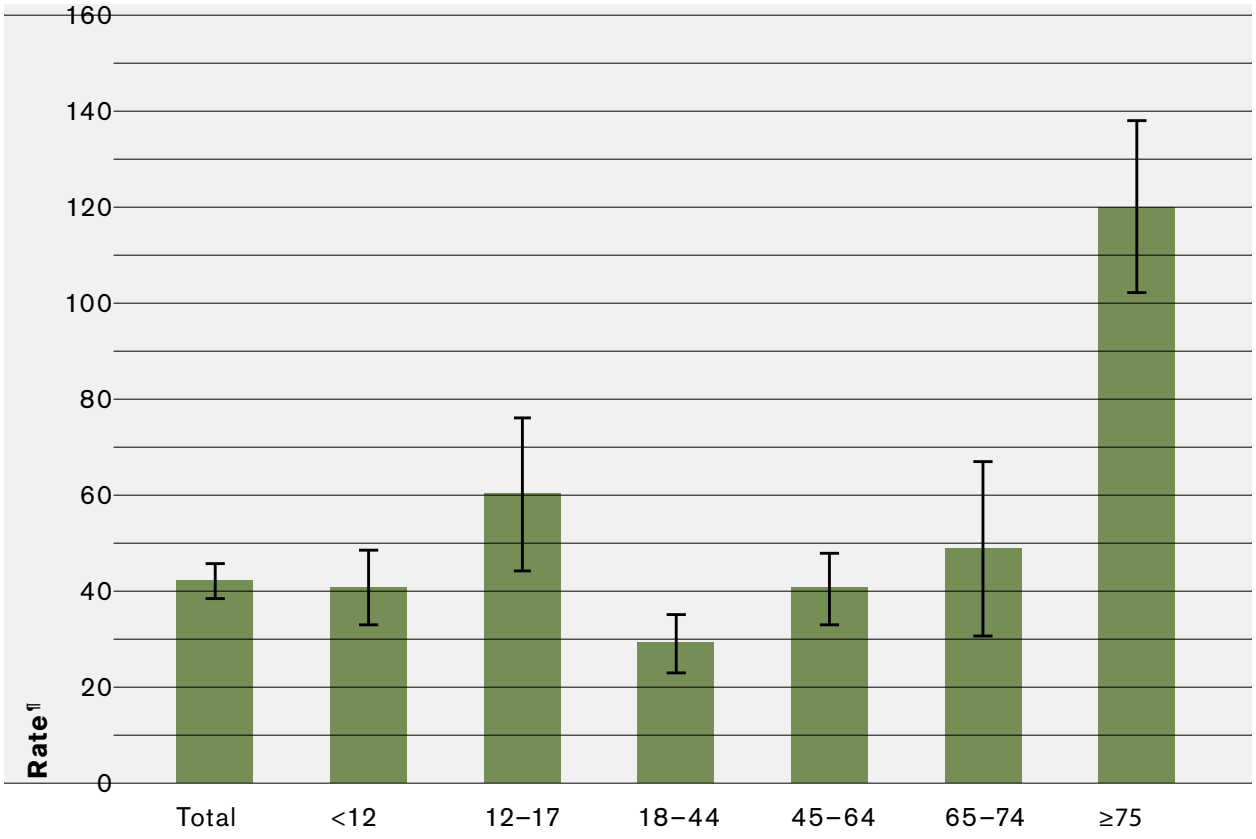
The recommended measures for the prevention of falls include the modification of home environments to reduce hazards such as slippery floors and poor lighting. Changes in the home environment that reduce these hazards have the potential to produce immediate reductions in the incidence of falls.

It is very well established that the incidence of fall-related injuries and the severity of their outcomes increase with age and increases exponentially among persons in the older age groups.

As indicated in Figure 8.1, the national rate of non-fatal fall related injuries in 2011 among those greater than or equal to 75 years of age is 115/1,000 per year or an average of 0.115 falls per person with a very wide confidence interval. The data do not, however, include deaths from falls.

Figure 8.1 Rate* of Nonfatal, Medically Consulted Fall Injury Episodes,† by Age Group – National Health Interview Survey, United States, 2010§

Age group (years)	Rate	Standard Error
Total	42.66	2.47
< 12	42.00	6.04
12 – 17	61.46	10.03
18 – 44	25.70	3.29
45 – 64	42.63	5.23
65 – 74	54.78	10.42
≥ 75	115.28	18.63



* Per 1,000 population

† Annualized rates of injury episodes for which a healthcare professional was contacted either in person or by telephone for advice or treatment. An injury episode refers to a traumatic event in which the person experienced one or more injuries from an external cause.

§ Estimates are based on household interviews of a sample of the civilian, noninstitutionalized population.

¶ Standard error bars represent a 95% confidence interval.

The most recent data for Maricopa County (2008) show that falls accounted for 71 percent of unintentional injury deaths among persons 65+ years of age (ADHS, 2010). The effect of the aging of the population is represented by the 91 percent increase in the rate of deaths over the nine year period 2000-2008 (ADHS, 2010). It is notable that the increase is in the rate of deaths from 49.6 deaths per 100,000 residents to 94.9 deaths per 100,000 residents and not just the number of deaths.

Falls are one of the most important contributors to the healthcare costs of elderly persons. A recent systematic review of studies of falls finds that fall-related costs in Australia and the United States range from 0.85% and 1.5% of total health care expenditures (Heinrich, 2010). Among elderly persons, falls are the leading contributor to the lifetime costs of injuries. There is increasing concern in the United States and with the likely increase in the number of deaths, injuries and associated health care costs among the very large number of elderly persons in the baby boomer bulge in the population.

Charges are a poor proxy for the costs of health care but costs are not available for falls treated in Maricopa County. Falls among elderly residents in Maricopa County that resulted in a hospitalization in 2008 produced average charges of $43,496. Adjusted to 2012 dollars using the CPCI-U medical care component of the CPI, the charges increase by 13.95% to equal $49,564. There was a very wide variation in lengths of stay from 4.9 days to 52 days.

National data on the costs of care for falls treated and released by emergency departments in the United States averaged approximately $1,100 per incident in 2005 for persons 70+ years of age (CDC, 2006). In 2012 dollars, using the medical care component of the CPI, the average cost increases by 27.43% to equal $1,402.

Many studies of the costs of falls focus on emergency department and hospital care alone. Among elderly persons, however, the costs of long term care are several times the costs for emergency care. People age 75 and older who fall are, for example, four to five times more likely than persons age 65-74 to be admitted to a long-term-care facility for a year or longer (Stevens, 2005). The type and amounts of incurred costs vary over a very wide range depending upon the severity of the fall related injuries and the health capital of the affected individual at the time of a fall. The more fragile the overall health of the individual, the more severe the effects of a particular fall and the longer the time to recovery and the higher the probability of a permanent physical impairment. Estimates of the health care costs of falls among older adults vary among studies and populations as well as among individuals with different health profiles.

The health care costs associated with injurious falls can include emergency department care, inpatient care, rehabilitation costs and the costs of skilled nursing facilities. One of the few studies to estimate the health care costs of falls for each of these categories shows that emergency department care is the least costly with inpatient care the most costly, followed closely by health care delivered in nursing homes (Rizzo, 1998). Converted to 2012 dollars using the medical care component of the CPI-U, Rizzo's estimated average costs of care increased by 70.62% to equal: $23,624 for hospital costs; $21,883 for nursing home costs; $3,184 for home health care; and $653 for emergency department care. These estimates are averaged across all persons with 1 or more injurious falls. If the data are, for example, restricted to just the persons who use a category of care, the estimates are much higher for that category. The cost of hospitalization for those who are hospitalized, for example, is $51,208.

8.3 Results

This analysis relies on the information presented in Chapter 6 of this report and will be summarized as relevant but not repeated in detail.

8.3.1. Costs

Detailed costs on each element of the renovation are available from the construction budget. We have selected those elements that can be related to the reduction in the risks of falls, including improved lighting, improvements in floor treatments that can reduce the risk of tripping and improvements in stairway hand rails. As we indicated, it is not strictly correct to attribute the total costs of these renovations to the reductions in the risk of falling since they are also part of routine maintenance of a residential facility. Thus, our estimated costs are somewhat overstated relative to the true costs attributable to risk reduction.

A total of $41,000 was expended to replace and improve lighting in all parts of Sunnyslope Manor. An additional $245,000 was spent to replace and improve interior carpets and common area floor coverings. Obviously the object of these renovations was not simply to reduce the risk of falling. It is also true, however, that many of the individual changes to room layouts, such as kitchen cabinet realignments, could also reduce the risks of falling and those costs have not been included.

8.3.2 Potential Benefits

The average age of the Sunnyslope residents is 74 with a range from 62 to 92. The Sunnyslope residents were asked in the initial, pre-renovation survey about their experience with falls during the three months prior to interview. Nearly 20% of the residents had fallen once during the three months, an additional four percent had fallen twice and nearly three percent had fallen three times. In other words, 27 falls occurred among the 77 residents of Sunnyslope in a three month period. This translates into approximately 0.35 falls per resident per quarter. Assuming the quarter is representative of other three month periods in the year, there would be 108 falls per year. Four of the 20 persons reporting falls indicated that their home environment contributed to their falls. Annually, the home environment would contribute to approximately 22 falls. Less than one-third of the total number of falls resulted in a restriction in activity or required medical care. The baseline target for potential health care costs would, therefore, be limited to approximately 7 falls per year, or a rate of .091 injurious falls per resident per year.

The Sunnyslope rate is not, however, restricted to falls that result in injuries but it also does not represent the cumulative numbers of falls for a full year. Losses due to attrition reduced the number of residents who answered both Panel 1 & Panel 2 questions to 59 persons. Sixteen residents had fallen in the three months prior to interview at P1; five residents had fallen since the renovation of their units (P2) and twelve residents reported falling during the three months prior to their interview at P3. Since some of the residents had fallen multiple times, there were 21 falls in the three months prior to P1; 11 in the three months prior to P2; and 20 in the three months prior to P3. The rate of falls per quarter, based on the 59 person cohort, was approximately the same as the P1 rate for the larger cohort, averaging 0.36 falls per resident. The rate after renovation (P2) was substantially lower, equaling 0.19 falls per resident. During the three months prior to interview at one year post-retrofit (P3), the rate of falls increased to 0.34 per person per quarter. The reduction in falls after the completion of the resident's unit (P2) is quite substantial and must, in part, be attributable to the effects of the renovation. At P3, however, the rate of falls is only approximately 6% lower. The P2-P3 increase in the rate of falls is, however, confusing and may reflect changes in the residents' health. The severity of injuries resulting from falls, described next, tends to support this speculation.

There was also an apparent increase in the severity of falls over the project period. At P1, 31% of the persons reporting falls indicated that the fall limited their activities for at least one day or required a visit to a physician. At P2, the percentage increased to 40% and increased again to 50% at P3. The increase in severity that occurred even at P2 where the rate of falls had substantially declined may reflect the fact, noted above, that persons with multiple falls are at an increased risk of falling as the number of falls increase and that the severity of a fall increases as the capacity to recover is reduced by each fall that results in a significant impact on physical capacity.

One very important fact should be noted. Although we have limited the target of falls for potential avoidance of health care costs to those resulting in injuries and related to environmental conditions, the total number of falls is a much more adequate description of the risks faced by these elderly residents. A fall from a particular hazard could, for example, be harmless at one occurrence and be injurious or even lead to death on another occurrence. The differences could occur simply by the positioning or responses of the resident at the time rather than any difference in the nature of the hazard.

Although the empirical results for the last two interviews are based on 59 persons, the agreement at P2 with the P1 rates suggests that it is reasonable to apply the observed P1 rates to the larger number of residents. Our projections of future falls will, therefore, assume a cohort of approximately 77 residents.

8.3.3 Benefit-Cost Estimates

To summarize, we will assume that there will be a cohort of residents numbering 77 persons, aged 62-92 for the next 15 years, recognizing that the individual members of the cohort will change. We will assume that pre-renovation rate of falls would have persisted in the absence of the renovations. Thus, in each of the 15 years, one would expect there to be 7 falls that resulted in injuries and were related in some way to the residential environment for a rate of .091 falls per resident per year. At that rate, there would be a total of 105 injurious falls for the fifteen year period, absent any effects of the renovation.

As indicated in a previous section, the health care costs of falls vary widely with the nature of the fall and the capacity of the affected individual to recover. The estimates of health care costs indicate a wide range of potential costs. The average charge for a fall related hospitalization in Maricopa County in 2012 dollars, for example, is $49,564. Problems of the differences between charges and payments aside, the mean charge is heavily influenced by cases in which hospitalization required a 52 day length of stay. Rizzo's estimated average costs of care from a Medicare population in another state equal: $23,624 for hospital costs; $21,883 for nursing home costs;$3,184 for home health care; and $653 for emergency department care (Rizzo, 1998). Thus, the average total cost for persons with one or more injurious falls equals $49,344 in 2012 dollars.

The data collected by this project do not include clinical measures of severity so we cannot further divide falls between those that are injurious and those which neither limit functional capacity nor require medical care. We will, therefore, use Rizzo's estimates for all persons with injurious falls as our initial estimates of potential health care costs.

In each of the fifteen years, the potential health care costs of injurious falls absent renovations is equal to $345,408. If, as between P1 and P2, there would be a 52% reduction in the rates of injurious falls from .091 per resident per year to .047, the number of injurious injuries avoided would equal approximately 4 injuries per year or a saving of 3 injuries per year. At an average cost of $49,344 per injury, the annual saving in avoided health care costs would equal $148,302. Using the real rate of interest of 2% for a period of 15 years, the present value of the savings in averted health care costs equals $1,905,571. The savings represented here would effectively cover nearly all of the costs of the total renovation, not restricted to any particular elements of the renovation.

