Expanding the Definition of Green: *Impacts of Green and Active Living Design on Health in Low Income Housing: Added Value of Behavioral Interventions as part of an Integrated Service Delivery Model*

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Executive Summary

The HUD Healthy Homes Technical Studies program funded a 3-year study at an Energy Star rated affordable multi-family residential building in the South Bronx, NY, which was completed in August 2013. The building, completed in 2009, contains 127 apartments on six and seven floors with a total floor area of slightly less than 150,000 square feet. The study used a participatory research design to investigate whether green-building objectives were in conflict with or complementary to health-related objectives for residents. The research design included baseline measurements of resident perceptions and apartment-specific indoor air quality (IAQ) and energy performance, followed by interventions designed to improve outcomes for residents, followed by additional rounds of measurements to determine the effects of the interventions. The number of participants was approximately 1/3 of all apartments (baseline n= 40 shared between control and treatment groups), and the results support several findings, summarized below.

Conflicts between green-building and resident health objectives emerged, some related to the design of the building, and others to its operation and leasing arrangements. The two most important were:

- The building was designed to have low ventilation rates to save energy, but odor problems and poor IAQ sometimes resulted.
- Statistically significantly higher CO_2 levels were found in apartments where recent (6-9 months ago) asthma attacks were reported stressing importance of proper ventilation.
- Sending price signals to residents helps them save energy. However, some asthmatic residents may be underutilizing needed air-conditioning equipment because of difficulties in affording the associated high utility bills.

Complementarities between green and healthy also emerged, including the following:

- The rooftop garden helped manage stormwater and urban heat island effects, and it also served as a catalyst for building - level interventions that inspired some residents to grow and eat local vegetables.

- An emphasis by the building management on low VOC materials, finishes and maintenance products provided the platform for programs on improving indoor air quality.

Two interventions had significant effects. Lower airborne particle concentrations were observed in apartments that received IAQ-related interventions, and utility bills dropped in apartments receiving energy-efficiency interventions. Healthy eating and active living interventions resulted in modest changes to self-reported behavior.

Based on this study, HUD should consider the following recommendations:

- Resist the temptation to under-ventilate in order to save energy.
- Treat air conditioning as a necessity not a luxury for asthmatic individuals.
- Expand the use of housing as a platform for social service delivery. Incorporate programming to support long-term initiatives for residents about available low VOC cleaning tools and supplies, healthy eating and active living, and energy conservation.
- Involve residents in the design of culturally-appropriate behavioral interventions to help transition behavior to more healthful or energy conserving habits.
- Encourage the incorporation of outside authorities and consultants into interventions where needed to offer specialization and preserve privacy.
- Prioritize moisture control and integrated pest management, and develop more cost-efficient means to identifying and managing such problems.

Project Report Overview

This report is the culmination of a 36-month longitudinal field study from August 2010 through August 2013. The associated research was supported by funding from HUD's Healthy Homes Technical Studies program, Grant # NJLHH0202-09 and contracted to Rutgers, the State University of New Jersey and its partners Polytechnic Institute of New York University, and the non-profit Women's Housing and Economic Development Corporation (WHEDco). Over the course of the project work, the research team provided regular technical reports as well as research briefs and presentations to HUD staff, research participants, and academic peers at conferences on green building, exposure science, housing and environmental psychology. The feedback received at each of these points has been valuable and we are grateful to those who have provided us with constructive comments during this time. We wish to particularly acknowledge the involvement of Dr. Kofi Berko, HUD Project Manager and also Karen Lee, New York Department of Health and Mental Hygiene, who provided much helpful advice and review on the Healthy Eating Active Living (HEAL) aspects of this research.

The organization of this report is as follows. In the section immediately following, we recount the study's needs, aims and objectives. Following this, we share a summary of our research design and methods and aspects of how the study was carried out, and then present our findings and significant outcomes. Beyond what is reported in this section, we also attach three free-standing reports/articles-in-progress regarding indoor air quality (IAQ) findings, IAQ measurement and methods, and the efficacy of energy efficiency interventions in an affordable/green housing context. The last section of this report comprises our conclusions and recommendations. Figures and tables referenced in the report text are found in Appendix A, while other attachments are located in Appendix B.

Study Need, Aims And Objectives

Government agencies, universities, non-profits, and private enterprises have been working together for generations to address the confluence of poverty and chronic health conditions. In recent decades, a focus on "green building" and "green living" within the context of affordable housing has been added to the toolkit of policy-makers and advocates. Green building design is widely believed to improve occupant health, comfort, and productivity by providing improved indoor air and environmental quality (IEQ) (U.S. Green Building Council, 2010; United Nations Environment Programme, 2012). Studies have shown the efficacy of healthy lifestyle interventions implemented through community centers (Russell, Rufus, Fogarty, Fiscella, & Jennifer, 2013) and in the workplace (Dubuy, De Cocker, De Bourdeaudhuij, Maes, Seghers, Lefevre, De Martelaer, Cardon, 2013; Niks, de Jonge, Gevers, Houtman, 2013). However, studies of these kinds of interventions within an affordable housing context are not well represented in the literature. This is surprising, given recent scholarship on healthy initiatives for low-wealth and underserved urban populations. In these groups, researchers have found unique barriers to healthy behavioral change such as limited access to healthy food (Russell, Rufus, Fogarty, Fiscella, & Jennifer, 2013) and deep legacies of disenfranchisement and environmental inequality (Rowe, 2010). Russell, et al (2013) also report that healthy behavioral changes were most often adopted when personal, interpersonal, programmatic, and community - level connections were integrated into an overall service delivery framework. This research finding and supporting anecdotal evidence point to the potential benefit of incorporating interventions into an affordable housing context to improve residents' lives.

The intent of this project was to identify and document experiences at the Intervale Green multi-family dwelling built and operated by WHEDCo as they relate to its ability to serve as a platform for improving occupant health. The project documented green/sustainable design features, operating practices, and resident behaviors, and performed interventions exploring potential trade-offs between energy efficiency and IAQ, and active living design and IAQ. Recognizing that building design, building operation and resident behavior can act at cross purposes an important aspect of this research is an evaluation of the interplay of these factors so as to better understand and take advantage of synergies among them, while avoiding or mitigating conflicts. This study is innovative as it broadens the definition of "green building" to demonstrate *empirically* how green building strategies within an affordable housing context may

serve as an opportunity to intervene broadly in the complex and intertwined challenges of poverty, environmental conditions, and poor health.

A multidisciplinary team of planners, behavioral and social scientists, indoor air quality specialists, and a community development and housing provider collaborated to test the following hypothesis: *Culturally appropriate behavioral interventions targeted to influence energy use, indoor air quality and levels of physical exercise and healthful eating will be adopted by residents and lead to improved outcomes* as measured through subjective and, for IAQ and energy consumption, objective data.

By culturally appropriate, we mean that needed materials were inexpensive, locally available and not inconsistent with or offensive to residents' values, tastes and preferences. By behavioral intervention, we mean the provision of tools and methods for improving energy, IAQ and healthy eating, active living (HEAL) outcomes, including information and feedback in a guided learning format, one-to-one instruction, workshops and reinforcing interviews and phone calls over a sufficient period of time for the health or energy conserving behavior to be adopted. We consider that an intervention has been adopted when there is a consistent pattern of use as reported by a resident and according to a variety of tracking tools we put in place to help the resident record adoptive practices. We also relied on researcher observational protocols and other objective data to confirm adoptive behavior. Thus, a related objective of this work was to better understand *patterns* of health and energy efficiency enhancing adoptive behavior in a green affordable housing setting.

Community and Resident Background

In the South Bronx neighborhood of New York City, approximately 37% of residents live below the federal poverty level and 17% live in severe poverty (da Costa Nunez, Harris, & Hribar, 2012). This population of residents is predominately made up of Blacks and Hispanics, the same racial and ethnic groups most affected by asthma. In the Bronx, 30% of the approximately 1.4 million inhabitants are African American and 54% are Hispanic[1]. Among Bronx residents, twenty-two percent of adults under the age of 65 are uninsured and approximately 17% state that in the past twelve months they were unable to see a doctor due to

[1] http://www.countyhealthrankings.org/app/new-york/2013/bronx/county/factors/3/additional/by-rank

cost. In addition to having the highest unemployment rate of the New York State counties, Bronx residents also suffer from poorer health outcomes than their state and national counterparts.

It is estimated that most people spend approximately 90 percent of their time indoors (Klepeis, Nelson, Ott, Robinson, Tsang, Switzer, Behar, Hern, & Engelmann, 2001; U.S. Environmental Protection Agency, 1995; Wu, Jacobs, Mitchell, Miller, & Karol, 2007). This statistic is most significant when taking into consideration that those populations most vulnerable to the effects of indoor air and environmental quality (IEQ), the elderly, children, and the ill are also the same populations likely to spend the most time indoors. In addition to the significant amount of time spent indoors, certain health conditions, like asthma, can be exacerbated by some pollutants found in indoor environments. Of the seven million children living with asthma, those living below the poverty level and/or minorities are disproportionately affected (U.S. Environmental Protection Agency, 2012c). From 2005-2007 Bronx county residents suffered the highest age-adjusted asthma mortality rate in New York State at 35.2 per 1,000,000 residents as compared with the rate for the state of 12.5 per 1,000,000[2]. Bronx residents also have a higher percentage of adults who are overweight or obese (BMI >=25), 68% as compared with the state rate of 59%[3].

Intervale Green: the Study Site

Completed in 2009, Intervale Green in the South Bronx, NY, was at the time the largest *EnergyStar* certified, multifamily, affordable high-rise residence in the United States, occupying almost 150,000 square feet with 127 one-, two- and three-bedroom apartments and over 6,000 square feet of ground-floor commercial space.[4] [5] [6] It was constructed to serve some of the area's lowest income and otherwise vulnerable residents. Building residents originated from various communities across New York City and many had previously lived under difficult situations in temporary homes, shelter homes, or doubled-up in shared households. Many Intervale Green households are headed by single females with two or more kids. Family incomes of the residents in the building are significantly below the median family income for the South Bronx, which is among the poorest counties in the state.