The increase in the rate and severity of injuries between P2 and P3 suggest that any effects attributed to the period immediately following the renovation (the P1 to P2 comparison) may have been transitory and not the permanent outcome of the renovations. That fact and the inherent uncertainty surrounding the medical outcomes of the self-reported consequences of the falls indicate a need for caution in terms of estimating the potential health care cost savings of the renovation. If the reduction in the rate of injurious falls related to the residential environment is reduced by approximately 6% for an average saving of 0.4 injuries per year, then the annual saving in averted health care costs would equal approximately $20,725.

Using the real rate of interest of 2% for a period of 15 years, the present value of the savings in averted health care costs equals $266,301.

We estimated the costs of those parts of the renovation that could be assumed to include reductions in the risks of falls to equal $286,000 recognizing that a substantial portion of the costs, such as the costs of carpeting, might not be strictly attributable to the reduction of that risk.

For the reductions in the rate of injurious, environmentally-related falls in the pre and post renovation periods (P1P2), the potential returns in averted health care costs represent benefits approximately 6.7 times the cost. At the reductions observed between P1 and the final P3 interview, the benefits are approximately equal to 0.93 of the costs.

If the services available from the capital investment in the renovation extended for ten years rather than fifteen, the present value of the averted health care costs would equal a maximum of $1,332,135 and a minimum of $186,164.

8.4 Conclusions

The estimates indicate that renovations that reduce the risk of injurious falls must reach a threshold of reducing injuries by approximately 0.5 injuries per resident per year to generate a benefit/cost ratio greater than one. The baseline to post renovation results reported in Chapter 6 of this report show a 52% reduction which greatly exceeds the minimum threshold. Our estimates provide a range based on the differences between the baseline and the two subsequent interviews.

The estimates are, however, subject to considerable uncertainty given the small numbers of residents in the database and the limitations on the ability to directly measure any causal relationships between the renovation elements for which costs are attributed to reductions in the risks for falls. Given the uncertainty inherent in the limitations of the data, we suggest that a reasonable estimate of the benefits and costs of the renovation on the health care costs of falls lies within the range that has been presented.

At the maximum, the averted costs of health care related to falls would be sufficient to offset nearly the total costs of the renovation.

Another limitation is that the resident's perception of the link between their environment and their falls is an imperfect indicator of that relationship. Persons who fall, especially if the fall is severe, are unlikely to have recognized the exact cause of their fall because recognition of the hazard would in many cases have prevented the fall.

The estimates do not directly consider the potential prevention of deaths from falls but this is indirectly reflected in the estimates of the health care costs which are not limited to non-fatal fall related injuries.

We have not addressed the potential benefits of improvements in air quality on avoided health care costs because of the absence of data that could be used to predict these long term impacts. The ability to make such projections is also inherently limited by the multiplicity of chronic conditions that affected the residents at baseline and the expected continued deterioration of their health as they age.

Improvements in the quality of life are generally more important to individuals than averted health care costs but they cannot be monetized and included in a benefit-cost analysis. Improvements in the quality of life are addressed in Chapter 6 of this report but are not considered here because of the focus on averted health care costs.

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Appendices

Hypothesis Set #1: Indoor Climate Quality

Hypotheses	Outcome Variables	Mediating or Moderating Variables (Covariates)	Measurement	Instrument	Frequency or Duration at Panel	Panels Tested and Compared	Statistical Analyses
1. Indoor Climate Temperature (i.e. temperature, RH, air exchange) will improve following Green Retrofit. These changes will be immediate (i.e. 2nd panel) and sustaining (third panel).	Temperature		Mean Unit Temperature (composite across 3 rooms) Unit_Temp_M (P2, P3) Minimum Unit Temperature (composite of min. recorded temperature in 3 rooms) Unit_Temp_Min (P2, P3) Maximum Unit Temperature (composite of max. temperature in 3 rooms) Unit_Temp_Max (P2, P3) Temperature Variability (composite of std. deviation of 3 rooms) Unit_Temp_Var (P2, P3)	Three HOBO temperature data loggers in each unit: kitchen, bedroom, living room locations	Every 15 minutes for 5 days, for total of 480 data points for each unit	P1 + P2 P1 + P3	Fixed Effects Regression
	Relative Humidity		Mean RH in LR L_RH_M (P2, P3) RH Variability (std. deviation) L_RH_Var (P2, P3)	One data logger in L.R.	Every 15 mins. for 5 days, for total of 480 data points for each unit	P1 + P2 P1 + P3	Fixed Effects Regression
	Air Exchange		Air exchanges per minute CFM50 (P2, P3)	Blower Door Test	Once each panel	P1 + P2 P1 + P3	Fixed Effects Regression

Hypotheses	Outcome Variables	Mediating or Moderating Variables (Covariates)	Measurement	Instrument	Frequency or Duration at Panel	Panels Tested and Compared	Statistical Analyses
1a. These changes (above) will meet thresholds of ASHRAE standards	Temperature exceeding		Temp Above 81 (composite of # of data points above 81° in 3 rooms) Unit_Above81 (P2, P3)	Three HOBO temperature data loggers in each unit: kitchen, bedroom, living room locations	Every 15 minutes for 5 days, for total of 480 data points for each unit	P1 + P2 P1 + P3	Fixed Effects Regression
1b. IEQ changes will be less in homes with certain residents characteristics/ behaviors and building/design characteristics than without these characteristics	[as above in #1 and #1a]	Age of resident	Year born (interval). Q2 Recode to 62-71; 72-81; 82 or older MOD_Q10	*Health at Home* Interview (item from BRFSS or NHIS)	1 question in each panel	P1 + P2 with Covariate P1 + P3 with Covariate	Fixed Effects Regression with Covariate
		Time living at Sunnyslope Manor	Years (interval). Q8 Recode to 0-2 years; 2.1-5 yrs; 5.1-10 yrs; 10 yrs or more. MOD_Q8	*Health at Home* Interview (item from BRFSS or NHIS)	1 question in each panel	P1 + P2 with Covariate P1 + P3 with Covariate	Fixed Effects Regression with Covariate
		Building characteristics where unit located	Floor level Floor North-South Orientation Orientation East-West Wing Wing			P1 + P2 with Covariate P1 + P3 with Covariate	Fixed Effects Regression with Covariate

Hypothesis Set #1: Indoor Climate Quality (Continued from page 119)

Hypotheses	Outcome Variables	Mediating or Moderating Variables (Covariates)	Measurement	Instrument	Frequency or Duration at Panel	Panels Tested and Compared	Statistical Analyses
1c. Tighter air exchange levels after the retrofit will also result in greater changes in temperature and relative humidity	Temperature	Air Exchange	[As above in #1]			P1 + P2 with Covariate P1 + P3 with Covariate	Fixed Effects Regression with Covariate
	Relative Humidity	Air Exchange	[As above in #1]			P1 + P2 with Covariate P1 + P3 with Covariate	Fixed Effects Regression with Covariate

Hypothesis Set #2: Indoor Air Quality

Hypotheses	Outcome Variables	Mediating or Moderating Variables (Covariates)	Measurement	Instrument	Frequency or Duration at Panel	Panels Tested and Compared	Statistical Analyses
2. IAQ – i.e. PM and aldehydes -- will change following Green Retrofit. These changes will be immediate (P2) and sustainability (P3). **2a.** PM levels are expected to increase and to exceed air quality standards immediately after retrofit due to the construction process. PM levels are expected to improve over time (i.e. sustaining)	Particulate Matter		PM2.5 in unit, averaged across 2 rooms (composite) UNIT_PM2.5 (P2,P3) I_O_PM2.5 (P2, P3) PM10 in unit, averaged across 2 rooms (composite) UNIT_PM10 (P2,P3) I_O_PM10 (P2, P3)	Dustrack 8533 Sampler	One hour	P1 + P2 P1 + P3	Fixed Effects Regression

Hypothesis Set #2: Indoor Air Quality (Continued from page 121)

Hypotheses	Outcome Variables	Mediating or Moderating Variables (Covariates)	Measurement	Instrument	Frequency or Duration at Panel	Panels Tested and Compared	Statistical Analyses
2b. Aldehyde levels are expected to improve at immediate and sustaining. Formaldehyde levels following retrofit will meet thresholds of health/safety standards.	Aldehydes		Acetone concentration in unit, averaged across 2 rooms (kitchen, living room) Acetone_UNIT (P2, P3) I_O_Acetone (P2, P3) Acetaldehyde concentration in unit, averaged across 2 rooms (kitchen, living room) AA_UNIT (P2, P3) I_O_AA (P2, P3) Formaldehyde concentration in unit, averaged across 2 rooms (kitchen, living room) FA_UNIT (P2, P3) I_O_FA (P2, P3) Formaldehyde concentration in KITCHEN and living room, FA_B (P2, P3) FA_A (P2, P3) # times Formaldehyde levels exceeded CA 8-hour ref. exposure level (27 ppb) (for living room, for kitchen) ExceedA (P2, P3) ExceedB (P2, P3)	Commercial samplers containing CNPH-coatedsilica gel	One hour	P1 + P2 P1 + P3	Fixed Effects Regression

Hypotheses	Outcome Variables	Mediating or Moderating Variables (Covariates)	Measurement	Instrument	Frequency or Duration at Panel	Panels Tested and Compared	Statistical Analyses
2c. IAQ changes will be less in homes with certain residents characteristics/ behaviors and building/design characteristics than without these characteristics	[as above in #2a and #2b]	Age of resident	Year born (interval). Q2 Recode to 62-71; 72-81; 82 or older MOD_Q10	*Health at Home* Interview (item from BRFSS or NHIS)	1 question in each panel	P1 + P2 with Covariate P1 + P3 with Covariate	Fixed Effects Regression with Covariate
		Time living at Sunnyslope Manor	Years (interval). Q8 Recode to 0-2 years; 2.1-5 yrs; 5.1-10 yrs; 10 yrs or more. MOD_Q8	*Health at Home* Interview (item from BRFSS or NHIS)	1 question in each panel	P1 + P2 with Covariate P1 + P3 with Covariate	Fixed Effects Regression with Covariate
		Smoking behavior	Do you smoke (dich) Q88, P2Q88, P3Q88 Smoke inside apt, for smokers P3Q88b	*Health at Home* Interview (item from BRFSS or NHIS)	1 question in each panel	P1 + P2 with Covariate P1 + P3 with Covariate	Fixed Effects Regression with Covariate
		Has pets	Have pets (dich) Q85, P2Q85, P3Q85	CBE Occupant IEQ Survey; Healthy Homes Rating Tool	1 question in each panel	P1 + P2 with Covariate P1 + P3 with Covariate	Fixed Effects Regression with Covariate
		Uses bug sprays	Use bug spray (dich) Q87, P2Q87, P3Q87	CBE Occupant IEQ Survey	1 question in each panel	P1 + P2 with Covariate P1 + P3 with Covariate	Regression with Covariate

Hypothesis Set #2: Indoor Air Quality (Continued from page 123)

Hypotheses	Outcome Variables	Mediating or Moderating Variables (Covariates)	Measurement	Instrument	Frequency or Duration at Panel	Panels Tested and Compared	Statistical Analyses
		Uses odor masking or other	Use anything to change smell of air in home more than once a week (dich) Q89, P2Q89, P3Q89 Use air freshner more than once a week (dich) Q89a3, P2Q89a3, P3Q89a3	CBE Occupant IEQ Survey	2 question in each panel	P1 + P2 with Covariate P1 + P3 with Covariate	Regression with Covariate
		Uses kitchen fan	Use fan over stove when cook (5 pt) Q83, P2Q83, P3Q83	CBE Occupant IEQ Survey	1 question in each panel	P1 + P2 with Covariate P1 + P3 with Covariate	Fixed Effects Regression with Covariate
		Uses new bedroom fan	Use new bedroom fan		1 question in Panels 2 and 3	P1 + P2 with Covariate P1 + P3 with Covariate	Fixed Effects Regression with Covariate
		Building characteristics where unit located	Floor level Floor North-South Orientation Orientation East-West Wing Wing			P1 + P2 with Covariate P1 + P3 with Covariate	Fixed Effects Regression with Covariate

Hypotheses	Outcome Variables	Mediating or Moderating Variables (Covariates)	Measurement	Instrument	Frequency or Duration at Panel	Panels Tested and Compared	Statistical Analyses
2d. Tighter air exchange levels after the retrofit will also result in greater changes in IAQ	Particulate Matter	Air Exchange CFM50 (P2, P3)	[as above in #2a]			P1 + P2 with Covariate P1 + P3 with Covariate	Fixed Effects Regression with Covariate
	Aldehydes	Air Exchange CFM50 (P2, P3)	[as above in #2a]			P1 + P2 with Covariate P1 + P3 with Covariate	

Hypothesis Set #3: Resident Perceptions of Improved IEQ/IAQ Conditions

Hypotheses	Outcome Variables	Predictor Variables	Measurement	Instrument	Frequency or Duration at Panel	Panels Tested and Compared	Statistical Analyses
3. Residents will perceive improved IEQ/IAQ conditions after ARRA Green Retrofit	Resident perceptions of temperature comfort and satisfaction Resident perceptions of home environment contributing to health problems	Mean Unit Temperature Minimum Unit Temperature Maximum Unit Temperature Temperature Variability Temp Above 81 (composite of # of data points above 81° in 3 rooms) RH Mean RH Variability Air Exchange	Satisfaction temp (7 pt) Q100 (P2, P3) Temp interfere or enhance comfort (7 pt) Q101 (P2, P3) Satisf temp kitchen (7 pt) Q108b (P2, P3) Satisf thermostat effectiveness (3 pt) Q109a (P2, P3) Believe home environment contributed to health problems (asthma, skin, join, emotions, physical limitations, falls) (yes/no,or scale convert to yes/no) Sum of above (Q33g, Q33h, Q39aF, Q39bF, Q42dF, Q56F, Q71F, Q73cF) (P2, P3)	CBE Occupant IEQ Survey; Healthy Homes Rating Tool; Green Apple Project	3 questions in each panel	P2, P3 P1 and P2 P1 and P3	Ordinal regression; ordered logit models

Hypotheses	Outcome Variables	Predictor Variables	Measurement	Instrument	Frequency or Duration at Panel	Panels Tested and Compared	Statistical Analyses
	Resident perceptions of air quality comfort and satisfaction	Mean Unit Temperature Minimum Unit Temperature Maximum Unit Temperature Temperature Variability Temp Above 81 (composite of # of data points above 81o in 3 rooms) RH Mean RH Variability Air Exchange PM2.5 in unit PM2.5 Indoor/ Outdoor Ratio PM10 in unit PM10 Indoor/Outdoor Ratio	Satisfaction with air quality (stuffy/stale, cleanliness, odors) in unit (7 pt) Q102 (P2, P3) Does air quality enhance or interfere with comfort (7 pt) Q103 (P2, P3) Does air quality enhance or interfere breathing-respiratory ailments after renovation (7 pt) P2Q103a, P3Q103a Does air quality enhance or interfere with sleep after renovation (7 pt) P2Q103b, P3103b Does air quality enhance or interfere w/ dizziness, headaches, nausea ater renovation (7 pt) P2Q103c, P3Q103c Satisfaction with AQ in kitchen (7 pt) Q108c (P2, P3)	CBE Occupant IEQ Survey; Healthy Homes Rating Tool; Green Apple Project	3 questions in each panel; 3 questions only in P2 + P3	P2, P3 P1 and P2 P1 and P3	Ordinal regression; ordered logit models

Hypothesis Set #3: Resident Perceptions of Improved IEQ/IAQ Conditions (Continued from page 127)

Hypotheses	Outcome Variables	Predictor Variables	Measurement	Instrument	Frequency or Duration at Panel	Panels Tested and Compared	Statistical Analyses
		Acetone concentration in unit Acetone Indoor/ Outdoor Ratio Acetaldehyde concentration in unit Acetaldehyde Indoor/Outdoor Ratio Formaldehyde concentration in unit Formaldehyde Indoor/Outdoor Ratio Formaldehyde in Kitchen Formaldehyde Indoor/Outdoor Ratio	Satisfaction with air quality (stuffy/stale, cleanliness, odors) in unit (7 pt) Q102 (P2, P3) Does air quality enhance or interfere with comfort (7 pt) Q103 (P2, P3) Does air quality enhance or interfere breathing-respiratory ailments after renovation (7 pt) P2Q103a, P3Q103a Does air quality enhance or interfere with sleep after renovation (7 pt) P2Q103b, P3103b Does air quality enhance or interfere w/ dizziness, headaches, nausea ater renovation (7 pt) P2Q103c, P3Q103c Satisfaction with AQ in kitchen (7 pt) Q108c (P2, P3)				

Hypotheses	Outcome Variables	Predictor Variables	Measurement	Instrument	Frequency or Duration at Panel	Panels Tested and Compared	Statistical Analyses
		Temp Above 81 (composite of # of data points above 81o in 3 rooms) Temp Below 68 (composite of # of data points below 68o in 3 rooms)					
	Lighting/visual comfort and satisfaction		Satisfaction with amount of light in unit (7 pt) Q105 (P2, P3) Satisfaction with visual comfort (glare, reflections, contrast) in unit (7 pt) Q106 (P2, P3) Does lighting quality enhance or interfere with comfort (7 pt) Q107 (P2, P3) Satisfaction with lighting in kitchen (7 pt) Q108a (P2, P3)	CBE Occupant IEQ Survey; Healthy Homes Rating Tool	4 questions in each panel	P1 and P2 P1 and P3	Ordinal regression

Hypothesis Set #3: Resident Perceptions of Improved IEQ/IAQ Conditions (Continued from page 129)

Hypotheses	Predictor Variables	Mediating or Variables	Measurement	Instrument	Frequency or Duration at Panel	Panels Tested and Compared	Statistical Analyses
	Noise from neighbors		Rate noise from neighbors (3 pt) Q96 (P2, P3)	CBE Occupant IEQ Survey; Healthy Homes Rating Tool	1 question each panel	P1 and P2 P1 and P3	Ordinal regression
	Home fixture or feature effectiveness/ ease		Believe home environment contributed to health problems (asthma, skin, join, emotions, physical limitations, falls) (yes/no,or scale convert to yes/no) Sum of above (Q33g, Q33h, Q39aF, Q39bF, Q42dF, Q56F, Q71F, Q73cF) (P2, P3) Difficulty using thermostat (3 pt) P2THERM1, P3THERM1 Difficulty ceiling fan (3 pt) P2FAN1, P3FAN1 Use of odor-masking products (candles, incense, air fresheners) Q89 (P2,P3)	CBE Occupant IEQ Survey; Healthy Homes Rating Tool	9 questions in each panel; 3 questions in P2+P3; 15 questions in P3	P1 and P2 P1 and P3 P2 and P3 P3	Ordinal regression; Frequencies

Hypotheses	Outcome Variables	Mediating or Moderating Variables (Covariates)	Measurement	Instrument	Frequency or Duration at Panel	Panels Tested and Compared	Statistical Analyses
			Type of cleaning products used in kitchen, bathroom, furniture (home-made, green commercial, non-green commercial)..... (P3Clean1_1, P3Clean1_2, P3Clean1_3, P3Clean1_4, P3Clean1_5, P3Clean2_1, P3Clean2_2, P3Clean2_3, P3Clean2_4, P3Clean2_5, P3Clean3_1, P3Clean3_2, P3Clean3_3, P3Clean3_4, P3Clean3_5) Use of self-cleaning oven P3OVEN1, P3OVEN2				

Hypothesis Set #4: Resident Health (Continued from page 131)

Hypotheses	Outcome Variables	Mediating or Moderating Variables (Covariates)	Measurement	Instrument	Frequency or Duration at Panel	Panels Tested and Compared	Statistical Analyses
4a. Changes in health conditions at Sunnyslope will be greater than changes in health conditions in the generational population, as measured by national health surveys	(see below in 4b)	(Same as outcome variables)	(See below in 4b; with corresponding items from NHIS and BFRSS surveys)	Green Apple Project; BRFSS; NHIS	During interview / survey	P1, P2, P3 P1 to P2 P1 to P3	Binominal Analysis; Chi-Square Mann-Whitney U Ordinal Regression
4b. Resident Health will improve following Green Retrofit. These changes will be immediate and sustaining.	Overall Health Status and Life Satisfaction		Five-point scales: Q12, Q15 (P2, P3) Four-point scales: MOD_Q13, MOD_Q16, MOD_Q20, MOD_Q57 (P2, P3) Three-point scale: Q58 (P2, P3) # of days Q13, Q57 (P2, P3) Any comorbidities (yes/no): AnyComorbities (P2, P3)	BRFSS or NHIS	During interview	P1, P2, P3	Fixed Effects Regression Ordinal Regression Frequencies

Hypotheses	Outcome Variables	Mediating or Moderating Variables (Covariates)	Measurement	Instrument	Frequency or Duration at Panel	Panels Tested and Compared	Statistical Analyses
			Add Scale Responses of Q12, Q12, Q48RR LifeQual (P2, P3)				
			Count/Continuous: P3Q12IMP_Count, P3Q12WORSE_Count	Green Apple Project		P3 only	
	Respiratory-Related Conditions		Diagnosis: Yes/No response: Q32, Q33, Q36, Q37, Q38, AnyRespiratory (P2, P3) Episode: Q33b (P2, P3) Count/Composite: BreathingProb (P2, P3)	BRFSS or NHIS	During interview	5 questions (and composites) in each survey	Fixed Effectives Regression Ordinal Regression Binary Logistic Regression Frequencies
			Diagnosed with allergy since renovation: P2Q37a, P3Q37a	Green Apple Project		1 question in P2 and P3	
			Yes/No regarding improvement: Q12IMP_8, _9, _12, _13, _14, _15, _16; Q12WORSE_8, _9, _12, _13, _14, _15, _16	Green Apple Project		Questions and composites only in P3	

Hypothesis Set #4: Resident Health (Continued from page 133)

Hypotheses	Outcome Variables	Mediating or Moderating Variables (Covariates)	Measurement	Instrument	Frequency or Duration at Panel	Panels Tested and Compared	Statistical Analyses
			3-pt. scale re. improvement: P3RESHEALTH Yes/No diagnoses: P3Q38a, P3Q37b Count/Composite: P3BreathingIMP, P3BreathingWORSE				
	Emotional Distress		Diagnoses:Yes/No Q40, Q41 (P2, P3) Rating 5-point scale for individual items: Q48 through Q56 (P2, P3) Count of Low Life response + ratings: LowLife, CountLowLife (P2, P3) Any negative: Yes/No AnyLowLife (P2, P3)	BRFSS or NHIS	During interview	All composites and questions each survey	Fixed Effects Regression Binary Logistic Regression Frequencies
			Yes/No regarding improvement: P3Q12IMP_19, P3Q12IMP10, P3Q12WORSE_19, P3Q12WORSE_20	Green Apple Project		P3 only	
				BRFSS or NHIS		All questions in each survey	

Hypotheses	Outcome Variables	Mediating or Moderating Variables (Covariates)	Measurement	Instrument	Frequency or Duration at Panel	Panels Tested and Compared	Statistical Analyses
Sleep			5-point scale: Q18 (P2, P3) # of days or hours: Q16, Q17, Q20 (P2, P3)	BRFSS or NHIS	During interview	All questions in each survey	Fixed Effects Regression
			Yes/no re. improvement: P3Q12IMP_1, Q12WORSE_1	Green Apple Project		P3 only	
Functional Limitations/ Activities of Daily Living			Yes/no for special equipment: Q59 (P2, P3) Difficulty: 5-point scale Q60 through Q70 (P2,P3) Very Difficult or Worse Count for All Activities, UB, LB DiffActive, DiffLB, DiffUB (P2, P3) Somewhat Difficult or Worse Count for All Activities, UB, LB SomeActive, SomeLB, SomeUB (P2, P3) SomeDiffActive, SomeDiffLB, SomeDiffUB (P2, P3) Add Scale Responses for All Activities, UB, LB AllActiveProbRR, UBActiveProbRR, LBActiveProbRR (P2, P3)	BRFSS or NHIS	During interview	All questions and composites in each survey	Fixed Effects Regression

Hypothesis Set #4: Resident Health (Continued from page 135)

Hypotheses	Outcome Variables	Mediating or Moderating Variables (Covariates)	Measurement	Instrument	Frequency or Duration at Panel	Panels Tested and Compared	Statistical Analyses
	Falls		# of occurrences Q73, Q73b (P2, P3)	BRFSS or NHIS	During interview	All questions each survey	Fixed Effects Regression Frequencies
			Fall in Home: yes/no P3FallinHome Fall in Sunnyslope: yes/no P3FallSunny	Green Apple Project		P3 only	

Hypothesis Set #5: Integrative Model

Hypotheses	Outcome Variables	Mediating or Moderating Variables (Covariates)	Measurement	Instrument	Frequency or Duration at Panel	Panels Tested and Compared	Statistical Analyses
5a. Changes in residents' health (hypothesis 4) will correspond with changes in IEQ/IAQ (hyp 1 and 2)	*Significant* IEQ, IAQ variables in Hypotheses 1 and 2; *Significant* Health variables in Hypothesis 4		See above in Hypotheses 1, 2, 4	See above in Hypotheses 1, 2, 4	See above in Hypotheses 1, 2, 4	All panels	Fixed Effects Regression
5b. Changes in residents' health (hypothesis 4) will correspond with changes in IEQ/IAQ (hyp 1 and 2); but will be mediated by resident characteristics + behaviors + perceptions	*Significant* IEQ, IAQ variables in Hypotheses 1 and 2; *Significant* Health variables in Hypothesis 4	Age of resident	Year born (interval). Recode to 62-71; 72-81; 82 or older	BRFSS or NHIS	1 question in Panel 1	P1	Fixed Effects Regression with Covariate
		Time living at Sunnyslope Manor	Years (internval). Recode to 0-2 years; 2.1-5 yrrs; 5.1-10 yrs; 10 yrs or more.	BRFSS or NHIS	1 question in Panel 1	P1	
		Smoking behavior	Do you smoke (dich)	BRFSS or NHIS	1 question all surveys	All	
		Has pets	Have pets (dich)	CBE Occupant IEQ Survey; Healthy Homes Rating Tool	1 question each survey	All	

Hypothesis Set #5: Integrative Model (Continued from page 137)

Hypotheses	Outcome Variables	Mediating or Moderating Variables (Covariates)	Measurement	Instrument	Frequency or Duration at Panel	Panels Tested and Compared	Statistical Analyses
		Uses air fresheners or other	Use anything to change smell of air in home more than once a week (dich); use air freshner more than once a week (dich)	CBE Occupant IEQ Survey	2 questions each survey	All	
		Types of cleaning products used	What kind of clean solution to clean kitchen; bathroom; dust and clean furniture (open-ended, recoded for type)	Green Apple Project	3 questions in Panel 2	Panel 3	
		Building characteristics where unit located	Floor level Floor North-South Orientation Orientation East-West Wing Wing	Green Apple Project		All	

Appendix 2.2 Panel 3 Interview

Question Item: Yellow highlighted question indicates it was asked on Panel 3, but no previous panel
Question Item: Orange highlighted question indicates it was on Panel 1 and 2, but not panel 3
Question Item: Red text indicates slight changes made to question or responses from previous panels

Instructions: The following questions are mostly multiple choices, however, some are more specific. Depending on your answer, some questions may be skipped. Please answer the question the best that you can. You can refuse to answer any question.

The interviewer will read the questions to you and supply any additional information that you may need. Ask the interviewer if you need clarification or have questions.

If you need a break tell the interviewer.

ADULT DEMOGRAPHICS

HEALTH STATUS

12. **Question Text:** How would you say that your health is, in general?

1 Excellent
2 Very good
3 Good
4 Fair
5 Poor

(If can't answer choose below)
97 Refused
99 Don't know / Not sure

12IMP. Please look at this list of health conditions, and tell me if you have had noticeable improvement since the renovation in any of these.