[2] http://www.health.ny.gov/statistics/ny_asthma/pdf/2009_asthma_surveillance_summary_report.pdf#page=1
[3] http://www.health.ny.gov/statistics/prevention/obesity/county/bronx.htm
[4] WHEDco's Intervale Green Initial Resident Report 2010
[5] WHEDco – Intervale Green Website http://www.whedco.org/greenhomes/intervalegreen
[6] Gb NYC commercial property leasing and sales website - http://www.greenbuildingsnyc.com/2008/07/02/intervale-green-affordable-sustainable-wired-in-the-bronx/

A number of green building features were incorporated into Intervale Green's building design, including low flow faucets and showerheads, Energy Star fixtures and appliances, and energy-efficient windows with transparent metal coated (low-e) double-pane windows to reflect heat during summer and retain heat during winter. An energy efficient ventilation system and insulation were incorporated in the building's construction. Compact fluorescent lights and occupancy sensors for lights were installed both in common areas and inside apartments. The interior of the building was finished with recycled and low - VOC materials, paints, sealants and caulks.

Additionally, the two-wing six and seven story complex includes a green roof for flowering and vegetable gardens, private courtyards for residential use, and a sculpture garden featuring local Bronx artists. The green apartment building was also designed to support healthy and active living for occupants. The private courtyard located between two wings of the building was fitted with a hopscotch surface and a grassy area to encourage children to play.

Building maintenance personnel intentionally reduce the use of harsh chemical cleaners and pesticides. There are on-site licensed social workers who provide social services to residents and coordinate social and health-related activities in the building; an onsite security office monitoring the single entrance; and an onsite part-time property manager. Upon move in, tenants are provided with a handbook and information on green and affordable cleaning materials and the health, recreational, and on-site social services. As described later in this report, WHEDco regularly has worked to try and align resident health promoting behaviors with the mission of the building, consciously promoting an integrated service delivery model[7].

[7] Orly Gilat, PhD, Director of Housing, WHEDCo. Personal interview with Jennifer Senick, Rutgers University, August 8, 2013.

Execution of Project

This section of the report discusses the research design and methods, and the interventions performed by the study team. The appendices include additional details on selected interventions.

Research Approach

Partnership model. This study employed a community based collaborative research (CBCR) design in which university-based researchers partnered with the Women's Housing and Community Development Corporation (WHEDco), a non-profit organization, and a self-selected group of Intervale Green residents. The multidisciplinary research team members consisted of the Rutgers Center for Green Building, Rutgers School for Environmental and Biological Sciences and the Polytechnic Institute of New York University. Throughout the project, WHEDco was kept fully informed of all aspects of the study, and was involved in its overall design and the development of research instruments and behavioral interventions. WHEDco played a particularly key role in the design and implementation of building wide interventions, both prior to the introduction of individual or apartment - level interventions and also concurrently with them. They were kept fully up-to-date with results throughout the period of project, and were part of interpreting the findings. WHEDco staff also facilitated the formation of a voluntary (self-selected) Residents' Advisory Committee consisting of six residents of the apartment building. This group met with the university based researchers, separately from WHEDco staff, four times over the course of the study to offer feedback on methods, the design of behavioral interventions and study progress.

Given the possibility for a conflict of interest, WHEDco—the housing provider—was not involved in study participant selection, contact, or data collection and had no ability to view any information from individual participants, as required also by the Rutgers Institutional Review Board protocol for this project (Rutgers IRB protocol #10-13M). Community organization staff did not at any point gain access to names or apartment numbers of residents who were involved in the research project, unless that was independently shared with them by the participants themselves.

Study Design

Collectively, the research team developed a longitudinal quasi-experimental design incorporating building – and apartment–level data collection and behavioral interventions spanning 36 months. Interventions were designed in the areas of indoor air quality, healthful eating and active living and energy use, taking advantage of an integrated, multilevel delivery mechanism such that the university based research team mainly focused on providing apartment-level interventions and WHEDco on building-level ones. University researchers also supported the provision of building wide interventions by partnering with WHEDCo on workshops and in providing information for distribution to all IG residents. Table 1 provides a detailed chronology of the eight study phases including intervention time periods.

It was decided early on in the study to try and prioritize participation in the IAQ aspect of the study by residents with more severe asthma and related health problems (self-reported). With a limited budget for IAQ testing and given a relatively small sample size, it was felt that this design parameter would enable the strongest 'signal' of the efficacy of IAQ interventions. Moreover, we believed that these residents were likely to be the most motivated to participate fully in the lengthy study. However, no resident was turned down for participation in the study generally. On a related note, the study was presented to residents as a Healthy Family study in the recognition that many of the interventions (e.g., to improve IAQ or to decrease energy use) are effectuated at an apartment-level and that they may involve multiple (family) actors. We also recognized, as emphasized by members of the Resident Advisory Committee that parents care deeply about the health of their children and had specific concerns regarding respiratory health (asthma and allergies) and diseases of overweight (diabetes).

Data Collection

Participant Interview Schedule. An interview instrument was fielded at beginning of the study to collect baseline data and repeated (with minor modifications) at the final phase of data collection. Participants were asked how they felt about the building in general and as a green building, indoor environmental conditions (temperature, air flow, humidity, dust, odors, etc.), apartment cleaning habits, behaviors that affect air quality (opening windows, changing air filters, smoking etc.), physical activity levels for themselves and their family, food purchasing and eating habits, use of courtyards and roof garden, energy use, and family health (such as presence or absence of asthma and obesity). Interviews were usually conducted in the respondent

apartments, where interviewers also noted conditions of the apartment – particularly aspects that could affect respiratory issues (such as use of carpets, pets, and plants; presence of mold).

Indoor air quality testing. A three-phase indoor air quality (IAQ) testing protocol was incorporated into the study for a subsample of 21 participants (apartments) to examine the presence of environmental contaminants, including potential triggers for asthma exacerbation and the effects of interventions intended to reduce those triggers. Phase I provided baseline values of CO, CO_2, temperature, humidity, various particulate matter size fractions, viable bacteria, viable and total mold and volatile organic compounds (VOCs), including formaldehyde. During each sampling day, 1-3 apartments were sampled and outdoor samples of the same parameters were taken as well. Absolute values of each variable indoors and outdoors were determined and indoor/outdoor ratios were calculated. Phase II testing was conducted 2-3 months later and approximately 2 weeks after the participating group received information and supplies to help reduce airborne contaminants that are associated with occupant life style activities. Phase III testing was performed approximately 4-5 months later and after follow-up interviews that served to reinforce the IAQ intervention.

Interventions

HEAL - Healthy Eating and Active Living Interventions. The Healthy Eating and Active Living interventions were designed to be available to all participants on a one-to-one basis and encouraged them and their families to substitute water for other beverages (free re-useable water bottles were distributed), provided tips manuals with information on community resources and ways to increase family levels of physical activity (a free pedometer was distributed) (see appendix x), and with information on healthy eating, including references to http://myplate.gov/ (and a sectioned plate as a prop).

Energy interventions. All participants were also offered a tips manual on ways to save energy, power strips to make it easier to turn off multiple appliances when not in use, and a line logger to help them learn how much energy various appliance use. Readings on the monitors were taken during "reinforcement" visits.

Indoor Air Quality (IAQ) Interventions with Participating Resident Units. A subsample of participating apartments, including all those where detailed IAQ measurements were

performed, were selected to receive supplies and information to help them improve indoor air quality in their apartments. The supplies, which included Swiffer-like mops fitted with microfiber cloths, vinegar, and baking soda, were intended to be easily accessible to residents and build on information already provided by WHEDco to its residents.

Building - level interventions. Interventions intended to be integrated into the entire building programming, or made available to all residents, were designed and put into place by the building owners in collaboration with the research team as the need was identified.

Reinforcement Interventions. Between the first intervention and follow-up interviews, "reinforcement" visits were made to record observations and spontaneous reports on the adoption of interventions and to encourage persistence of the new learning materials.

Results

The project included multiple data collection activities over several time periods. This section summarizes key results by time and category.

Participant Enrollment

Participants were recruited in the building with open sessions and advertisements that were available to the entire building population from 127 units throughout the initial period of the study. All interested parties were informed of the voluntary nature of the study, time and effort required for their participation, incentives s being offered to participants and confidentiality of the data, as detailed in the IRB Informed Consent. The period of recruitment lasted for two months. No residents who wanted to participate in this study were rejected. Of all residents who attended such sessions or otherwise met with study representatives, a total of forty (40) residents (representing 40 different apartment units) agreed to participate and to be contacted for the initial phase of the study. All 40 reviewed and signed the IRB approved Informed Consent forms , and went on to complete Baseline Interviews.

The study sample closely mirrored the study population based on demographic data provided by the building owner. The study sample was largely women/female heads of households (82.5% of participants were female, 12.5% male), African American and Latino (12.5% of participants were interviewed in Spanish, and 15% listed Spanish as their primary language), with an average age of 35 years (SD=11).

Of the 40 participants who completed baseline interviews, 32 were willing to participate in the next phase of the study, which entailed the Healthy Eating, Active Living (HEAL) and Energy Efficiency interventions. Thirty-one (31) participants (representing 31 apartment units) stayed involved in the program through the entire project including the reinforcement of the interventions and follow-up interviews.

A subset of 21 residents who had completed baseline interviews were offered the opportunity to participate in the Indoor Air Quality interventions and associated measurements. This involved being part of three phases of IAQ testing. Sixteen (16) participants completed all three phases. As noted earlier, these residents were not randomly chosen but were, rather, selected to include families in which there were health problems that could be related to IAQ (such as asthma), so that there was the potential to see impacts of any air quality improvements not only in terms of decreased presence of air pollutants, but also changes in health conditions,

such as asthma. Effectiveness of healthy eating or activity interventions also had a higher likelihood to be successful in this selected group.

Participant Background Health Information

Baseline interviews were conducted in 40 households. Results indicated that 65% of participating households have self-reported asthma, with 40% of the respondents having had a self-reported asthma attack within the previous 12 months of the interview. Of the respondents who reported that smoking occurred inside their apartments (50%), 38% of the respondents indicated the co-occurrence of smoking and household member with asthma. Further results of the health findings indicated that many of the residents had a sedentary lifestyle and that 50% of the households had at least one family member who had exceeded the recommended Body Mass Index (BMI); 38% of the respondents indicated the presence of both asthma and BMI issues among their household members. Approximately 33% of the respondents had hypertension, 13% reported diabetes, and 30% had cholesterol.