12WORSE: Now look at the same list, and tell me if you have had noticeable worsening of any these health conditions since the renovation.

SAME LIST FOR BOTH QUESTIONS, ALL "YES/NO"

1. Sleep
2. Hypertension
3. Coronary Heart Disease
4. Angina
5. Heart Attack
6. Any other heart condition or heart disease
7. Stroke
8. Emphysema
9. Asthma
10. Diabetes or sugar diabetes
11. Seizure disorder or epilepsy
12. Hay fever
13. Sinusitis
14. Allergy
15. Chronic bronchitis
16. Any other respiratory condition
17. Skin condition
18. Cancer
19. Anxiety disorder
20. Depressive disorder
21. Arthritis
22. Carpal Tunnel syndrome
23. Don't know/Refused

13. **Question Text:** Now thinking about your physical health, which includes physical illness and injury, for how many days during the past 30 days was your physical health not good?

_____Number of days

(If can't answer choose below)
97 Refused
99 Don't know / Not sure

EMOTIONAL SUPPORT AND LIFE SATISFACTION

14. **Question Text:** How often do you get the social and emotional support you need? (If asked, say "please include support from any source.")
1 Always
2 Usually
3 Sometimes
4 Rarely
5 Never
Do not read:
97 Refused
99 Don't know / Not sure

15. **Question Text:** In general, how satisfied are you with your life?
1 Very satisfied
2 Satisfied
3 Dissatisfied
4 Very dissatisfied
Do not read:
97 Refused
99 Don't know / Not sure

SLEEP

16. **Question Text:** During the past 30 days, for about how many days have you felt you did not get enough rest or sleep?

_____Number of days
8 None
97 Refused
99 Don't know / Not sure

17. **Question Text:** On average, how many hours of sleep do you get in a 24-hour period? Think about the time you actually spend sleeping or napping, not just the amount of sleep you think you should get.

(Enter hours of sleep in whole numbers, rounding 30 minutes (1/2 hour) or more up to the next whole hour and dropping 29 or fewer minutes)
_____Number of hours [01-24]
97 Don't know / Not sure
99 Refused

18. **Question Text:** Over the last 30 days, have you had trouble with any sleep issues like falling asleep or staying asleep or sleeping too much?
1 Yes
2 No
97 Refused
99 Don't know

19. **Question Text:** Do you snore?
(If the respondent indicates that their spouse or someone told him/her that they snore, then the answer to the question is "Yes," the respondent snores.)
1 Yes
2 No
97 Refused
99 Don't know / Not sure

20. **Question Text:** During the past 30 days, for about how many days did you find yourself unintentionally falling asleep during the day?
_____Number of days [01-30]
98 None
97 Refused
99 Don't know / Not sure

ADULT HEALTH CONDITIONS

These next questions are about your hearing and vision.

21. **Question Text**: Do you now use a hearing aid(s)?
1 Yes
2 No
97 Refused
99 Don't know

~~**22.** **Question Text:** Have you ever used a hearing aid(s) in the past?~~

23. **Question Text:** WITHOUT the use of hearing aids or other listening devices, how would you rate your hearing? P1 Original

1 Excellent
2 Good
3 A little trouble hearing
4 Moderate trouble
5 A lot of trouble
6 Deaf
97 Refused
99 Don't know

24. **Question Text:** Do you have any trouble seeing, even when wearing glasses or contact lenses? P1 Original
1 Yes
2 No
97 Refused
99 Don't know

24ADL. **Question Text:** Are you now limited in any way in any of activities listed here because of your vision?
1. Bathing Yes No
2. Dressing Yes No
3. Grooming: Yes No
4. Oral Care: Yes No
5. Toileting: Yes No
6. Transferring: Yes No
7. Walking: Yes No
8. Climbing Stairs: Yes No
9. Eating: Yes No
10. Shopping: Yes No
11. Cooking: Yes No

12. Managing Medications: Yes No
13. Using the Phone: Yes No
14. Housework: Yes No
15. Doing Laundry: Yes No
16. Driving: Yes No
17. Managing Finances: Yes No
18. Don't know/Refused: Yes No

~~**25.** **Question Text:** Are you blind or unable to see at all?~~

Now I am going to ask you about certain medical conditions.

26. **Question Text:** Since the renovation of your apartment, have you been newly diagnosed with any of the following illnesses, diseases, or other medical conditions? ... Hypertension, also called high blood pressure?
1 Yes
2 No
97 Refused
99 Don't know

27. **Question Text:** Since the renovation of your apartment, have you been newly diagnosed with any of the following illnesses, diseases, or other medical conditions? ... Coronary heart disease?
1 Yes
2 No
97 Refused
99 Don't know

28. **Question Text**: Since the renovation of your apartment, have you been newly diagnosed with any of the following illnesses, diseases, or other medical conditions? ... Angina, also called angina pectoris?
1 Yes
2 No
97 Refused
99 Don't know

29. **Question Text:** Since the renovation of your apartment, have you been newly diagnosed with any of the following illnesses, diseases, or other medical conditions? ... A heart attack (also called myocardial infarction)?
1 Yes
2 No
97 Refused
99 Don't know

30. **Question Text:** Since the renovation of your apartment, have you been newly diagnosed with any of the following illnesses, diseases, or other medical conditions? ... Any kind of heart condition or heart disease?
1 Yes
2 No
97 Refused
99 Don't know

31. **Question Text:** (Read if necessary) Since the renovation of your apartment, have you been newly diagnosed with any of the following illnesses, diseases, or other medical conditions? ... A stroke?
1 Yes
2 No
97 Refused
99 Don't know

32. **Question Text:** (Read if necessary) Since the renovation of your apartment, have you been newly diagnosed with any of the following illnesses, diseases, or other medical conditions? ... Emphysema?

1 Yes
2 No
97 Refused
99 Don't know

33. **Question Text:** (Read if necessary)) Since the renovation of your apartment, have you been newly diagnosed with any of the following illnesses, diseases, or other medical conditions? ... Asthma?

1 Yes
2 No
97 Refused
99 Don't know
(IF YES, ask)

b) **Question Text:** Have you had an episode of asthma or an asthma attack since the renovation of your apartment?
1 Yes
2 No
97 Refused
99 Don't know

c) **Question Text:** Since the renovation, have you had to visit an emergency room or urgent care center because of asthma?
1 Yes
2 No
97 Refused
99 Don't know

d) **IF YES on (c):** How many visits?
_____

e) **IF YES on (c)**: Were any of these visits to...
1 Physician's office
2 Emergency room of hospital
3 Emergency health clinic
4 In-patient at hospital or clinic

h) **Question Text:** Do you believe that your asthma was probably related to something in your home?
1 Yes
2 No
97 Refused
99 Don't know

34. **Question Text:** Since the renovation of your apartment, have you been newly diagnosed with diabetes or sugar diabetes? [Other than during pregnancy)

1 Yes
2 No
3 Borderline
97 Refused
99 Don't know

35. **Question Text:** Since the renovation of your apartment, have you been newly diagnosed with a seizure disorder or epilepsy?

1 Yes
2 No
97 Refused
99 Don't know

(IF YES, ask)

a) **Question Text:** Are you currently taking any medicine to control your seizure disorder or epilepsy?

1 Yes
2 No
97 Refused
99 Don't know

36. **Question Text:** Since the renovation of your apartment, have you been newly diagnosed with … Hay fever?

1 Yes
2 No
97 Refused
99 Don't know

37. **Question Text:** Since the renovation of your apartment, have you been newly diagnosed with … Sinusitis?

1 Yes
2 No
97 Refused
99 Don't know

37a. **Question Text:** Since the renovation of your apartment, have you been newly diagnosed with …Allergy?

1 Yes
2 No
97 Refused
99 Don't know

37b. **IF YES for 37a**: Is that a respiratory allergy?

1 Yes
2 No
97 Refused
99 Don't know

38. **Question Text:** Since the renovation of your apartment, have you been newly diagnosed with … Chronic bronchitis?

1 Yes
2 No
97 Refused
99 Don't know

38a. Since the renovation of your apartment, have you been newly diagnosed with … any other respiratory condition?

1 Yes
2 No
97 Refused
99 Don't know

38b. **IF YES on 38a**: What was the respiratory condition?

39. **Question Text:** Since the renovation of your apartment, have you been newly diagnosed with a skin condition?

1 Yes
2 No
97 Refused
99 Don't know

IF YES on 39:

a) **Question Text:** Have you been told by a health professional that your skin condition was probably related to something in your home?

1 Yes
2 No
97 Refused
99 Don't know

b) **Question Text:** Do you believe that your skin condition is probably related to something in your home?

1 Yes
2 No
97 Refused
99 Don't know

39x. **Question Text:** Since the renovation of your apartment, have you been newly diagnosed with CANCER?

1 Yes
2 No
97 Refused
99 Don't know

40. **Question Text:** Since the renovation of your apartment, have you been newly diagnosed with an anxiety disorder (including acute stress disorder, anxiety, generalized anxiety disorder, obsessive-compulsive disorder, panic disorder, phobia, posttraumatic stress disorder, or social anxiety disorder)?

1 Yes
2 No
97 Refused
99 Don't know / Not sure

41. **Question Text:** Since the renovation of your apartment, have you been newly diagnosed with a depressive disorder (including depression, major depression, dysthymia, or minor depression)?

1 Yes
2 No
97 Refused
99 Don't know / Not sure

The next questions refer to your joints. Please do NOT include the back or neck.

42. **Question Text:** Since the renovation of your apartment, have you been newly diagnosed with some form of arthritis, rheumatoid arthritis, gout, lupus, or fibromyalgia (fy-bro-my-AL-jee-uh)?

1 Yes
2 No
97 Refused
99 Don't know

(If yes ask)

b) **Question Text:** What joint is most problematic (allow participant to answer and choose corresponding selection)

Enter ONLY ONE

1 Shoulder-right
2 Shoulder-left
3 Elbow-right
4 Elbow-left
5 Hip-right
6 Hip-left
7 Wrist-right
8 Wrist-left
9 Knee-right
10 Knee-left
11 Ankle-right
12 Ankle-left
13 Toes-right
14 Toes-left
15 Fingers/thumb-right
16 Fingers/thumb-left
17 Other joint not listed
97 Refused
99 Don't know

c) **Question Text:** Did your joint symptoms FIRST begin before the renovation of your apartment?
1 Yes
2 No
97 Refused
99 Don't know

d) **Question Text:** How MUCH does your home environment contribute to your joint stiffness?
1 A lot
2 Some
3 A little
4 Not at all
97 Refused

43. **Question Text:** Are you now limited in any way in any of your usual activities because of arthritis or joint symptoms?
1 Yes
2 No
97 Refused
99 Don't know

43ADL. **If Yes AT Q43:** Which of the following activities listed here are you limited in because of arthritis or joint symptoms?

1. Bathing	Yes	No
2. Dressing	Yes	No
3. Grooming	Yes	No
4. Oral Care	Yes	No
5. Toileting	Yes	No
6. Transferring	Yes	No
7. Walking	Yes	No
8. Climbing Stairs	Yes	No
9. Eating	Yes	No
10. Shopping	Yes	No
11. Cooking	Yes	No
12. Managing Medications	Yes	No
13. Using the Phone	Yes	No
14. Housework	Yes	No
15. Doing Laundry	Yes	No

16. Driving	Yes	No
17. Managing Finances	Yes	No
18. Don't know/Refused	Yes	No

44. **Question Text:** Since the renovation of your apartment, have you been newly diagnosed with a condition affecting the wrist and hand called carpal tunnel syndrome?

1 Yes
2 No
97 Refused
99 Don't know

PAIN P1 Original

The following questions are about pain you may have experienced in the PAST THREE MONTHS. Please refer to pain that LASTED A WHOLE DAY OR MORE. Do not report aches and pains that are fleeting or minor.

45. **Question Text:** DURING THE PAST THREE MONTHS, did you have ... Neck pain?

1 Yes
2 No
97 Refused
99 Don't know

46. **Question Text:** (Read if necessary) DURING THE PAST THREE MONTHS, did you have ... Low back pain?

1 Yes
2 No
97 Refused
99 Don't know

If yes, then ask next question:

a) **Question Text:** Did this pain spread down either leg to areas below the knees?

1 Yes
2 No
97 Refused
99 Don't know
88 Not asked

47. **Question Text:** (Read if necessary) DURING THE PAST THREE MONTHS, did you have ...Severe headache or migraine?

1 Yes
2 No
97 Refused
99 Don't know

FEELINGS

Now I am going to ask you some questions about feelings you may have experienced over the PAST 30 DAYS.

48. **Question Text:** During the past 30 days, how often did you feel healthy and full of energy?
1 ALL of the time
2 MOST of the time
3 SOME of the time
4 A LITTLE of the time
5 NONE of the time
97 Refused
99 Don't know

49. **Question Text:** DURING THE PAST 30 DAYS, how often did you feel ... So sad that nothing could cheer you up?
1 ALL of the time
2 MOST of the time
3 SOME of the time
4 A LITTLE of the time
5 NONE of the time
97 Refused
99 Don't know

50. **Question Text:** (Read if necessary) During the PAST 30 DAYS, how often did you feel ... Nervous?
1 ALL of the time
2 MOST of the time
3 SOME of the time
4 A LITTLE of the time
5 NONE of the time
97 Refused
99 Don't know

51. **Question Text:** (Read if necessary) During the PAST 30 DAYS, how often did you feel ... Restless or fidgety?
1 ALL of the time
2 MOST of the time
3 SOME of the time
4 A LITTLE of the time
5 NONE of the time
97 Refused
99 Don't know

52. **Question Text:** (Read if necessary) During the PAST 30 DAYS, how often did you feel ... Hopeless?
1 ALL of the time
2 MOST of the time
3 SOME of the time
4 A LITTLE of the time
5 NONE of the time
97 Refused
99 Don't know

53. **Question Text:** (Read if necessary) During the PAST 30 DAYS, how often did you feel ... That everything was an effort?

1 ALL of the time
2 MOST of the time
3 SOME of the time
4 A LITTLE of the time
5 NONE of the time
97 Refused
99 Don't know

54. **Question Text:** (Read if necessary) During the PAST 30 DAYS, how often did you feel ... Worthless?

1 ALL of the time
2 MOST of the time
3 SOME of the time
4 A LITTLE of the time
5 NONE of the time
97 Refused
99 Don't know

55. **Question Text:** We just talked about a number of feelings you had during the PAST 30 DAYS. Altogether, how MUCH did these feelings interfere with your life or activities: a lot, some, a little, or not at all?

1 A lot
2 Some
3 A little
4 Not at all
97 Refused
99 Don't know

56. **Question Text:** We just talked about a number of feelings you had during the PAST 30 DAYS. Altogether, how MUCH did your home environment contribute to these feelings?

1 A lot
2 Some
3 A little
4 Not at all
97 Refused
99 Don't know

56a. **Question Text:** To what extent did the renovation of your home affect your emotions overall? Would you say your feelings and emotions are: Same as P2

1 Much better
2 Somewhat better
3 The same
4 Somewhat worse
5 Much worse
97 Refused
99 Don't know

IF NOT "The same" or DK or REF AT Q56A, ASK:

56b. **Question Text:** What aspects or features of the renovation made you feel that way? OPEN ENDED

57. **Question Text:** During the PAST 12 MONTHS, that is, since {12-month ref. date}, ABOUT how many days did illness or injury keep you in bed more than half of the day (include days while an overnight patient in a hospital)?
0 None
_____Number of days
97 Refused
99 Don't know

57a. If >0, How many of these days were before the renovation?
_____Number of days
97 Refused
99 Don't know

58. **Question Text:** Compared with 12 MONTHS AGO, would you say your health is better, worse, or about the same?
1 Better
2 Worse
3 About the same
97 Refused
99 Don't know

RESHEALTH.
Compared with 12 MONTHS AGO, would you say your respiratory health – that is your lungs, bronchial, sinuses and breathing – is better, worse or about the same?
1 Better
2 Worse
3 About the same

59. **Question Text:** Do you now have any health problem that requires you to use special equipment, such as a cane, a wheelchair, a special bed, or a special telephone?
1 Yes
2 No
97 Refused
99 Don't know

59a. What kind of special equipment do you use?
READ LIST, SELECT ALL THAT APPLY.
a. Cane
b. Wheelchair
c. Walker
d. A special bed
e. A special telephone
f. Some other special equipment that I didn't mention (Please state: _____)

59WHEN: **If YES to 59:** When did you first need to use this? Fill in year _____

The next questions ask about difficulties you may have doing certain activities because of a HEALTH PROBLEM. By "health problem" we mean any physical, mental, or emotional problem or illness (not including pregnancy). P1 Original

60. **Question Text:** By yourself, and without using any special equipment, how difficult is it for you to...Walk a quarter of a mile - about 3 city blocks?

61. **Question Text:** (Read lead-in if necessary) By yourself, and without using any special equipment, how difficult is it for you to... Walk up 10 steps without resting?

62. **Question Text:** (Read lead-in if necessary) By yourself, and without using any special equipment, how difficult is it for you to ... Stand or be on your feet for about 2 hours?

63. **Question Text:** (Read lead-in if necessary) By yourself, and without using any special equipment, how difficult is it for you to ... Sit for about 2 hours?

64. **Question Text:** (Read lead-in if necessary) By yourself, and without using any special equipment, how difficult is it for you t o... Stoop, bend, or kneel?

65. **Question Text:** (Read lead-in if necessary) By yourself, and without using any special equipment, how difficult is it for you to ... Reach up over your head?

66. **Question Text:** (Read lead-in if necessary) By yourself, and without using any special equipment, how difficult is it for you to ... Use your fingers to grasp or handle small objects?

67. **Question Text:** (Read lead-in if necessary) By yourself, and without using any special equipment, how difficult is it for you to ... Lift or carry something as heavy as 10 pounds such as a full bag of groceries?

68. **Question Text:** (Read lead-in if necessary) By yourself, and without using any special equipment, how difficult is it for you to ... Push or pull large objects like a living room chair?

69. **Question Text:** (Read lead-in if necessary) By yourself, and without using any special equipment, how difficult is it for you to ...Participate in social activities such as visiting friends, attending clubs and meetings, going to parties?

70. **Question Text:** (Read lead-in if necessary) By yourself, and without using any special equipment, how difficult is it for you to ... Do things to relax at home or for leisure (reading, watching TV, sewing, listening to music)?

SCALE FOR Q60-Q70

0 Not at all difficult
1 Only a little difficult
2 Somewhat difficult
3 Very difficult
4 Can't do at all
5 Do not do this activity
97 Refused
99 Don't know

71. **Question Text:** We just talked about your physical limitations. Altogether, how MUCH did your home structure contribute to difficulties?

1 A lot
2 Some
3 A little
4 Not at all
97 Refused
99 Don't know

72. **Question Text:** Of all the health conditions we have discussed today, which ones make you rely on others for help or keep you from doing the activities that you want to do?

(Do not read the conditions listed below unless help is needed. Do not probe, except to clarify answer)

1 Vision/problem seeing
2 Hearing problem
3 Arthritis/rheumatism
4 Back or neck problem
5 Fracture, bone/joint injury
6 Other injury
7 Heart problem
8 Stroke problem
9 Hypertension/high blood pressure
10 Diabetes
11 Lung/breathing problem(e.g., asthma and emphysema)
12 Cancer
13 Birth defect
14 Mental retardation
15 Other developmental problem (e.g., cerebral palsy)
16 Senility
17 Depression/anxiety/emotional problem
18 Weight problem
19 Missing limbs (fingers, toes or digits), amputee
20 Kidney, bladder or renal problems
21 Circulation problems (including blood clots)
22 Benign Tumors, Cysts
23 Fibromyalgia, lupus
24 Osteoporosis, tendinitis
25 Epilepsy, seizures
26 Multiple Sclerosis (MS), Muscular Dystrophy (MD)
27 Polio(myelitis), paralysis, para/quadriplegia
28 Parkinson's disease, other tremors
29 Other nerve damage, including carpal tunnel syndrome
30 Hernia
31 Ulcer
32 Varicose veins, hemorrhoids
33 Thyroid problems, Grave's disease, gout
34 Knee problems (not arthritis (03), not joint injury(05))
35 Migraine headaches (not just headaches)
90 Other impairment/problem (write in_____)
91 Other impairment/problem (write in_____)
99 Don't know/Not sure

73. **Question Text:** In the past 3 months, how many times have you fallen?
P1 Original

_____Number of times
97 Refused
99 Don't know

(If >1 ask next 3 questions)

a) **Question Text:** Did this fall cause an injury?"
1 Yes
2 No
97 Refused
99 Don't know
88 Not asked

b) **Question Text:** How many of these falls caused an injury? By an injury, we mean the fall caused you to limit your regular activities for at least a day or to go see a doctor.
_____Number of falls
97 Refused
99 Don't know

c) Did the fall create an injury that required medical care?
(If yes, then ask: Would you say:)

1	I was transported by ambulance to receive care	Yes	No
2	I received care at an emergency department of a hospital	Yes	No
3	I received care at an urgent care center	Yes	No
4	I received care at a physician's office	Yes	No
5	I received care at a community health center	Yes	No
6	The care included staying overnight in a hospital. (If YES, ask how many nights_____)	Yes	No
7	The care included follow-up visits	Yes	No
8	The follow-up care included physical therapy visits (if YES, ask: how many visits:_____)	Yes	No

IF MORE THAN 0 for Q73: For the first fall that happened, where did you fall? Was it in -

FALL1_Home - Your home?	Yes	No
(IF YES ABOVE) FALL1_Where_In_Home - Where in your home did you fall?		
FALL1_Sunny - Not in your unit but elsewhere in Sunnyslope Manor?	Yes	No
(IF YES ABOVE) FALL1_Where_In_Sunny - Where in Sunnyslope Manor?		
(IF YES ABOVE) FALL1_Stairs - Did it involve stairs?	Yes	No
FALL1_NotAtSunny - Not at Sunnyslope?	Yes	No

IF MORE THAN 1 for Q73: For the second fall that happened, where did you fall? Was it in -

FALL2_Home - Your home?	Yes	No
(IF YES ABOVE) FALL2_Where_In_Home - Where in your home did you fall?		
FALL2_Sunny - Not in your unit but elsewhere in Sunnyslope Manor?	Yes	No
(IF YES ABOVE) FALL2_Where_In_Sunny - Where in Sunnyslope Manor?		
(IF YES ABOVE) FALL2_Stairs - Did it involve stairs?	Yes	No
FALL2_NotAtSunny - Not at Sunnyslope?	Yes	No

IF MORE THAN 2 for Q73: For the third fall that happened, where did you fall? Was it in –

FALL3_Home - Your home?	Yes	No
(IF YES ABOVE) FALL3_Where_In_Home - Where in your home did you fall?		
FALL3_Sunny - Not in your unit but elsewhere in Sunnyslope Manor?	Yes	No
(IF YES ABOVE) FALL3_Where_In_Sunny - Where in Sunnyslope Manor?		
(IF YES ABOVE) FALL3_Stairs - Did it involve stairs?	Yes	No
FALL3_NotAtSunny - Not at Sunnyslope?	Yes	No

e) **Question Text:** We just talked about falls during the last 3 months. How MUCH did your home environment contribute to these falls?

1 A lot
2 Some
3 A little
4 Not at all
97 Refused
99 Don't know
88 Not asked

75. **Question Text:** How would you rate the comfort of your home in terms of temperature in the summer? P1 Original

1 Hot
2 Neither not nor cold
3 Cold
97 Refused
99 Don't know

76. **Question Text:** How would you rate the comfort of your home in terms of temperature in the winter? P1 Original

1 Hot
2 Neither hot nor cold
3 Cold
97 Refused
99 Don't know

77. **Question Text:** Is it difficult to control your heating? P1 Original

1 yes
2 No
97 Refused
99 Don't know / Not sure

78. **Question Text:** Since the renovation, how difficult is it to control the temperature with the air conditioner? Would you say:

1 Much more difficult
2 Somewhat more difficult
3 About the same
4 Somewhat easier
5 Much easier
97 Refused
99 Don't know

79. **Question Text:** How often do you open the windows for comfort? Would you say:

1 Much more than before
2 Somewhat more than before
3 About the same
4 Somewhat less than before
5 Much less than before
97 Refused
99 Don't know

80. **Question Text:** How often do you use air conditioning and open the windows at the same time? Would you say:

1 Much more than before
2 Somewhat more than before
3 About the same
4 Somewhat less than before
5 Much less than before
97 Refused
99 Don't know

81. **Question Text:** Does the inside of your home get damp when it rains? P1 Original
1 yes
2 No
97 Refused
99 Don't know / Not sure

82. **Question Text:** Does your home frequently have a mildew odor or musty smell? P1 Original
1 Yes
2 No
97 Refused
99 Don't know

83. **Question Text:** If you have a fan over the stove, how often is it used when someone cooks? P1 Original
1 Always
2 Frequently
3 Sometimes
4 Rarely
5 Never
6 No one cooks in this apartment
8 No fan over the stove or fan not working
97 Refused
99 Don't know

84. **Question Text:** If you have a fan in the bathroom, how often is it used when someone takes a bath or shower? P1 Original
1 Always
2 Frequently
3 Sometimes
4 Rarely
5 Never
8 No bathroom fan in any bathrooms or fan(s) do/did not work
97 Refused
99 Don't know

84a. Have you used the new fan in the bedroom?
1 Yes
2 No
97 Refused
99 Don't know

IF NO AT Q84A:
84b. Why haven't you used it yet?
1 No reason to use it yet
2 Too difficult to use it
3 I don't know how to use it
97 Refused
99 Don't know

IF TOO DIFFICULT AT 84B:
84c. Why is it too difficult to use? **OPEN ENDED.**

85. **Question Text:** Do you have pets?
1 Yes
2 No
97 Refused
99 Don't know / Not sure

(if yes ask next 2 questions)

a) Question Text: What type of pet do you have?

1 Dog
2 Cat
97 Refused
89 Other _____

b) Question Text: Does your pet have full access to your home?

1 yes
2 No
97 Refused
89 Restricted to _____ room

86. **Question Text:** Do you have indoor pests? P1 Original

1 Roaches
2 No
3 Mice/rats
4 bedbugs
97 Refused
99 Don't know / Not sure

87. **Question Text:** Do you use bug sprays?

1 Yes
2 No
97 Refused
99 Don't know / Not sure

88. **Question Text:** Do you smoke?

1 Yes
2 No
97 Refused
99 Don't know / Not sure

88a. IF YES AT Q88: Approximately how many cigarettes a day do you smoke:
(1) Less than 5 cigarettes a day;
(2) More than 5 but less than one package/day;
(3) 1 package/day;
(4) 2-3 packages/day;
(5) More than 3 packages/day

88b. IF YES AT Q88: Do you smoke inside your apartment? YES NO

88c. IF YES AT Q88B: How much of your smoking is inside your apartment? Would you say:
(1) Nearly all my smoking is inside my apartment;
(2) About half of my smoking is inside my apartment;
(3) Very little of my smoking is inside my apartment

88d. IF YES on Q88: At what age did you start smoking? _____

88e. IF NO on Q88: Did you ever smoke? YES NO

88f. IF YES on Q88E: How many years ago did you stop? _____

89. **Question Text:** Do you use anything to change the smell of the air in your home (more than once/week)?

1 Yes
2 No
97 Refused
99 Don't know / Not sure

(If yes, ask next question)

a) Question Text: What do you use? (pick all that apply)

1 Candles
2 Incense
3 Air freshener
4 Other _____
97 Refused
99 Don't know

90. **Question Text:** Do you use an air purifier?