When the respondents were asked questions about active living, 55% of the households reported having an exercise routine, 78% of the interviewees' desired to be more active in order to avoid health issues, and 44% of the interviewees' indicated that they wanted their children to be more active and healthy.

Baseline Participant Assessment of Green Affordable Housing

Overall, on the baseline measure participants expressed a good deal of satisfaction with their experience at Intervale Green. A number of building design- and operations-related parameters were described as being related to participants' sense of the building site's safety, cleanliness, child-friendliness, convenience to needed and desired services, and apartment comfort.

Building security, management, and programming. There are several aspects of the building that offer particular benefits to occupant well-being. While 57% of participants on the baseline expressed that they were somewhat to very satisfied about their safety from crime in the neighborhood, 93% stated the same level of satisfaction with their sense of safety from crime in the building, due in large part to added security in the building (See Figure 1). These include the ability to contact security via the intercom or using a cell phone and overall protection of the building aided by cameras. Cameras installed after complaints by participants about disorderly behavior in common halls have reportedly led to improved conditions.

Other positive features of programming in the building that participants pointed to included rules that help keep the building clean and well maintained, the friendliness of the staff and presence of the social workers, and the availability of resources and services, such as activities, education classes, and programs aimed at healthy eating and living, and the afterschool program for the kids. The location offered access to a variety of services: It is close to stores, other conveniences, a block away from public transportation, and within reach of a farmers' market (See Figure 2).

Building and apartment layout. Participants (63%) were generally satisfied with the design and appearance of the apartment, including the layout, spaciousness, access to storage space, large windows, appliances, kitchen and bathroom. Figure 3 summarizes residents' levels of satisfaction. Participants also noted positive aspects to include courtyard, the rooftop garden, and/or access to vegetables grown there although some did not participate in the garden for reasons that included not having time, being too hot, and having physical limitations. Participants spoke favorably about outdoor spaces, but also expressed a desire for a gym in the building, as well as more play and activity space for children, such as a courtyard where the kids can play during the day. The existing courtyard designed to be nestled between the two wings to afford a safe play area was subsequently closed to use when occupants in adjacent apartments complained about noise rising from the play activities (See Figure 4).

While overall satisfaction was noted on many points during the baseline interviews, participants expressed concerns about some important issues in their apartments including leaks (reported by 55% of participants) and a stubborn pest problem (92% response). In addition, some felt that the tenant screening process should be more stringent and rigorous, in order to avoid the inclusion of individuals who were inconsiderate and disruptive as neighbors (8%).

Finishes, materials, and construction. Apartment finishes and construction had mixed reviews for performance. Approximately 60% of interviewees on the baseline reported that the apartment was easy or very easy to take care of and clean (see Figure 5). Some of the same interviewees also reported excessive dust as a reoccurring problem in their apartments (45%). In addition, a fair number expressed concerns about the quality of the building construction (28%), including the low quality of the materials, which make them permeable to rodents, not durable, and easy to damage. Dissatisfaction stemmed from the low quality of the wall paint

(18%), which gets dirty easily and is hard to clean. Other construction and materials issues included cabinets and door knobs which broke easily, unevenness of the floors, the difficulty of replacing the lights, and the shape of the window bars which prevent installation of air conditioning. Observations supported the lack of scrub-ability of the interior paint (which was applied as a flat finish), presence of numerous cracks in common area floor tiles, and floor covering lifting in bedrooms.

Thermal comfort. Baseline responses about thermal comfort were mapped according to where they occurred in the building. The responses are depicted on collapsed floor plans as part of the apartment "lines" to help identify any patterns that might exist through the building systems (see Figures 6-8). The mappings suggest similar parts of the building that are experienced as either too hot or cold.

Indoor Air Quality. Air quality problems in the form of odors were reported by 75% of the participants completing the baseline. While a few reported odors (e.g., cigarette, chemical smells) intruded from outside of the apartments through vents, windows, and outlets, most were recurrent odors of garbage (48%) in hallways and common areas. Observations revealed signs of odor management challenges (See Figures 9 & 10). Reports of odors from the baseline were also mapped as a three dimensional model (Figure 11) to visualize any patterns of reporting and assist with analysis. The data were separately mapped for garbage and other odors. The 3D plan, created by "stacking" each of the floor plans on top of each other to provide a look at the building's floors in relation to each other, shows the location of all the vertical accesses in the building as well as distribution of odor percentages by each floor. Note that the two lower floors have the least number of odor reports.

Follow-up visits

Participants of the building were visited a year later for follow-up interviews, with much of the content intended to assess changes in participants' experiences after an additional year at the residence and a series of interventions. Among other questions, 31 participants who were available for the follow-up interviews were asked about the extent to which they experienced the building as a comfortable place to live. A majority (approximately 81%) still found it to be comfortable while a few expressed some degree of discomfort (See Figure 12).

During the follow-up, 40% of the participants indicated that their perception of the building changed over the past year. While some of the change was perceived to be positive (e.g., management was more on top of repairs and pest problem), other comments suggested dissatisfaction with loss of a courtyard play area for children and what was seen as disruptive behaviors by other residents.

Pest and mold reports. More than 90% of the participants in baseline interviews reported pests whereas approximately 68% reported problems with pests in the follow-up interviews (see Figure 13) suggesting a 22% reduction in the problem over the year's time. Some participants had complaints about more than one type of pest in their apartment, but the majority of the participants reporting pests on the baseline (78%) indicated that mice were a problem. This was followed by reports about roaches by 27% of the respondents, and complaints about ants, worms and other bugs. Pest reports from the baseline were also mapped according to their location in the building (Figure 14) showing a rather pervasive problem. Results from follow-up interviews suggest a marked improvement (22%) in pest control in the follow-up with continuing challenges in this area.

From the baseline and follow-up interview results shown in Figure 15, the mold problem appears to have persisted in only few apartments, as a majority of the interviewed participants did not report mold. Comparison of baseline and follow-up interview data suggest modest decreases in reports of mold between the two measurement points. A number of leaks had also been reported by participants on the baseline (55%) to occur either as a single event or as repeated problems around windows, from ceilings, and under cabinets. During the study the building owner was in the process of having window frames resealed on the exterior; the number of apartments that had reported water damage or leaks was subsequently reduced in the follow-up (see Figure 16). At the same time, however, it was found that 9 apartments that reported water damage or leaks in the baseline did not report the problem in the follow up but 5 more apartments that previously did not have any problems reported water damage and leaks in the follow up. While there was abatement of some reports of apartment problems, this did not appear to be the case with reported odors (see Figure 17).

Interventions and Responses

This section highlights the results of intensive interventions and indoor air quality testing.

Building - level interventions. Interventions intended for the general population of building occupants were designed by WHEDco to support their programming objectives. Interventions included promotions of healthy eating and use of the roof top garden with demonstrations by coordinators of roof top gardening; promotion of physical activity by placing signs offering "take the stairs" next to each elevator and organizing mural painting in stairwells; offering exercise classes such as yoga; and through informational sessions on less-toxic, safer cleaning products. Table 2 describes additional building-wide interventions provided by WHEDco. The study team also collaborated with WHEDco staff to create interventions as a result of the iterative nature of the research. For example, researchers and student coordinators of the roof top garden collaborated to produce a building-wide event featuring vegetables from the roof top garden prepared for sampling by residents and images of the garden; residents offered excellent feedback. Also, in response to baseline interviews, significant problems with mice and roaches in apartments were apparent. To help address this problem immediately rather than waiting until the end of the study, a best practices integrated pest management (IPM) guide was developed in collaboration with Rutgers University Cooperative Extension Urban Entomology specialist and provided to the building owners. See Appendix B.

Also, as a building - level intervention and in response to persistent reports of odors, a ventilation model, shown diagrammatically in Figure 18, was created to help provide understanding on the operation of the mechanical ventilation system. The model was developed based upon building location, prevailing winds, hypothetical apartment location, window use, and estimated infiltration (uncontrolled flow of air). Figure 18 suggests that at some times of the year the mechanical ventilation may be overwhelmed by infiltration and provide inadequate ventilation. During the autumn, winter, and spring seasons the uncontrolled air infiltration may create conditions for inadequate ventilation. During the summer season, use of operable windows also may overwhelm the mechanical ventilation system. In addition, it was learned from the energy consultants and verified through site visits that the refuse rooms located on each floor may not be adequately ventilated.

Individual apartment interventions. Intervention visits were made between baseline and follow-up interviews. At the individual and apartment - level, all participants were offered Healthy Eating Active Living (HEAL) and energy efficiency interventions at the apartment - level. A subsample (n=21) were also offered indoor air quality (IAQ) guides and supplies during scheduled interviews. Interventions were provided in individual apartments and supported by supplies that were (1) economically feasible for a very low income population, and (2) available in the community of our study site. Participants were engaged in discussions about the intervention topics and areas of focus and demonstrations were based on participants' particular interests or needs. In total, 32 participants received apartment - level interventions (8 were lost to contact or withdrew after baseline interviews).

IAQ. Sixteen residents completed indoor air quality (IAQ) interventions and three phases of IAQ testing in the summer, fall, and spring. Interventions took place between July and October 2011 and were designed to broadly inform participants about the relationship between indoor air quality and occupant health in addition to providing strategies occupants could adopt to improve their air quality. Findings highlights include significantly higher concentrations of CO_2 in households where an asthma attack in the past 9-12 months was reported, $p<.011$ and significantly higher indoor/outdoor ratios of CO_2 in households where an asthma attack in the past 9-12 months was reported, $p=0.014$. Further, higher levels of particulates and some chemicals were found in apartments with no air conditioners (n=2 apartments). Higher levels of PM2.5 and benzene were found in apartments where smoking was reported compared to those where smoking was not reported. Lower levels of airborne particulate matter were detected in apartments where microfiber mops were used and participants were satisfied compared to those where microfiber mops were not used or residents not satisfied. More IAQ results are provided in Appendix B.