1 Yes
2 No
97 Refused
99 Don't know / Not sure

91. **Question Text:** How easy is it for you to keep your home clean? P1 Original

1 Easy
2 Neither easy nor hard
3 Hard
97 Refused
99 Don't know

92. **Question Text:** What type of cleaning of the floors do you most frequently use? (HEPA vacuum is different than a regular household vacuum in that it contains a special filter that is able to trap very fine dust particles that are too small to see. This type of filter is called a High Efficiency Particulate Air (HEPA) filter).

1 Vacuum
2 HEPA vacuum
3 Sweep or dry mop
4 Wet mop
97 Refused
99 Don't know

92b. **Question Text:** How easy or difficult is it to clean the carpet? Please use a scale from 1 to 7, with 1 meaning "Very easy" and 7 meaning "Very difficult".

1 Very easy
2
3
4
5
6
7 Very difficult
97 Refused
99 Don't know

93. **Question Text:** How frequently do you clean the floors?

1 Daily
2 Weekly
3 Monthly
4 Never
97 Refused
99 Don't know

OVEN1: Have you ever used the self-cleaning feature on your oven? YES NO
OVEN2: IF YES ABOVE: How many times since the renovation when you got this new oven did you use the self-cleaning feature?_____
OVEN3: IF NO ON OVEN1: Why don't you use the self-cleaning feature? Is it because:

(1) I don't need to clean my oven at all;
(2) I prefer to clean my oven by hand, or have someone else clean it by hand;
(3) the odor it produces with the self-cleaning feature;
(4) the self-cleaning feature takes too long;
(5) I didn't know there was a self-cleaning feature

CLEAN1: **Question Text:** I'd like to know what kind of cleaning solutions you use to clean the KITCHEN. Please indicate all that apply (hand them card with response set)

1 Homemade solutions from water, lemon, unscented soap, borax, vinegar, cornstarch or other common household products
2 Store-bought commercial cleaning solutions that are labeled "green" or "natural"
2a If 2 is checked: Can you tell me the brand or show it to me? Record _____
3 Store-bought commercial cleaning solutions that are not labeled "green"
3a If 3 is checked, Can you tell me the brand or show it to me? Record _____
4 Bleach
5 Ammonia
6 Other _____

CLEAN1FREQ:
Question Test: How often do you clean the kitchen?
1 Daily
2 Weekly
3 Monthly
4 Never
97 Refused
99 Don't know

CLEAN2: **Question Text:** I'd like to know what kind of cleaning solutions do you use to clean the BATHROOM? Please indicate all that apply (hand them card with response set)
1 Homemade solutions from water, lemon, unscented soap, borax, vinegar, cornstarch or other common household products
2 Store-bought commercial cleaning solutions that are labeled "green" or "natural"
2a If 2 is checked: Can you tell me the brand or show it to me? Record _____
3 Store-bought commercial cleaning solutions that are not labeled "green"
3a If 3 is checked, Can you tell me the brand or show it to me? Record _____
4 Bleach
5 Ammonia
6 Other _____

CLEAN2FREQ:
Question Test: How often do you clean the bathroom?
1 Daily
2 Weekly
3 Monthly
4 Never
97 Refused
99 Don't know

CLEAN3 **Question Text:** I'd like to know what kind of cleaning solutions do you use to DUST AND CLEAN YOUR FURNITURE? Please indicate all that apply (hand them card with response set)

1 Homemade solutions from water, lemon, unscented soap, borax, vinegar, cornstarch or other common household products
2 Store-bought commercial cleaning solutions that are labeled "green" or "natural"
2a If 2 is checked: Can you tell me the brand or show it to me? Record _____
3 Store-bought commercial cleaning solutions that are not labeled "green"
3a If 3 is checked, Can you tell me the brand or show it to me? Record _____
4 Bleach
5 Ammonia
6 Other _____

CLEAN3FREQ:

Question Test: How often do you dust and clean clean your furniture?
1 Daily
2 Weekly
3 Monthly
4 Never
97 Refused
99 Don't know

94. **Question text:** Do you change the reservoir on your humidifier or dehumidifier every week?
1 Yes
2 No
3 Don't have one
97 Refused
99 Don't know / Not sure

BOOK1: Did you get a copy of the booklet on keeping your home green and healthy (show copy)? YES NO
[IF NO ON BOOK1: I'll ask the property manager to give you a copy]
BOOK2: IF YES ABOVE: Have you looked at it? YES NO
BOOK3: IF YES ON BOOK2: Were any of the recommendations new to you? YES NO
BOOK4: IF YES ABOVE: Which ones? **Open-ended**

Home Safety

TRIP1: Have you tripped when walking in your home? YES NO
TRIP2: IF YES above: Did you trip when walking in your home before it was renovated? YES NO
TRIP3: IF YES above: Was any of that tripping because of (check all that apply):
(1) carpet or flooring;
(2) furniture or cabinetry that got in the way of walking;
(3) water or spill on the floor;
(4) loose rugs;
(5) I was sleepy or dizzy or distracted;
(6) I couldn't see well because of poor or inadequate lighting;
(7) I couldn't see well because of my eyes;
(8) Other _____
TRIP4: IF YES on TRIP1: Did you trip when walking in your home AFTER it was renovated? YES NO
TRIP5: If YES above: Was any of that tripping because of (check all that apply):
(1) carpet or flooring;
(2) furniture or cabinetry that got in the way of walking;
(3) water or spill on the floor;
(4) loose rugs;
(5) I was sleepy or dizzy or distracted

(6) I couldn't see well because of poor or inadequate lighting;
(7) I couldn't see well because of my eyes;
(8) Other _____

95. **Question Text:** Do you turn off the space heater when you leave the room?
1 Yes
2 No
3 Don't have one
97 Refused
99 Don't know / Not sure

96. **Question Text:** How would you rate the amount of noise that you can/could hear from your neighbors at your home?
1 Very noisy
2 Some noise
3 Quiet
97 Refused
99 Don't know / Not sure

97. **Question Text:** How would you rate the odors that you can smell from your neighbors at your home?
1 Very Smelly
2 Some smell
3 No smell
97 Refused
99 Don't know / Not sure

97a. **Question Text:** How would you rate the amount of odors that come from your own home, since the renovation? Would you say there is:
1 Much more smell than before
2 Somewhat more smell than before
3 About the same amount of smell
4 Somewhat less smell than before
5 Much less smell than before
97 Refused
99 Don't know

The last 11 questions are about your comfort in your apartment.

99. **Question Text:** Which of the following do you personally adjust or control in your unit? (check all that apply)
1) Window blinds or shades
2) Operable window
3) Thermostat
4) Portable heater
5) Permanent heater
6) Room air-conditioning unit
7) Portable fan
8) Ceiling fan
9) Adjustable air vent in wall or ceiling
10) Adjustable floor air vent (diffuser)
11) Door to interior space
12) Door to exterior space
13) None of the above
14) Other _____

GRAB1. Do you have grab bars in your bathroom? YES NO

GRAB 2: IF YES ON GRAB1: Were the grab bars installed:

a. by Sunnyslope Manor before the renovation
b. by Sunnyslope Manor after the renovation
c. by yourself, or someone in your family or friend
d. other _____

GRAB3: IF NO ON GRAB1: Would you find it useful to have grab bars in your bathroom? YES NO

THERM1. How difficult is it to use the THERMOSTAT? Would you say very easy, somewhat difficult, or very difficult?

1 Very easy
2 Somewhat difficult
3 Very difficult
97 Refused
99 Don't know / Not sure

IF VERY OR SOMEWHAT DIFFICULT, ASK:

THERM2 **Question Text:** Can you tell me how it is difficult? OPEN ENDED

FAN1 **Question Text:** How difficult is it to use the CEILING FAN? Would you say very easy, somewhat difficult, or very difficult?

1 Very easy
2 Somewhat difficult
3 Very difficult
97 Refused
99 Don't know / Not sure

IF VERY OR SOMEWHAT DIFFICULT, ASK:

FAN2 **Question Text:** Can you tell me how it is difficult? OPEN ENDED

The next questions will ask you to rate on a scale from 1- 7, with 1 the lowest and 7 highest. (The participant may need to be shown the scale to help understand the rating scale.)
P1 Original

100. **Question Text:** How satisfied are you with the temperature in your unit?

Very Dissatisfied						Very Satisfied	Refused	Don't know
1	2	3	4	5	6	7	97	99

101. **Question Text:** Overall, does the temperature in your unit enhance or interfere with your comfort?

Interferes						Enhances	Refused	Don't know
1	2	3	4	5	6	7	97	99

Air Quality P1 Original

102. **Question Text:** How satisfied are you with the air quality in your unit (i.e. stuffy/stale air, cleanliness, odors)?

Very Dissatisfied						Very Satisfied	Refused	Don't know
1	2	3	4	5	6	7	97	99

103. **Question Text:** Overall, does the air quality in your unit enhance or interfere with your comfort?

Interferes						Enhances	Refused	Don't know
1	2	3	4	5	6	7	97	99

103a **Question Text:** Does the air quality enhance or interfere with any BREATHING OR RESPIRATORY AILMENTS YOU HAVE?

Interferes						Enhances	Refused	Don't know
1	2	3	4	5	6	7	97	99

8 = I DO NOT HAVE ANY BREATHING AILMENTS

103b **Question Text:** Does the air quality enhance or interfere with YOUR SLEEP?

Interferes						Enhances	Refused	Don't know
1	2	3	4	5	6	7	97	99

103c **Question Text:** Does the air quality enhance or interfere with any FEELINGS OF DIZZINESS, HEADACHES OR FEELINGS OF NAUSEA?

Interferes						Enhances	Refused	Don't know
1	2	3	4	5	6	7	97	99

8 = I DO NOT HAVE THESE AILMENTS

Lighting P1 Original

104. **Question Text:** Which of the following controls do you have over the lighting in your unit? (check all that apply)

a. Light dimmers
b. Window blinds or shades
c. Desk (task) lights
d. None of the above
e. Other _____

105. **Question Text:** How satisfied are you with the amount of light in your unit?

Very Dissatisfied						Very Satisfied	Refused	Don't know
1	2	3	4	5	6	7	97	99

106. **Question Text:** How satisfied are you with the visual comfort of the lighting (e.g., glare, reflections, contrast)?

Very Dissatisfied						Very Satisfied	Refused	Don't know
1	2	3	4	5	6	7	97	99

107. **Question Text:** Overall, does the lighting quality in your unit enhance or interfere with your comfort?

Interferes						Enhances	Refused	Don't know
1	2	3	4	5	6	7	97	99

Kitchen Environment Satisfaction P1 Original

108. **Question Text:** How satisfied are you with the following aspects of your kitchen?

a. Lighting

Very Dissatisfied						Very Satisfied	Refused	Don't know
1	2	3	4	5	6	7	97	99

b. Temperature conditions

Very Dissatisfied						Very Satisfied	Refused	Don't know
1	2	3	4	5	6	7	97	99

c. Air quality

Very Dissatisfied						Very Satisfied	Refused	Don't know
1	2	3	4	5	6	7	97	99

Building Features P1 Original

109. **Question Text:** For each of the features listed below, please indicate how satisfied you are with the effectiveness of that feature:

a. Thermostats

Very Dissatisfied						Very Satisfied	Refused	Don't know
1	2	3	4	5	6	7	97	99

b. Water-efficient fixtures (for example, low flow toilets, instant hot water heaters, or low flow shower heads)

Very Dissatisfied						Very Satisfied	Refused	Don't know
1	2	3	4	5	6	7	97	99

c. Recycling bins (location, availability)

Very Dissatisfied						Very Satisfied	Refused	Don't know
1	2	3	4	5	6	7	97	99

200. **Question Text:** Overall, what features in your home are you most pleased with? Name as many as you want. P3 Change
OPEN ENDED

201. **Question Text:** Overall, what features in your home are you displeased with? Name as many as you want. P3 Change
OPEN ENDED

202. **Question Text:** Is there anything about your home that you think is not comfortable or does not make you feel good? Name as many as you want. P3 Change
OPEN ENDED

203. **Question Text:** Do you have any additional comments about the renovation or changes made to your home? P3 NEW
OPEN ENDED

Appendix 2.3 Source of Health at Home Interview Questions

Question	Source
Gender	Green Apple Project
Age	NHIS
Birth: Month	NHIS
What date was the renovation completed on your apartment? Please tell me the month, day, and year.	NHIS
Birth: Day	NHIS
Birth: Year	NHIS
Day of the month (ENTER A NUMBER BETWEEN 1 AND 31)	NHIS
Year	NHIS
Do you consider yourself to be Hispanic or Latino?	NHIS
What races do you consider yourself to be?	NHIS
White	NHIS
Black/African American	NHIS
African	NHIS
Indian (American)	NHIS
Alaska Native	NHIS
Asian	NHIS
Pacific Islander	NHIS
Asian Indian	NHIS
Some other race	NHIS
Refused	NHIS
Don't know	NHIS
Do you consider yourself retired from working?	NHIS
What type of work did (do) you do?	NHIS
Management	NHIS
Business or finance	NHIS
Computer or mathematical	NHIS
Architecture or engineering	NHIS
Life, physical or social sciences	NHIS
Community or social services	NHIS
Legal	NHIS
Education, training or library	NHIS
Arts, design, entertainment, sports or media	NHIS
Healthcare support	NHIS
Protective services	NHIS
Food preparation or serving	NHIS
Building grounds cleaning or maintenance	NHIS
Personal care or service	NHIS
Sales related	NHIS
Office or administrative support	NHIS
Farming fishing or forestry	NHIS
Construction or extraction	NHIS
Installation, maintenance or repair	NHIS
Production	NHIS
Transportation or material moving	NHIS
Military	NHIS
Household care or organization	NHIS
Other	NHIS
Refused	NHIS
Don't know	NHIS
Other type of employment: Open ended question.	NHIS
How long have you lived at Sunnyslope?	NCHH
Have you lived in ANOTHER home outside Sunnyslope within the past 6 months?/Since we interviewed you in June or July of 2010, have you lived in ANOTHER home outside Sunnyslope Manor?	NCHH

Question	Source
How many persons live in this apartment, including yourself?	Green Apple Project
Does the additional person (or persons) help with your healthcare?	Green Apple Project
Do you have a person come to visit that helps you with your healthcare?	Green Apple Project
How many days of the week does your healthcare helper come to your home?	Green Apple Project
How would you say that your health is, in general? Would you say Excellent, Very Good, Good, Fair, or Poor?	BRFSS
Now thinking about your physical health, which includes physical illness and injury, for how many days during the past 30 days was your physical health not good? ENTER A WHOLE NUMBER BETWEEN 0 AND 30.	BRFSS
How often do you get the social and emotional support you need? Would you say Always, Usually, Sometimes, Rarely, or Never?	BRFSS
In general, how satisfied are you with your life? Would you say Very satisfied, Satisfied, Dissatisfied, or Very dissatisfied?	BRFSS
During the past 30 days, for about how many days have you felt you did not get enough rest or sleep? ENTER A WHOLE NUMBER BETWEEN 0 AND 30.	BRFSS
On average, how many hours of sleep do you get in a 24-hour period?	BRFSS
Over the last 30 days, have you had trouble with any sleep issues, like falling asleep OR staying asleep OR sleeping too much?	BRFSS
Do you snore?	BRFSS
During the past 30 days, for about how many days did you find yourself unintentionally falling asleep during the day?	BRFSS
Do you now use a hearing aid(s)?	NHIS
Have you ever used a hearing aid(s) in the past?	NHIS
WITHOUT the use of hearing aids or other listening devices, how would you rate your hearing? Would you say your hearing is Excellent, Good, A little trouble hearing, Moderate trouble, A lot of trouble, or are you Deaf?/WITHOUT the use of hearing aids or other listening devices, since the renovation of your apartment, would you say your hearing is: Much better, somewhat better, the same, somewhat worse, or much worse?	NHIS
Do you have any trouble seeing, even when wearing glasses or contact lenses?/Even when wearing glasses or contact lenses, since the renovation of your apartment, would you say your vision is:	NHIS
Are you blind or unable to see at all?	NHIS
Hypertension, also called high blood pressure / Since the renovation of your apartment, have you been NEWLY DIAGNOSED with:	NHIS
Coronary heart disease / Since the renovation of your apartment, have you been NEWLY DIAGNOSED with:	NHIS
Angina, also called angina pectoris / Since the renovation of your apartment, have you been NEWLY DIAGNOSED with:	NHIS
A heart attack (also called myocardial infarction) / Since the renovation of your apartment, have you been NEWLY DIAGNOSED with:	NHIS
Any kind of heart condition or heart disease (other than the ones I just asked about) / Since the renovation of your apartment, have you been NEWLY DIAGNOSED with:	NHIS
A stroke / Since the renovation of your apartment, have you been NEWLY DIAGNOSED with:	NHIS
Emphysema / Since the renovation of your apartment, have you been NEWLY DIAGNOSED with:	NHIS
Asthma / Since the renovation of your apartment, have you been NEWLY DIAGNOSED with:	BRFSS, NHIS
Do you still have asthma?	NHIS

Question	Source
DURING THE PAST 12 MONTHS, have you had an episode of asthma or an asthma attack?/Have you had an episode of asthma or an asthma attack since the renovation of your apartment?	BRFSS, NHIS
DURING THE PAST 12 MONTHS, have you had to visit an emergency room or urgent care center because of asthma?/Since the renovation, have you had to visit an emergency room or urgent care center because of asthma?	NHIS
How old were you when you were first told you had asthma? ENTER A WHOLE NUMBER.	NHIS
Were you less than 16, or 16 or older, when you were first told you had asthma?	NHIS
Compared to when you were first told you had asthma, would you say your asthma has been better, worse, or about the same as an adult?	Green Apple Project
Have you been told by a doctor or other health professional that your asthma was probably related to something in your home?	Green Apple Project
Do you believe that your asthma was probably related to something in your home?	Green Apple Project
Have you EVER been told by a doctor or other health professional that you have diabetes or sugar diabetes? [Other than during pregnancy)/ Since the renovation of your apartment, have you been NEWLY DIAGNOSED with diabetes or sugar diabetes?	BRFSS, NHIS
How old were you when a doctor or other health professional FIRST told you that you had diabetes or sugar diabetes?	BRFSS, NHIS
Are you now taking blood sugar medicine (mouth or injections)?	BRFSS, NHIS
Have you ever been told by a doctor or other health professional that you have a seizure disorder or epilepsy?/Since the renovation of your apartment, have you been NEWLY DIAGNOSED with a seizure disorder or epilepsy?	NHIS
Are you currently taking any medicine to control your seizure disorder or epilepsy?	NHIS
Think back to last year about the same time. About how many seizures of any type have you had in the past year?	Green Apple Project
Hay fever / Since the renovation of your apartment, have you been NEWLY DIAGNOSED with:	NHIS
Sinusitis / Since the renovation of your apartment, have you been NEWLY DIAGNOSED with:	NHIS
Allergy : Since the renovation of your apartment, have you been NEWLY DIAGNOSED with:	NHIS
Chronic bronchitis / Since the renovation of your apartment, have you been NEWLY DIAGNOSED with:	NHIS
Have you ever seen a doctor or other health professional for a skin condition?/Since the renovation of your apartment, have you been NEWLY DIAGNOSED with a skin condition?	NHIS
Have you been told by a health professional that your skin condition was probably related to something in your home?	Green Apple Project
Do you believe that your skin condition is probably related to something in your home?	Green Apple Project
Since the renovation of your apartment, have you been NEWLY DIAGNOSED with cancer?	Green Apple Project
Has a doctor or other healthcare provider EVER told you that you have an anxiety disorder?/Since the renovation of your apartment, have you been NEWLY DIAGNOSED with an anxiety disorder (including acute stress disorder, anxiety, generalized anxiety disorder, obsessive-compulsive disorder, panic disorder, phobia, posttraumatic stress disorder, or	BRFSS

Question	Source
Has a doctor or other healthcare provider EVER told you that you have a depressive disorder (including depression, major depression, dysthymia, or minor depression)?/Since the renovation of your apartment, have you been NEWLY DIAGNOSED with a depressive disorder (including depression, major depression, dysthymia, or minor depression)?	BRFSS
Have you EVER been told by a doctor or other health professional that you have some form of arthritis, rheumatoid arthritis, gout, lupus, or fibromyalgia?/Since the renovation of your apartment, have you been NEWLY DIAGNOSED with some form of arthritis, rheumatoid arthritis, gout, lupus, or fibromyalgia (fy-bro-my-AL-jee-uh)?	NHIS
DURING THE PAST 30 DAYS, have you had any symptoms of pain, aching, or stiffness in or around a joint?	NHIS
Shoulder-right	NHIS
Shoulder-left	NHIS
Elbow-right	NHIS
Elbow-left	NHIS
Hip-right	NHIS
Hip-left	NHIS
Wrist-right	NHIS
Wrist-left	NHIS
Knee-right	NHIS
Knee-left	NHIS
Ankle-right	NHIS
Ankle-left	NHIS
Toes-right	NHIS
Toes-left	NHIS
Fingers/thumb-right	NHIS
Fingers/thumb-left	NHIS
Other joint not listed	NHIS
Refused	NHIS
Don't know	NHIS
What joint is most problematic?	NHIS
Did your joint symptoms FIRST begin more than 3 months ago?/Did your joint symptoms FIRST begin before the renovation of your apartment?	NHIS
How MUCH does your home environment contribute to your joint stiffness?	Green Apple Project
Are you now limited in any way in any of your usual activities because of arthritis or joint symptoms?	NHIS
Have you EVER been told by a doctor or other health professional that you have a condition affecting the wrist and hand called carpal tunnel syndrome?/Since the renovation of your apartment, have you been NEWLY DIAGNOSED with a condition affecting the wrist and hand called carpal tunnel syndrome?	NHIS
DURING THE PAST THREE MONTHS, did you have ... Neck pain?/Since the renovation of your apartment, have you had ... Neck pain?	NHIS
DURING THE PAST THREE MONTHS, did you have ... Low back pain?/Since the renovation of your apartment, have you had ... Low back pain?	NHIS
Did this pain spread down either leg to areas below the knees?	NHIS
DURING THE PAST THREE MONTHS, did you have ...Severe headache or migraine?/Since the renovation of your apartment, have you had ... Severe headache or migraine?	NHIS
During the past 30 days, how often did you feel: Healthy and full of energy	NHIS

Question	Source
During the past 30 days, how often did you feel: So sad that nothing could cheer you up	NHIS
During the past 30 days, how often did you feel: Nervous	NHIS
During the past 30 days, how often did you feel: Restless or fidgety	NHIS
During the past 30 days, how often did you feel: Hopeless	NHIS
During the past 30 days, how often did you feel: That everything was an effort	NHIS
During the past 30 days, how often did you feel: Worthless	NHIS
We just talked about a number of feelings you had during the PAST 30 DAYS. Altogether, how MUCH did these feelings interfere with your life or activities: a lot, some, a little, or not at all?	NHIS
We just talked about a number of feelings you had during the PAST 30 DAYS. Altogether, how MUCH did your home environment contribute to these feelings: a lot, some, a little, or not at all?	Green Apple Project
To what extent did the renovation of your home affect your emotions overall? Would you say your feelings and emotions are: much better, somewhat better, the same, somewhat worse, or much worse?	Green Apple Project
What aspects or features of the renovation made you feel that way?	Green Apple Project
During the PAST 12 MONTHS, that is, since {TODAY'S DATE LAST YEAR}, ABOUT how many days did illness or injury keep you in bed more than half of the day (include days while an overnight patient in a hospital)?/Since the renovation of your apartment, ABOUT how many days did illness or injury keep you in bed more than half of the day (include days while an overnight patient in a hospital)?	NHIS
Compared with 12 MONTHS AGO, would you say your health is better, worse, or about the same?/Since the renovation, would you say your health is better, worse, or about the same?	NHIS
Do you now have any health problem that requires you to use special equipment, such as a cane, a wheelchair, a special bed, or a special telephone?/Since the renovation, do you now have any NEW health problem that requires you to use special equipment, such as a cane, a wheelchair, a special bed, or a special telephone?	NHIS
Since the renovation / by yourself, and without using any special equipment, how much more difficult is it for you to...	
Walk a quarter of a mile - about 3 city blocks	NHIS
Walk up 10 steps without resting	NHIS
Stand or be on your feet for about 2 hours	NHIS
Sit for about 2 hours	NHIS
Stoop, bend, or kneel	NHIS
Reach up over your head	NHIS
Use your fingers to grasp or handle small objects	NHIS
Lift or carry something as heavy as 10 pounds such as a full bag of groceries	NHIS
Push or pull large objects like a living room chair	NHIS
Participate in social activities such as visiting friends, attending clubs and meetings, going to parties	NHIS
Do things to relax at home or for leisure (reading, watching TV, sewing, listening to music)	NHIS
We just talked about your physical limitations. Altogether, how MUCH did your home structure contribute to difficulties?	Green Apple Project
Vision/problem seeing	NHIS
Hearing problem	NHIS
Arthritis/rheumatism	NHIS
Back or neck problem	NHIS

Question	Source
Fracture, bone/joint injury	NHIS
Other injury	NHIS
Heart problem	NHIS
Stroke problem	NHIS
Hypertension/high blood pressure	NHIS
Diabetes	NHIS
Lung/breathing problem(e.g., asthma and emphysema)	NHIS
Cancer	NHIS
Birth defect	NHIS
Mental retardation	NHIS
Other developmental problem (e.g., cerebral palsy)	NHIS
Senility	NHIS
Depression/anxiety/emotional problem	NHIS
Weight problem	NHIS
Missing limbs (fingers, toes or digits), amputee	NHIS
Kidney, bladder or renal problems	NHIS
Circulation problems (including blood clots)	NHIS
Benign Tumors, Cysts	NHIS
Fibromyalgia, lupus	NHIS
Osteoporosis, tendinitis	NHIS
Epilepsy, seizures	NHIS
Multiple Sclerosis (MS), Muscular Dystrophy (MD)	NHIS
Polio(myelitis), paralysis, para/quadriplegia	NHIS
Parkinson's disease, other tremors	NHIS
Other nerve damage, including carpal tunnel syndrome	NHIS
Hernia	NHIS
Ulcer	NHIS
Varicose veins, hemorrhoids	NHIS
Thyroid problems, Grave's disease, gout	NHIS
Knee problems (not arthritis (03), not joint injury(05))	NHIS
Migraine headaches (not just headaches)	NHIS
Other impairment/problem 1 (write in)	NHIS
Other impairment/problem 2 (write in)	NHIS
Refused	NHIS
Don't know/Not sure	NHIS
Other	NHIS
Other	NHIS
In the past 3 months, how many times have you fallen? /Since your apartment was renovated, how many times have you fallen?	BRFSS
Did this fall cause an injury?	BRFSS
How many of these falls caused an injury? By an injury, we mean the fall caused you to limit your regular activities for at least a day, or to go see a doctor.?	BRFSS
How much did your home environment contribute to these falls?	Green Apple Project
Have you changed or has someone else changed your heating or air conditioning filters in past 8 months?	HHIM
How would you rate the comfort of your home in terms of temperature in the summer? Would you say Hot, Neither not nor cold, or Cold?	Green Apple Project
How would you rate the comfort of your home in terms of temperature?	Green Apple Project
How would you rate the comfort of your home in terms of temperature in the winter? Would you say Hot, Neither hot nor cold, or Cold?	Green Apple Project
How would you rate the comfort of your home in terms of indoor humidity or moisture?	Green Apple Project
How difficult is it to control your heating?	HHIM
Do you use air conditioning for comfort?	Green Apple Project