Reinforcement contacts. Spontaneous and scheduled visits were made after the interventions to reinforce the adoption of health promoting and energy conserving behaviors for individual participants. Qualitative analysis of data from these contacts identified themes in participants' comments that are highlighted in Table 3 and illustrate the role of reusable water bottles and other props incorporated into interventions.

Participant Health Status on Follow-Up Interviews

Follow-up interviews were completed with 31 participants, who reported fewer asthma attacks since the first interventions (approximately 7 months earlier, but more emergency room visits for attacks than the baseline (Figures 19 & 20).

While those who reported smoking in apartments did not change measurably (43% on the baseline and 47% on the follow-up interview) the frequency of days during the week that people reported smoking in the apartment did change. Figure 21 illustrates 11 % reductions in self-reported daily smoking that occurred in the apartment.

Of the 88% of participants who reported reading labels, 29% focused on calories and salt while 48% paid attention to sugar, and another 42% watched for other ingredients such as high fructose corn syrup, cholesterol, fat, and MSG. More than half of the participants used the sectioned plate to portion out food and stated their meals since the intervention were more balanced. With respect to healthy eating objectives, the frequency of visits to the roof top garden increased from the baseline (Figure 22) as did visits to farmers' markets (Figure 23). A number of participants expressed hesitation about visiting the roof because of the excess heat, not wanting to mix with other residents of the building, or because of a work and/or school schedule.

In spite of some of these important advances in health promoting behavior, however, participants' ratings of their general health status did not show the same kinds of improvements (Figure 24).

Conclusions and Recommendations

The challenges and opportunities of building on a green housing platform to enhance health-promoting behaviors for lowest income residents became clear through many phases of the research. Over time it was apparent that a number of variables outside of the study played a role in affecting participants' and residents' attempts to improve their health status: participants lost jobs, lost medical services, food stamps and public assistance were decreased, and residents moved out and into the building. These factors and others form the background of participants' ratings of their general health status and may help to explain that efforts to improve health status are often met with losses in resources essential to maintaining health. As an example, while fewer participants reported having asthma attacks later in the study more reported going to the emergency department for those attacks, possibly a result of lost health benefits or limited access to practitioners. Similarly, residents are not always able to afford to replace low VOC apartment finishes in-kind or to afford filter replacement or repair costs for air conditioning units, let alone the utility bills.

Conclusions

This study hypothesized that (1) IAQ would improve with increased adoption of green strategies, (2) levels of physical activity would increase with adoption of active living strategies, and as a result of both, (3) symptoms of related conditions would be reduced, in particular (asthma along with obesity, which is, for this study, considered a related condition). These hypotheses found partial support, but only after we subdivided the definition of "green." IAQ improved in apartments subject to the IAQ intervention, and energy efficiency improved temporarily in apartments receiving the EE intervention. While the HEAL intervention did not yield statistical changes in symptoms, there were modest improvements in a number of self-reported parameters. Also interesting were the synergies and tradeoffs identified during the study, discussed below.

Programming and operation activities. Positive synergies were found in the mission of the non-profit building developer / owners and their commitment to applying their limited resources toward positive environmental, social, and economic effects. Because of this mission it was possible to incorporate multilevel interventions into the building, and in some cases the local neighborhood environment. Building - level initiatives of IPM best practices may have contributed to a decrease in pest complaints, as did some participants' experience with

employing aspects of IPM, such as sealing up access holes. Similarly, the combination of reinforcement of the benefits of the rooftop garden were emphasized through a number of events including the interviews, the presence of a rooftop coordinator cooking samples in the lobby, and a building wide event. Clearly, interventions on multiple levels and over time are especially needed for value shifts in conditions of high risk, vulnerable populations.

Moderate successes were achieved in encouraging the adoption and persistence of new health promoting behaviors, again in part due to the integration of strategies at multiple levels: reinforcement over time at the individual apartment - level, support at the building - level, and through the culture of the organization. Apartment-level interventions were provided through individual meetings in apartments where discussions could be individualized and strategies could be customized for the participant's use. Products or "props" that were adopted most consistently (e.g., Swiffer-like mops fitted with reusable microfiber cloths) had a readily visible effect and were supported by outside authority (e.g., health care providers and media), were convenient, and were easy to use (e.g., powerstrips, water bottles). The possibilities for engaging building residents in delivering interventions in a participatory fashion was considered but rejected, as concerns about privacy were borne out in some cases with participants' hesitancy to mingle in the building.

Design effects. Various aspects of the building and apartment design supported healthful living, including ample kitchen cabinet storage space, low VOC materials, and secure spaces. Unintended effects of the design did pose some constraints to active living, however, as, for example, the private courtyard was closed because of the noise and privacy disruption of children playing in proximity to windows of the two building wings. Signs encouraging the use of the stairs were positioned near the elevator which was more immediate to the lobby entrance and the stairs more remote.

Design Trade-offs. A number of trade-offs became apparent in efforts to combine healthy with green. Materials and construction that emphasize low environmental impact at times performed poorly possibly because the application was not appropriate for the activities in the space (e.g., non-scrubbable low VOC flat paint where children are active), or floor material installation was not done correctly or with correct adhesive.

Perhaps the most important, multi-faceted, trade-off is manifest in the HVAC system design. First, low income populations suffering from high rates of respiratory and other chronic diseases in areas exposed to sources of chronic air pollution will often need to rely on air conditioning especially on poor air quality days. Limited evidence in this study suggests an important role for air conditioning for controlling particulate matter exposures, but many health-compromised residents were unable to afford to purchase window air-conditioning units or pay the ongoing utility costs.

Secondly, energy efficiency standards may be requiring reductions in ventilation rates that at times create marginal conditions for healthy indoor air quality. The apartment building owners had obtained a waiver from the NYC Buildings code for cubic feet per minute (cfm) air exchanges to meet requirements for Energy Star and qualify for critical funding to support development of the building. Both IAQ testing and the ventilation modeling suggested that indeed apartment air quality was compromised on some days in some apartments. In addition to the buildup of CO_2 and particulate matter at times, there were pervasive complaints by participants of odors in both common and apartment areas that sometimes led to occupants using air fresheners, another source of chemical exposure.

Finally, the study found a gradual increase in visits to the vegetable gardens on the roof top. The rooftop location of the garden frees up space on the ground level for other activities, but is out of sight of residents who have not incorporated its benefits into their lives, suggesting that it requires ongoing promotion. In addition, there is a lingering question as to whether the source of some ceiling leaks might be the roof top design, a topic that is beyond the scope of this study.

There are important limitations in the study. First is the relatively small number of individuals participating, which limits the generalizability of the findings. Some findings regarding thermal comfort conditions are difficult to analyze in terms of building-wide patterns as the data does not include all apartments. Further, contacts with participants varied in frequency due to their sometimes-precarious financial circumstances that resulted in loss of phone service or change in contact information.

Recommendations

The following recommendations emerge from this study:

- Revisit ventilation standards. The study offers compelling reasons for revisiting energy efficiency policies that require substantially reduced ventilation standards, particularly in the case of vulnerable populations.
- Treat air conditioning as a necessity not a luxury for asthmatic individuals. Access to air conditioning should not further stress the limited financial resources of those individuals who need the service for medical conditions.
- Expand the use of housing as a platform for social service delivery. Incorporate programming to support long-term initiatives that educate residents about healthy eating and active living.
- Involve residents in the design of culturally-appropriate behavioral interventions to help transition behavior to more healthful or energy conserving habits.
- Encourage the incorporation of outside authorities and consultants into interventions where needed to offer specialization and preserve privacy.
- Prioritize moisture and pest management. Develop cost effective and efficient means of identifying building problems involving moisture and pest intrusion as a means of managing exposures of occupants to biological asthma and allergy triggers.

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Appendix A. Expanding the Definition of Green: Graphs and Tables

Table 1. Chronology of the eight study phases including intervention time periods

Intervale Green				
	population = 127 units			
Step 1	*screen residents for appropriateness*			
Step 2	*select families (respiratory conditions) (30-50 +-??)*			
Step 3	Randomly assign to 2 groups			random assignment allows for a true control group in a repeated measure, within subject study - a powerful design. If we assume moderate effect size (.2 - .25), high correlation between repeated measures (.6), 2 groups & 3 repeated measures, we can find stat significance with as few as 30 - 35 subjects
	Group 1 (experimental) - 14 units	Group 2 (control) - remaining units (15-30+_)		
Step 3	***Time 1 - Baseline Data Collection***			
	Interview	X	X	***interview*** - includes health measures, perceived env quality measures, per. Green measures, etc.
	IAQ	X	-	***IAQ*** - indoor & outdoor air quality measurements
	Observation	X	-	***observation*** - elements in apartment, cleaning style, etc.
Step 4	***Time 2 - Intervention***			
	Bldg scale - Information, signs, etc.	X	X	
	Unit scale -Intensive IAQ	X	-	
Step 5	***Time 3 - Followup data collection #1***			
	Interview	X	X	
	IAQ	X	-	
	Observation	X	-	
Step 6	***Time 4 - Intervention***			
	Bldg scale - Information, signs, etc.	X	X	
	Unit scale -Intensive IAQ	X	-	
Step 7	***Time 5 - Followup data collection #2***			
	Interview	X	X	
	IAQ	X	-	
	Observation	X	-	
Step 8	Report back to residents - make all interventions available as possible			

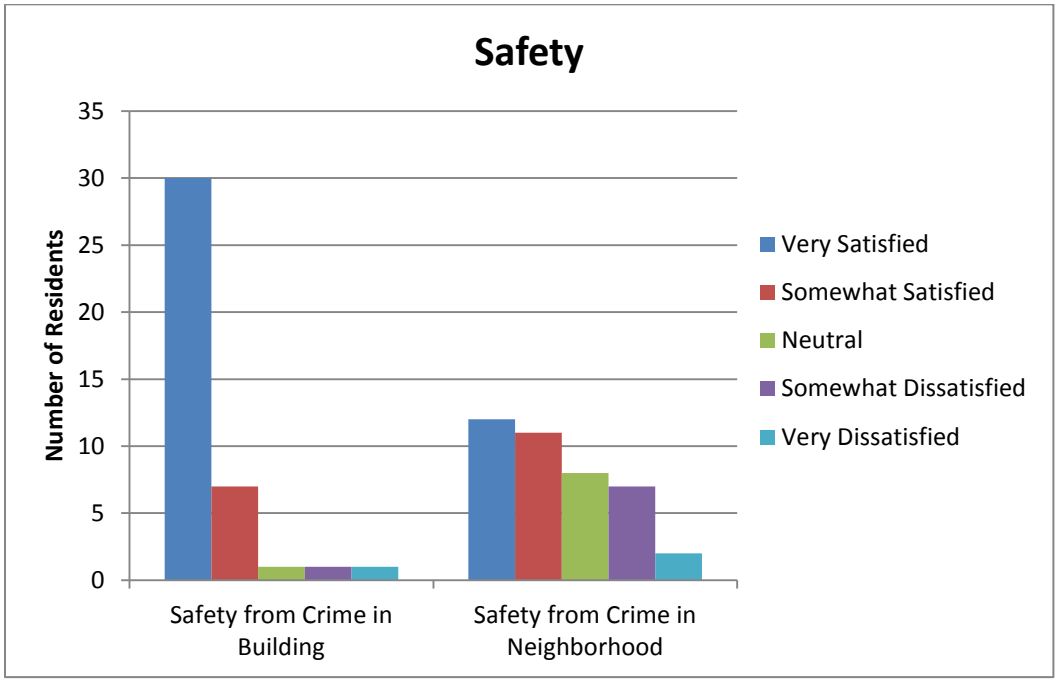


Figure 1. Satisfaction with building safety, baseline interviews (N=40).

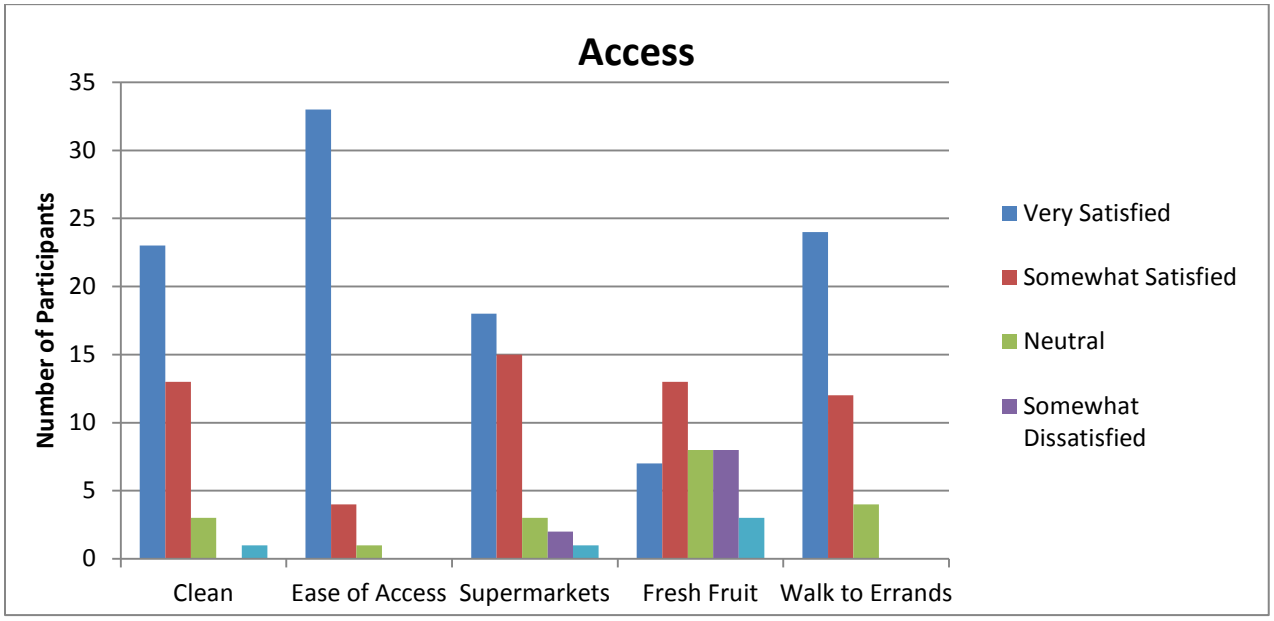


Figure 2. Satisfaction with building location and accessibility, baseline interviews

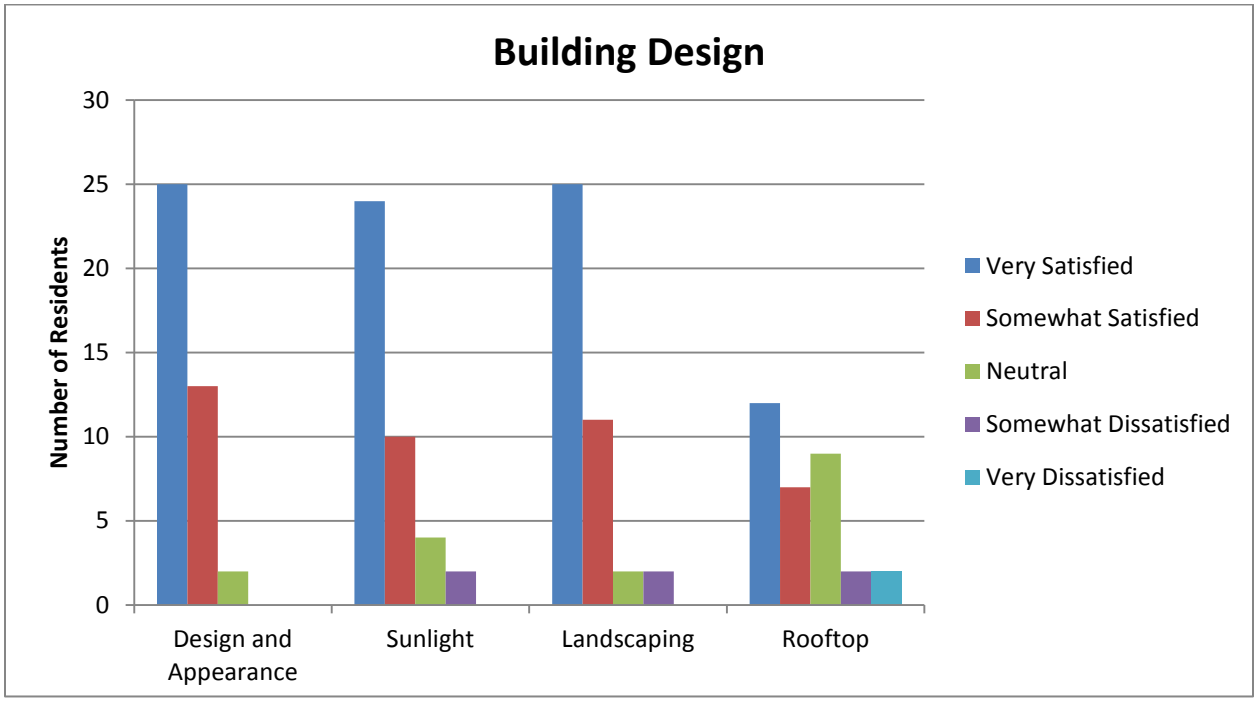


Figure 3. Satisfaction with building design, baseline interviews (N=40).

Figure 4. Interior courtyard *(Source: Rutgers Center for Green Building 2012).*

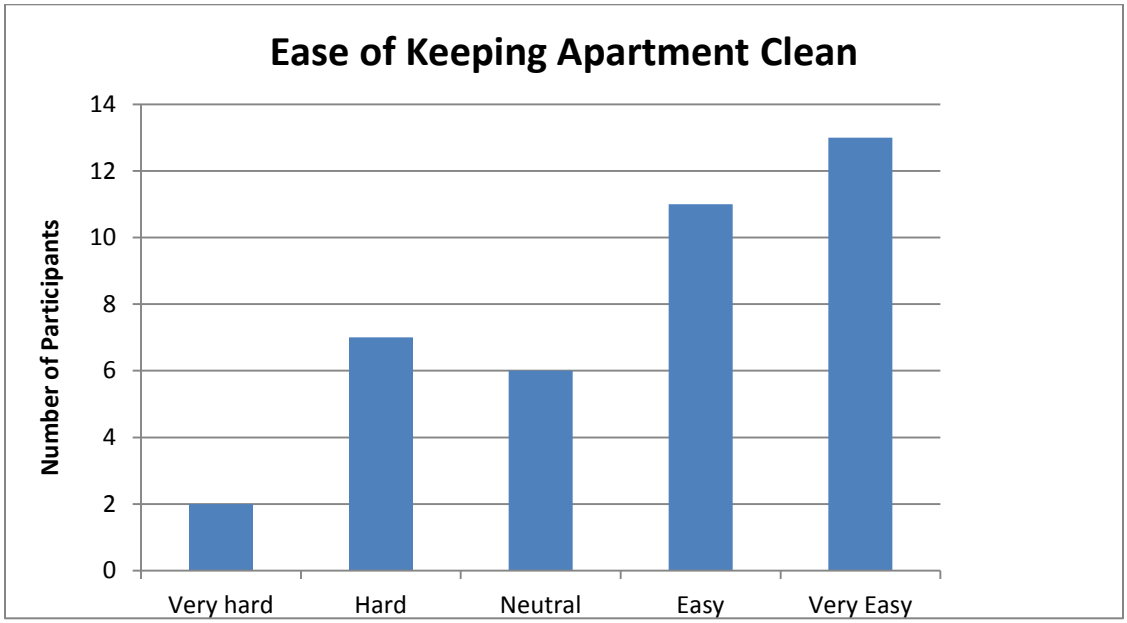


Figure 5. Reports of ease of cleaning apartment, N=40 (missing: 1)

Figure 6. Reports of apartment thermal comfort, too cold (N=40)

Figure 7. Reports of apartment thermal comfort, drafts (N=40)

Figure 8. Reports of apartment thermal comfort, too warm (N=40)

Figure 9. Covered vent in apartment

Figure 60. Recycling/garbage room showing accumulation and undersized chute

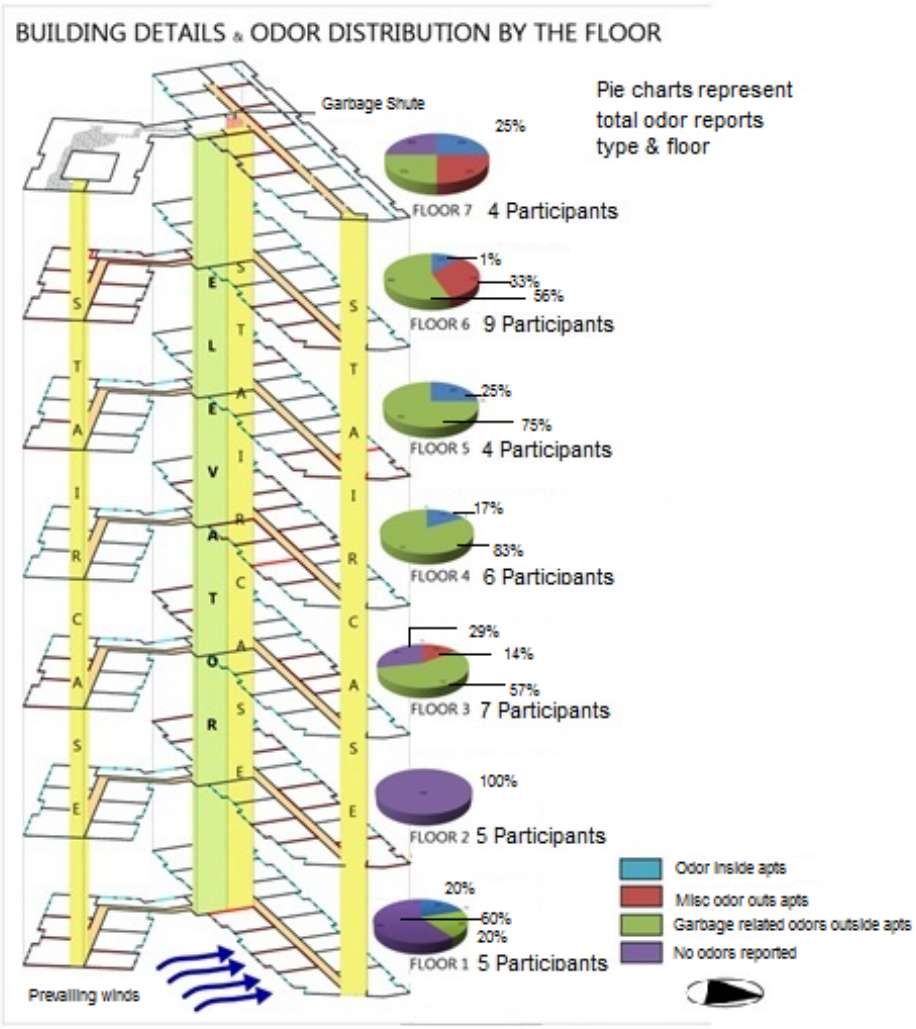


Figure 71. Three dimensional representation of odor reports, N=40.

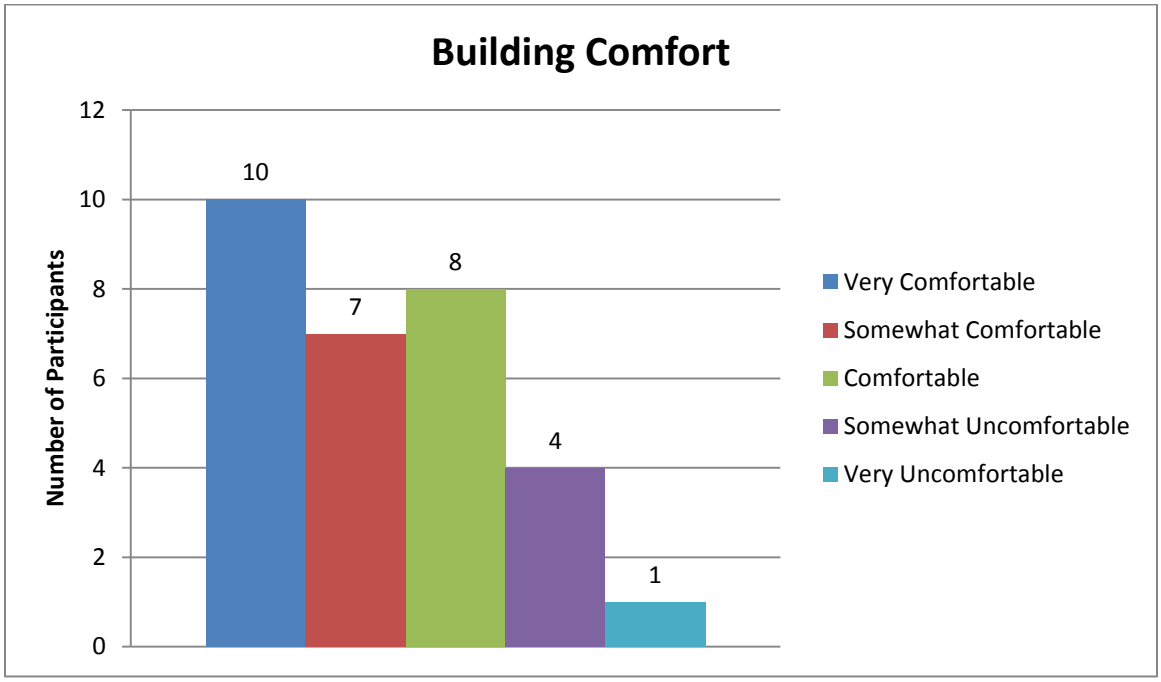


Figure 12. Building comfort, follow-up interviews (N=30, missing = 1)

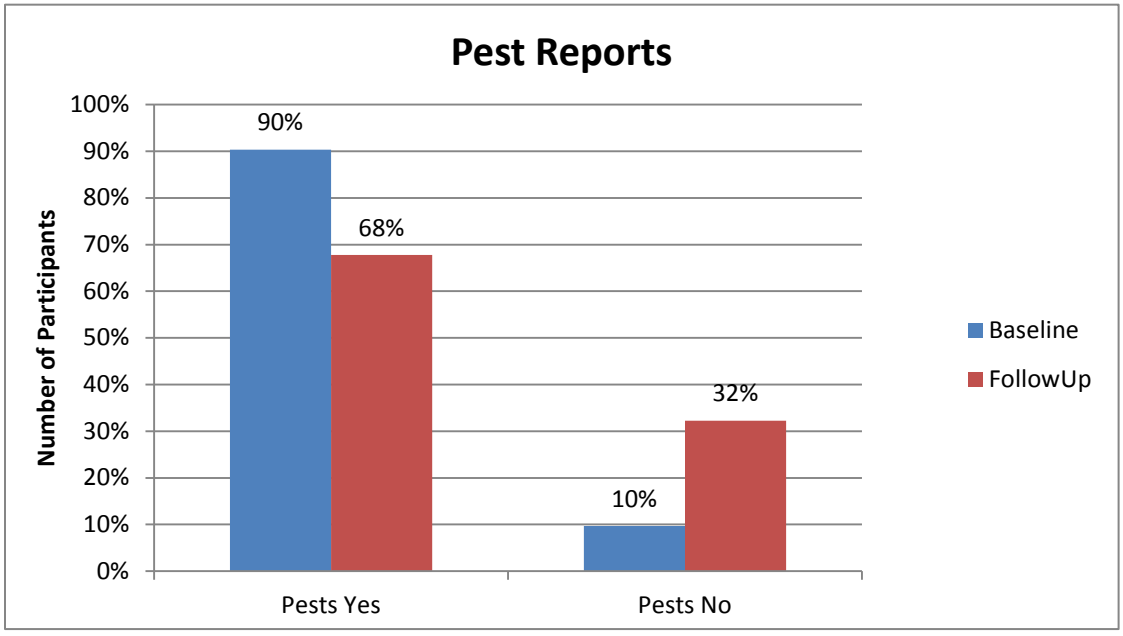


Figure 83. Pest reports, baseline and follow up interviews, (N=31)

Figure 14. Pest reports, baseline interviews (N=40)

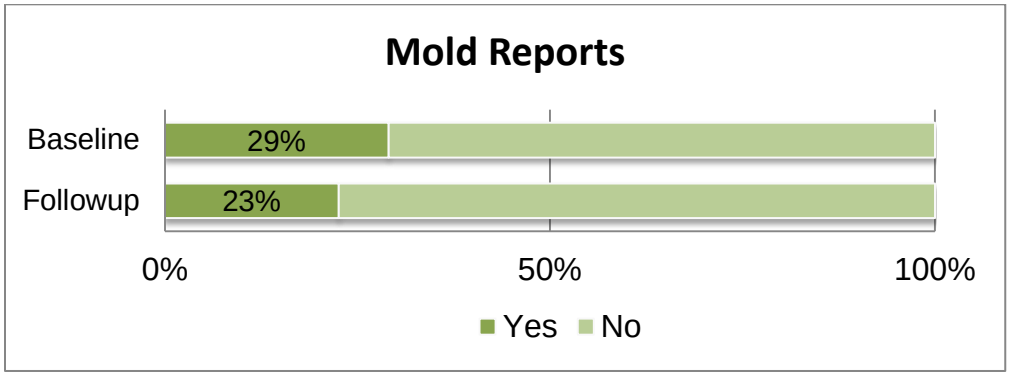


Figure 15. Mold reports comparing baseline and follow-up measurements, (N=31)

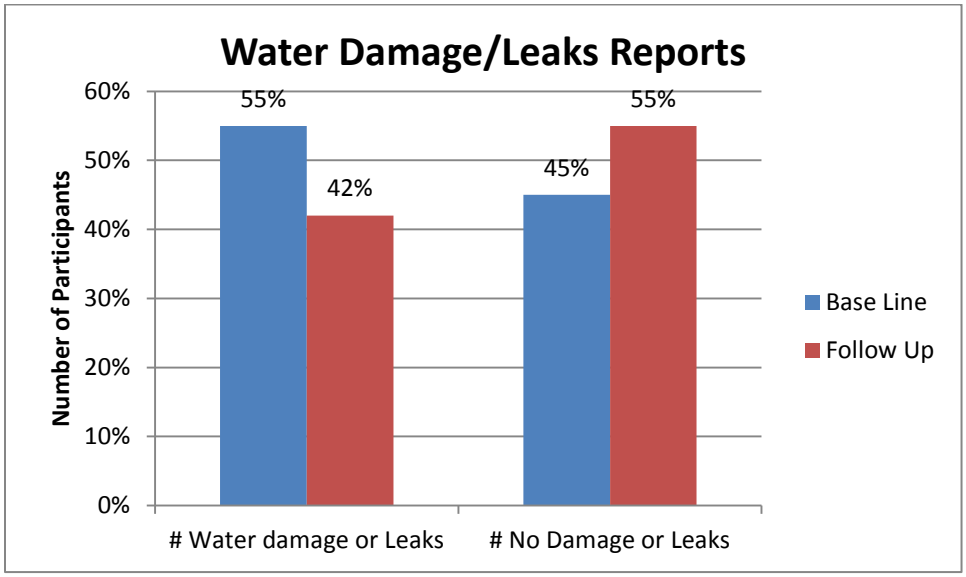


Figure 16. Reports of water damage and apartment leaks, baseline and follow-up, N=30 (missing=1)

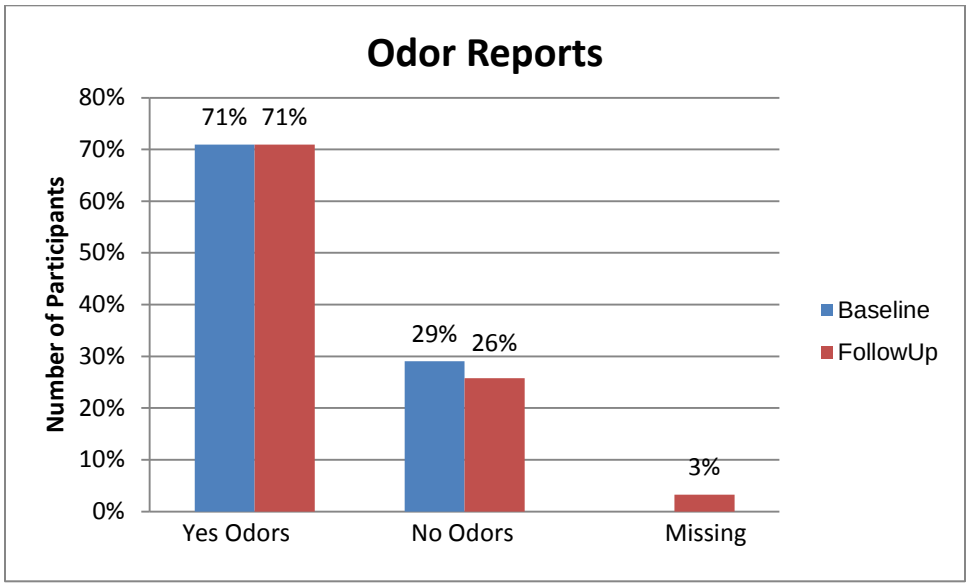
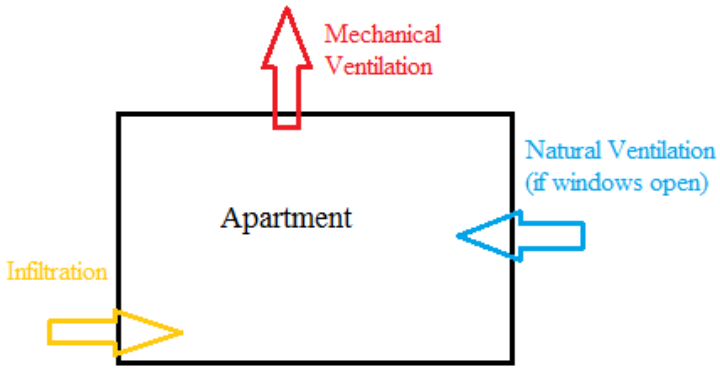


Figure 97. Odor reports, baseline and follow-up comparisons (N=31)

Table 2. Sample of WHEDco building-level interventions

Roof Top Initiatives	Healthy Eating	Active Living	Children's Activities	Resource Conservation
Meet with residents to plan garden each winter- spring	Organized pot luck luncheons & exchange of healthy recipes	Swimming pool outings	Planning heatlhy activities for summer	Plan to promote recycling
" Halloween Festival" with information about composting and nutrition	Promotion of "Green Cart" for purchase of vegetables & fruits with food stamps from vendor carts	Cosponsored free Zumba classes in partnership with Urban Health Plan	Cosponsored "Positive Deviance Program" with Children's Aid Society to improve teen success in school	Work with engineer to identify air circulation patterns based on Rutgers study findings
	DOH anti-sugar presentation			Worked on water collection and preservation on roof top garden
	Weekly healthy cooking and tasting demonstrations			
	Tenant healthy eating class retention planning			



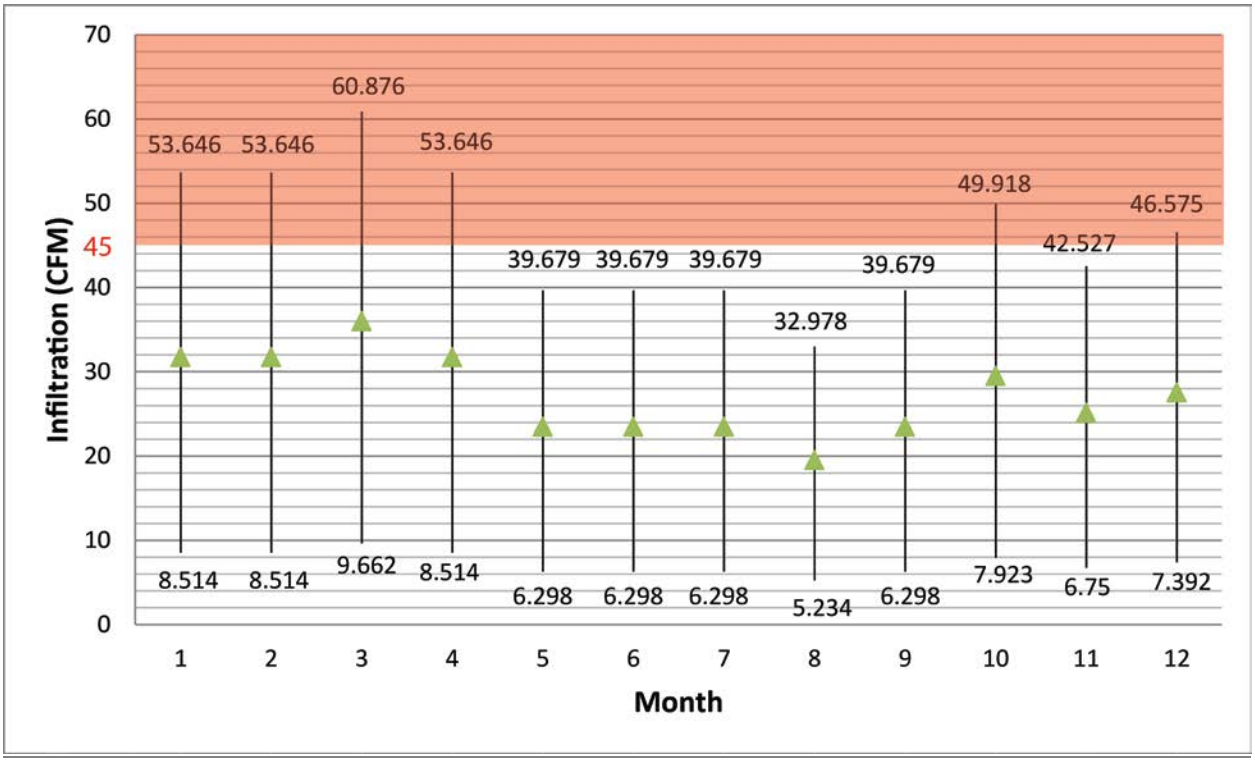


Figure 108. Ventilation model illustrating how infiltration may be overwhelming mechanical ventilation lending to days with less than optimal air exchanges (in orange area).

Table 3. Highlights of HEAL and energy conservation interventions, derived from reinforcement contacts.

Objective	Intervention	Findings Highlights
↑ Water Consumption	Reusable Water bottles	• Of 28 comments, 25 were positively related to use of water bottles over time • Often shared with children • Observations included bottles out in open
↑ Physical Activity	Pedometer, Tips Manual, Community Resources Info	• Less positive / more limited use e.g., immediately following intervention) • Some participants had physical limitations
↑ Roof Top / Veggies	Tips Manual, Community Resources Info, Building Wide Event	• Observed veggies brought in from roof top • Participation in sampling from cooking demos • Garden coordinator is key for some • Children are "picky"
↑ Energy Efficiency	Line Loggers, Power strips, Tips Manual	• Using power strips, less microwave use reported • Fans are being used, can be an economic challenge to purchase

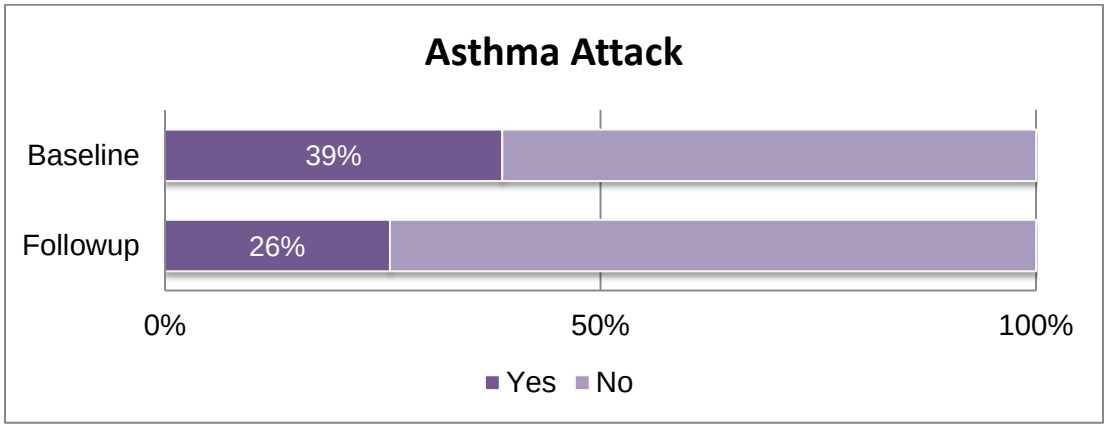


Figure 119. Reported asthma attacks by household members comparing baseline and follow-up interviews (N=31)

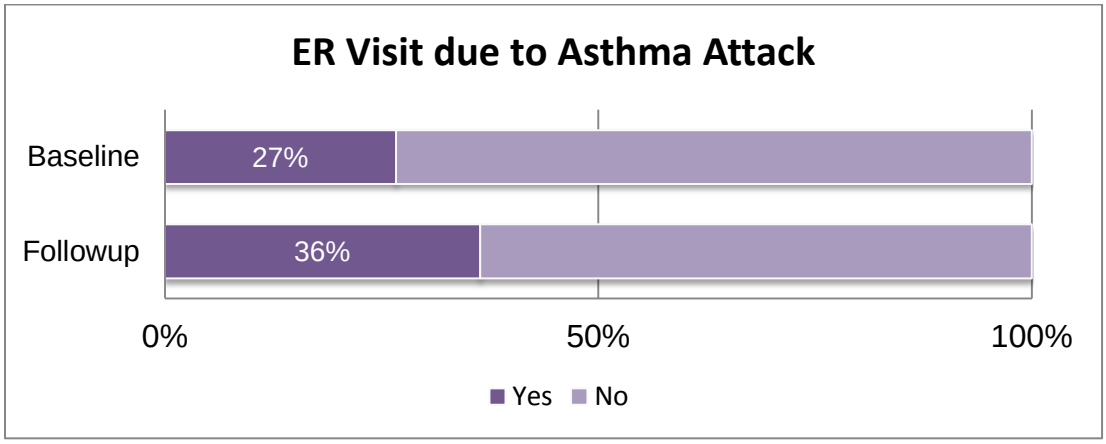


Figure 20. Percent of participants reporting emergency room visits due to asthma (n=22). Of 12 reporting asthma attacks on baseline, 8 required emergency treatment. Of the 8 reporting attacks on follow-up, 8 required emergency care.

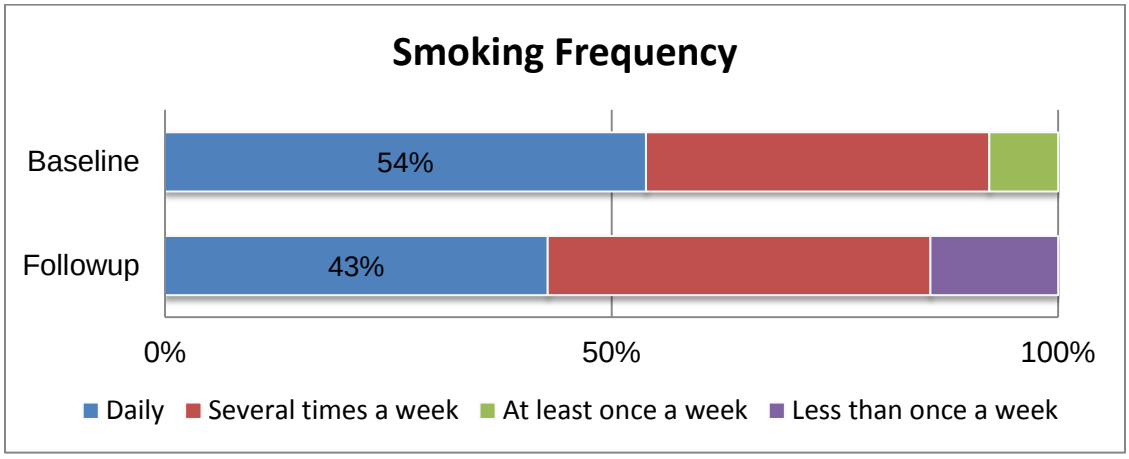


Figure 21. Frequency of smoking in apartment, n=31. Subgroup consists of 14 reporting smoking activity occurring by someone in the apartment.

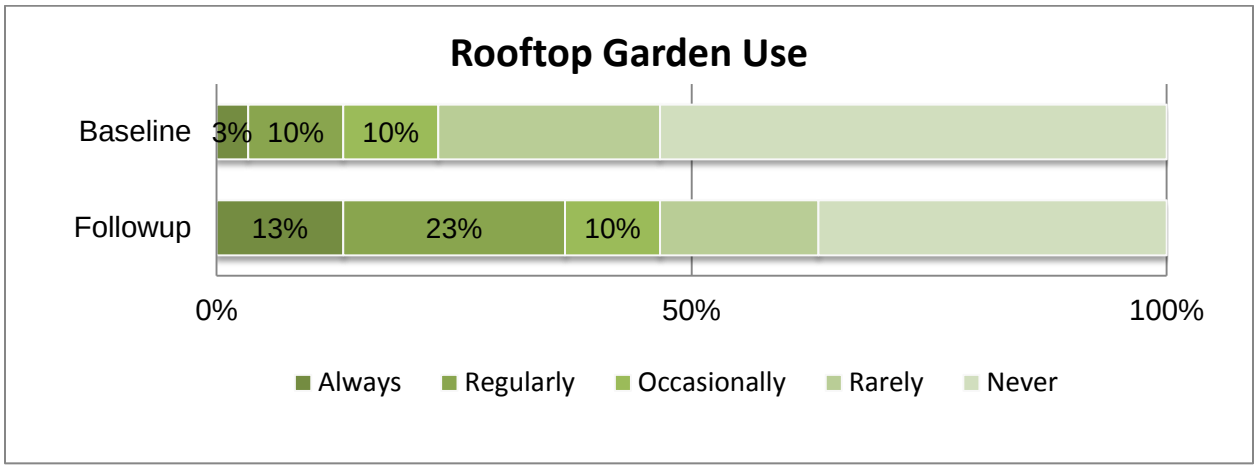


Figure 22. Frequency of roof garden visits (N=31)

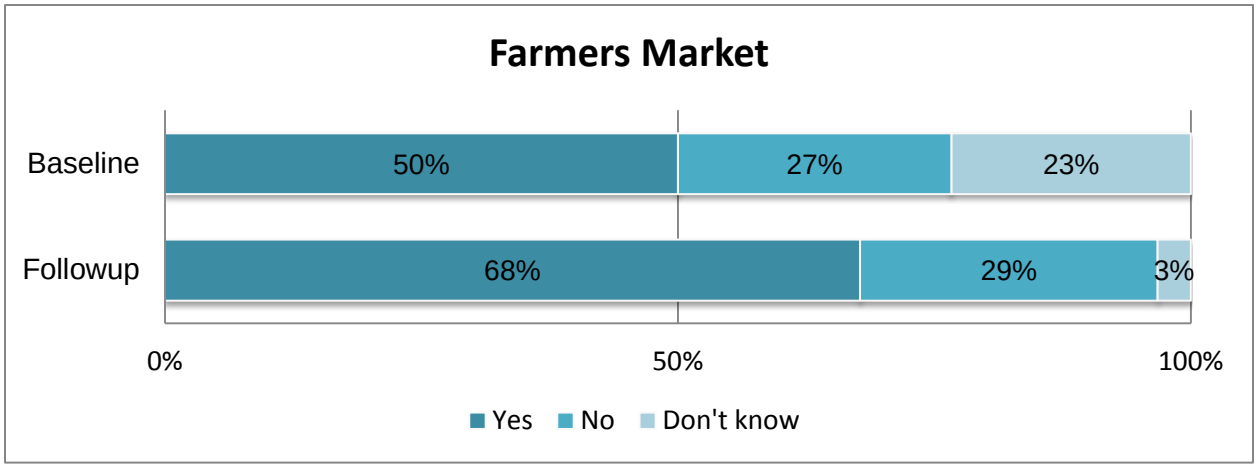


Figure 23. Visits to farmer's markets, baseline and follow-up comparisons (N=31)

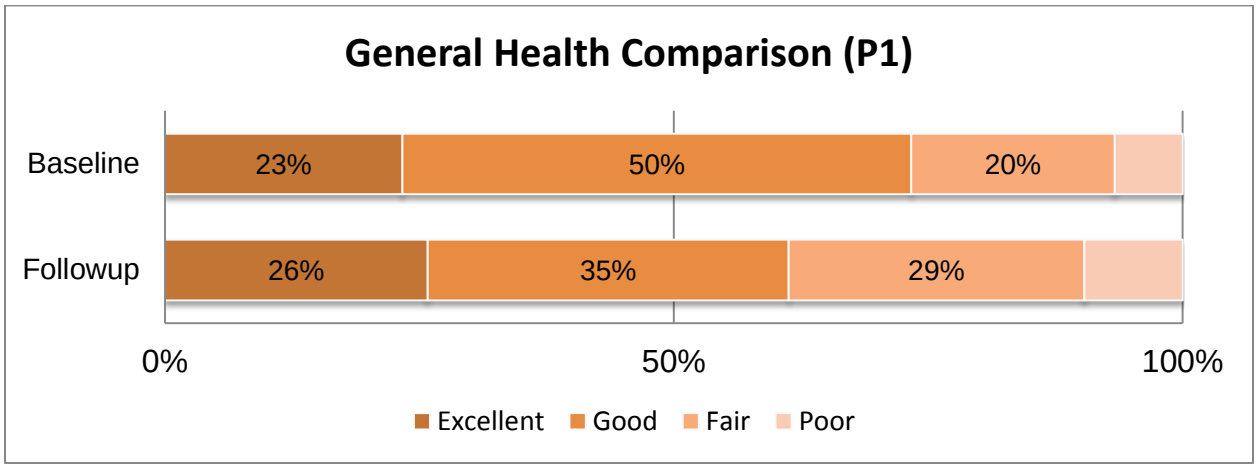


Figure 24. General health reporting, baseline and follow-up comparisons (N=31)