Question	Source
How difficult is it to control the temperature with the air conditioner?	Green Apple Project
For questions Q79-Q82, Panel 1 asks if the resident does the activity and Panel 2 asks how often they do that activity	Green Apple Project
Do you open the windows for comfort?/How often do you open the windows for comfort?	Green Apple Project
How often do you use air conditioning and open the windows at the same time?	Green Apple Project
How often does the inside of your home get damp when it rains?	HHIM
How often does your home have a mildew odor or musty smell?	HHIM
If you have a fan over the stove, how often is it used when someone cooks?	Green Apple Project
If you have a fan in the bathroom, how often is it used when someone takes a bath or shower?	Green Apple Project
Have you used the new fan in the bedroom?	Green Apple Project
Why haven't you used it yet?	Green Apple Project
Why is it too difficult to use?	Green Apple Project
Do you have pets?	HHIM
What type of pet do you have?	HHIM
Other type of pet: open ended	HHIM
Does your pet have full access to your home?	HHIM
Other pet access: open ended	HHIM
Do you have indoor pests?	HHIM
Compared to your home before the renovation, do you have ROACHES in your home now?	Green Apple Project
Compared to your home before the renovation, do you have MICE in your home now?	Green Apple Project
Compared to your home before the renovation, do you have RATS in your home now?	Green Apple Project
Compared to your home before the renovation, do you have BEDBUGS in your home now?	Green Apple Project
Do you use bug sprays?	HHIM
Do you smoke?	HHIM
Do you use anything to change the smell of the air in your home (more than once a week)?	HHIM
Candles	HHIM
Incense	HHIM
Air freshener	HHIM
Other	HHIM
Refused	HHIM
Don't know	HHIM
Other	HHIM
Do you use an air purifier?	HHIM
How easy is it for you to keep your home clean?/Compared to your home before the renovation, how easy is it for you to keep your home clean?	HHIM
What type of cleaning do you most frequently use?	HHIM
Vacuum	HHIM
HEPA vacuum	HHIM
Sweep or dry mop	HHIM
Wet mop	HHIM
Refused	HHIM
Don't know	HHIM
How easy or difficult is it to clean the new carpet? Please use a scale from 1 to 7, with 1 meaning "Very easy" and 7 meaning "Very difficult". You can select any number between 1 and 7.	Green Apple Project

Question	Source
How frequently do you clean with the above item?	HHIM
How frequently do you clean the floors?	HHIM
What kind of cleaning solutions do you use to clean the KITCHEN?	Green Apple Project
What kind of cleaning solutions do you use to clean the BATHROOM?	Green Apple Project
What kind of cleaners do you use to DUST AND CLEAN YOUR FURNITURE?	Green Apple Project
Do you change the reservoir on your humidifier or dehumidifier every week?	HHIM
Do you turn off the space heater when you leave the room?	HHIM
How would you rate the amount of noise that you can hear from your neighbors at your home?	BRFSS
How would you rate the odors that you can smell from your neighbors at your home? Would you say very smelly, only some smell, or no smell at all?	Green Apple Project
How would you rate the odors that you can smell coming from your own home since the renovation? Would you say very smelly, only some smell, or no smell at all?	Green Apple Project
How would you rate the amount of odors that come from your neighbors' homes, since the renovation? Would you say there is:	Green Apple Project
How would you rate the amount of odors that come from your own home, since the renovation? Would you say there is:	Green Apple Project
How would you rate the odors that you can smell from your neighbors at your home? Would you say very smelly, only some smell, or no smell at all?	Green Apple Project
Do the smells ever make you feel NAUSEOUS?	Green Apple Project
Do the smells ever make you feel DIZZY?	Green Apple Project
Window blinds or shades	Green Apple Project
Operable window	Green Apple Project
Thermostat	Green Apple Project
Portable heater	Green Apple Project
Permanent heater	Green Apple Project
Room air-conditioning unit	Green Apple Project
Portable fan	Green Apple Project
Ceiling fan	Green Apple Project
Adjustable air vent in wall or ceiling	Green Apple Project
Adjustable floor air vent (diffuser)	Green Apple Project
Door to interior space	Green Apple Project
Door to exterior space	Green Apple Project
Other	Green Apple Project
NONE OF THE ABOVE	Green Apple Project
Resident controls or adjusts personally:Other: open ended	Green Apple Project
How difficult is it to use the THERMOSTAT? Would you say very easy, somewhat difficult, or very difficult?	Green Apple Project
Can you tell me how it is difficult?	Green Apple Project
How difficult is it to use the CEILING FAN? Would you say very easy, somewhat difficult, or very difficult?	Green Apple Project
Can you tell me how it is difficult?	Green Apple Project
How satisfied are you with the temperarature in your unit / after the renovation?	IEQ
Overall, does your temperature in your unit enhance or interfere with your comfort / after the renovation?	IEQ
How satisfied are you with the air quality in your unit (i.e. stuffy/stale air, cleanliness, odors) / after the renovation?	IEQ
Overall, does the air quality in your unit enhance or interfere with your comfort / after the renovation?	IEQ

Question	Source
Does the air quality in your unit enhance or interfere with ANY BREATHING OR RESPIRATORY AILMENTS YOU HAVE (such as allergies, bronchitis, hay fever) after the renovation?	IEQ
Does the air quality in your unit enhance or interfere with YOUR SLEEP after the renovation?	IEQ
Does the air quality in your unit enhance or interfere with FEELINGS OF DIZZINESS, HEADACHES, OR FEELINGS OF NAUSEA after the renovation?	IEQ
Light dimmers	IEQ
Window blinds or shades	IEQ
Desk (task) lights	IEQ
Other	IEQ
None of the above	IEQ
How satisfied are you with the amount of light in your unit / after the renovation?	IEQ
How satisfied are you with the visual comfort of the lighting (e.g., glare, reflections, contrast) / after the renovation?	IEQ
Overall, does the lighting quality in your unit enhance or interfere with your comfort?	IEQ
How satisfied are you with the LIGHTING in your kitchen / after the renovation?	IEQ
How satisfied are you with the TEMPERATURE CONDITIONS in your kitchen / after the renovation?	IEQ
How satisfied are you with the AIR QUALITY in your kitchen / after the renovation?	IEQ
Thermostats : For each of the features listed here, please indicate how satisfied you are with the effectiveness of that feature / after the renovation.	IEQ
Water-efficient fixtures (for example, low flow toilets, instant hot water heaters, or low flow shower heads) : For each of the features listed here, please indicate how satisfied you are with the effectiveness of that feature / after the renovation.	IEQ
Recycling bins (location and availability) : For each of the features listed here, please indicate how satisfied you are with the effectiveness of that feature / after the renovation.	IEQ
How would you rate the safety of your neighborhood? Would you say - Safe, Neither safe nor unsafe, or Unsafe?	IEQ
Overall, what features or changes in your new renovated home are you MOST pleased with? Please name as many as you want.	Green Apple Project
Overall, what features or changes in your new renovated home are you DISPLEASED with? Please name as many as you want.	Green Apple Project
Is there anything about your home that you think is not comfortable or does not make you feel good? Please name as many as you want.	Green Apple Project

BFRSS:	Behavioral Risk Factors Social Survey
Green Apple Project:	Unique to Health at Home interview
HHIM:	Healthy Housing Inspection Manual
IEQ:	University of California Center of Built Environment
NHIS:	National Health Interview Survey

Appendix 2.4 Resident IEQ Perceptions and Assessments Items on Health at Home Survey

Source: CBE Occupant IEQ Survey, Residential

- How satisfied are you with the temperature in your unit / after the renovation?
- Overall, does your temperature in your unit enhance or interfere with your comfort / after the renovation?
- How satisfied are you with the air quality in your unit (i.e. stuffy/stale air, cleanliness, odors) / after the renovation?
- Overall, does the air quality in your unit enhance or interfere with your comfort / after the renovation?
- Does the air quality in your unit enhance or interfere with any breathing or respiratory ailments you have (such as allergies, bronchitis, hay fever) / after the renovation?
- Does the air quality in your unit enhance or interfere with your sleep / after the renovation?
- Does the air quality in your unit enhance or interfere with feelings of dizziness, headaches, or feelings of nausea / after the renovation?
- Do you have control over your homes: light dimmers? Window blinds or shades? Des (task) lights? Other?
- How satisfied are you with the amount of light in your unit / after the renovation?
- How satisfied are you with the visual comfort of the lighting (e.g. glare, reflections, contrast) / after the renovation?
- Overall, does the lighting quality in your unit enhance or interfere with your comfort?
- How satisfied are you with the lighting in your kitchen / after the renovation?
- How satisfied are you with the temperature conditions in your kitchen / after the renovation?
- How satisfied are you with the air quality in your kitchen / after the renovation?
- How would you rate the safety of your neighborhood?

Source: Healthy Homes Inspection Manual

- Have you changed or has someone else changed your heating or air conditioning filters in the past 8 months?
- How difficult is it to control your heating?
- How often does the inside ofyour home get damp when it rains?
- How often does your home have a mildew odor or musty smell?
- Do you have pets?
- What type of pet do you have?
- Does your pet have full access to your home?
- Do you have indoor pests?
- Do you use bug sprays?
- Do you smoke?
- Do you use anything to change the smell of the air in your home (more than once a week)? Candles? Incense? Air freshener? Other?
- Do you use an air purifier?
- How is it for you to keep your home clean? / Compared to your home before the renovation, how easy it it for you to keep your home clean?
- What type of cleaning do you most frequently use? Vacuum? HEPA vacuum? Sweep or dry mop? Wet mop?
- How frequently do you clean with the above item?
- How frequently do you clean the floors?
- Do you change the reservoir on your humidifier or dehumidifier?
- Do you turn off the space heater when you leave the room?

Health at Home Survey (newly created items)

- For each of the features listed here, please indicate how satisfied you are with the effectiveness of that feature / after the renovation:
  (1) Thermostats
  (2) Water-efficient fixtures (e.g. low flow toilets, instant hot water heaters, low flow shower heads)
  (3) recycling bins(location and availability)
- *Approximately how many cigarettes a day do you smoke?
- *Do you smoke inside your apartment?
- *How much of your smoking is inside your apartment?
- *At what age did you start smoking?
- *Did you ever smoke?
- *How many years ago did you stop?
- *Have you ever used the self-cleaning feature on your oven?
- *How many times since the renovation when you this oven did you use the self-cleaning feature?
- *Why don't you use the self-cleaning feature?
- *I'd like to know what kind of cleaning solutions you use to clean the KITCHEN
- *How often do you clean the kitchen?
- *I'd like to know what kind of cleaning solutions you use to clean the BATHROOM
- *How often do you clean the bathroom?
- *I'd like to know what kind of cleaning solutions you use to DUST AND CLEAN YOUR FURNITURE
- *How often do you dust and clean your furniture?
- *Did you get a copy of the booklet on keeping your home green and healthy (show copy)?
- *Have you looked at it?
- *Were any of the recommendations new to you?
- *Have you tripped when walking in your home?
- *Did you trip when walking in your home before it was renovated?
- *Was any of that tripping because of:
  1. Carpet or Flooring
  2. Furniture or cabinetry that got in the way of walking
  3. Water or spill on the floor
  4. Loose rugs
  5. I was sleepy or dizzy or distracted
  6. I couldn't see well because of poor or inadequate lighting
  7. I couldn't see well because of my eyes
  8. Other
- *Did you trip when walking in your home AFTER it was renovated?
- *Was any of the tripping because of:
  1. Carpet or Flooring
  2. Furniture or cabinetry that got in the way of walking
  3. Water or spill on the floor
  4. Loose rugs
  5. I was sleepy or dizzy or distracted
  6. I couldn't see well because of poor or inadequate lighting
  7. I couldn't see well because of my eyes
  8. Other
- *Do you have grab bars in your bathroom?
- *Were the grab bars installed:
  1. By Sunnyslope Manor before the renovation
  2. By Sunnyslope Manor after the renovation
  3. By yourself, or someone in your family or friend
  4. Other
- *Would you find it useful to have grab bars in your bathroom?
- *Do you have any additional comments about the renovation or changes made to your home?

*** Included only in P3 interview**

Appendix 6.1. Panel 3 (2012) Percentages of SSM Residents Reporting Various Health Conditions (n=57)

Emotional Distress (n=57)

	All/ Most	Some/ Llittle	None
So sad nothing could cheer you	7 %	29 %	65 %
Nervous	5.5 %	47 %	47 %
Restless and fidgety	3.5 %	44 %	53 %
Hopeless	3.5 %	19 %	77 %
Everything is an effort	9 %	31.5 %	60 %
Worthless	2 %	9 %	89 %

Health and Full of Energy

	All/Most	Some/Little	None
Health and Full of Energy	55 %	38.5 %	7 %

General Health

	Excellent	Very Good	Good	Fair	Poor
General Health	03.5 %	17.5 %	40 %	28 %	10.5 %

Number of Days Physical Health Not Good, Unintentional Sleep

	0 days	1-7 days	8-23 days	24+ days
# Days Physical Health Not Good	47 %	26 %	12 %	14 %
# Days of Unintentional sleep	46 %	33 %	9 %	12 %

Satisfaction with Life

	Very Satisfied	Satisfied	Dissatisfied	Very Dissatisfied
Satisfaction with Life	26 %	61.5 %	10.5 %	2 %

Functional Assessments

Difficulty With	None	Little	Very	Can't
Walk 3 City Blocks	35 %	33 %	10.5 %	17.5 %
Stand For 2 Hours	21 %	31.5 %	19 %	23 %
Sit For 2 Hours	49 %	44 %	5 %	2 %
Stoop, Bend, Kneel	26 %	33 %	24.5 %	12 %
Reach Over Head	74 %	17.5 %	7 %	2 %
Grasp Handle Small Objects	74 %	17.5 %	9 %	0 %
Carry 10 Pounds	49 %	30 %	12 %	5 %
Push Pull Heavy Objects	60 %	23 %	9 %	7 %
Go Out Of Apt To Socialize	77 %	21 %	2 %	0 %

Reported Pain

Pain in neck (last 3 mos)	16%
Pain in Lower Back (last 3 mos)	51%
Arthritis limits activity (last 3 mos)	35%

Notes:

Notes: