Challenges and Opportunities in Creating Healthy Homes: Helping Consumers Make Informed Decisions

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Abstract

Since the energy crises of the 1970s, scientists have been studying the relationship(s) between energy efficiency and indoor air quality in commercial and residential buildings. The resulting literature on indoor environmental health is vast, highly technical, and largely inaccessible to households and other key stakeholders who inhabit, manage and construct our nation's diverse housing stock.

Recognizing the need for more specific information about Americans' healthy housing concerns and awareness, we developed three surveys of homeowners, renters, and contractors with the goal of comparing their perceptions and priorities to the current well-established principles of indoor air and environmental quality. These principles were articulated by leading indoor air scientist and editor of Indoor Air Journal William Nazaroff: minimize indoor emissions, keep the home dry, ventilate well, and protect against outdoor emissions.

Results of our surveys indicate that: nearly one quarter of homeowners had some concern about healthy-home problems or risks; homeowners cited indoor air quality issues as their leading concern, followed by water quality, harmful materials and chemicals, and indoor environmental quality (such as noise or light pollution). Homeowners are taking action to address healthy-home problems, but face obstacles such as lack of trustworthy, clear, and actionable information. In addition, many are unaware that improving their home's energy efficiency may also improve its indoor air quality.

As consumer awareness continues to grow, households and other stakeholders need access to more transparent, science-based information regarding chemicals in building and other consumer products. There is ample opportunity for private businesses and public sector organizations—including manufacturers, remodeling contractors, building/property managers and even public health professionals—to offer greater access to healthy housing information and services.

Renters are at a particular disadvantage when it comes to obtaining/occupying healthy homes. There is a clear need and market for healthier rental units, just as there is a growing market for "green" units.

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Introduction

Every few years, a high-profile news story shines a spotlight on indoor air quality. Recently, in March of 2015, investigative reporting by the CBS news program *60 Minutes* revealed that laminate flooring, imported from China and sold by Lumber Liquidators, contained dangerous levels of formaldehyde.[1]

This situation recalled a similar debacle in 2009, when drywall—also imported from China—was implicated in electrical corrosion and indoor air pollution in new homes (mainly in Florida, Louisiana, and Virginia). Investigators proposed that the combination of hydrogen sulfide gas (emitted from the drywall) and formaldehyde contributed to homeowners' respiratory problems. In the South, these problems were exacerbated by high heat and humidity, and by inadequate ventilation in tightly sealed, air-conditioned homes.[2]

Concerns about formaldehyde in building materials are not new. Along with radon and combustion pollution from heating and cooking, formaldehyde was one of the three major indoor air pollutants that scientists began to study in the mid-1970s, when indoor air pollution first began to emerge as a public health concern. Formaldehyde was the first volatile organic compound to be identified as a significant indoor toxin. By the late 1970s, formaldehyde captured media attention thanks to urea-formaldehyde foam insulation, or UFFI, a popular insulator during an energy-thrifty decade of homebuilding. If it did not dry properly after being sprayed between interior and exterior walls, UFFI could release formaldehyde gas into the home, causing a range of health problems. In 1978, the *New York Times* published a comprehensive investigation, citing the lack of any long-term cancer studies on the chemical and the inadequacy of the fragmented Federal response[3] (formaldehyde has since been established as a carcinogen[4]). The Consumer Products Safety Commission eventually banned UFFI in 1982. This episode played a major role in raising both consumer and governmental awareness of indoor air pollution as a public health problem.

In 1978, the *New York Times* titled one of its UFFI articles "Fumes: Washington is Confused." In March of 2015, the president of a Dallas, Texas flooring company used similar language to describe the fallout from the Lumber Liquidators exposé: "It's confusion. Everybody's confused, and everybody wants

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[1] Kessler and Abrams, "Homeowners Try to Assess Risks."
[2] Wayne, "Chinese Drywall Linked to Corrosion."
[3] Crittenden, "Built-in Fumes Plague Homes" and "Fumes: Washington is Confused."
[4] *New York Times*, "The Verdict on a Troublesome Carcinogen." Some companies are responding to consumer concerns by removing formaldehyde from products. For example, see Thomas, "The 'No More Tears' Shampoo."

it out of their house." This article's concluding paragraph could have described not only the Lumber Liquidators situation but also the past thirty-plus years of debate over residential indoor air quality and standards: "But while federal rules exist for workers, no federal rules protect consumers from formaldehyde or most other airborne chemicals in their homes. And while research exists on formaldehyde's health effects, experts have difficulty correlating levels of exposure with cancer risk since so many factors can affect the development of the disease."[5]

A follow-up report on Lumber Liquidators two days later also echoed the *Times'* 1978 analysis of the UFFI problem: "Federal regulators have scrambled to respond to public concern. While the Environmental Protection Agency is in the final stages of adopting rules similar to those in California, it does not yet enforce them. The Consumer Product Safety Commission, which typically oversees household items like kitchen appliances and toys, may wind up leading any investigation."[6]

Despite the exponential expansion of scientific research into and knowledge of indoor air quality over the past 40 years, media coverage and regulatory responses to the high-profile indoor hazards of 2009 (drywall and toxic mold) and 2015 (laminate flooring) appear to differ little from 1978 (UFFI). This continuity highlights persistent dilemmas in debates over indoor air quality since approximately 1980: Who is responsible for ensuring good indoor air quality in private homes? Private homeowners? Government? Manufacturers of building and household products? The construction industry?

When these questions were debated in 1980 at one of the first American meetings on the topic (the Interagency Working Group on Indoor Air Pollution), it was proposed that the Environmental Protection Agency should take responsibility for this problem under the provisions of the Clean Air Act. Today such an idea seems unrealistic. The air in a home is a complex and ever-changing combination of chemical and biological products; it is affected by factors such as location, local climate and weather, the chemical content of building materials and furnishings, temperature and humidity, natural and mechanical ventilation, and resident behaviors such as cooking, smoking, and the purchase and use of household products. This complexity is evident in Lumber Liquidators' response to concerned customers: the company offered free air quality test kits which, after analysis by a laboratory, would report the formaldehyde content of the air. But without testing the flooring itself (or without doing before-and-after comparisons surrounding the installation of the flooring), there would be no way to differentiate between formaldehyde emanating from the flooring and formaldehyde emanating from

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[5] Kessler and Abrams, "Homeowners Try to Assess Risks."
[6] Abrams, "Lumber Liquidators."

other household items. There would therefore be no way to implicate Lumber Liquidators' products specifically.

Extreme examples of polluting building materials certainly capture headlines; they may or may not raise consumer awareness of indoor air pollution and healthy-home issues in general. Consumer beliefs about what makes a home healthy or unhealthy play a critical role in the creation of healthy indoor environments. Whether accurate or not, such beliefs influence decision-making and spending on everything from whether to undertake a major retrofit or remodeling project to what sort of kitchen and bathroom cleaners to use.

In addition to the ever-growing body of evidence linking housing and health (a concern of public health professionals since the 19th century), research is also beginning to quantify the economic cost of unhealthy indoor environments. For example, in the European Union, exposure to endocrine-disrupting chemicals is estimated to cost more than $209 billion per year "in health care expenses and lost earning potential," according to findings recently published in the journal of the Endocrine Society.[7] William Fisk, an indoor air expert at the Lawrence Berkeley National Laboratory, has quantified the effects of improved ventilation on productivity and performance and estimated potential savings and productivity gains at $1-$4 billion from reduced allergies and asthma, $10 to $30 billion from reduced symptoms of sick building syndrome, and $20 to $160 billion from improved worker performance that is unrelated to health.[8] Whatever our motivation for investing in them, healthier buildings and homes have the potential to improve occupant health and quality of life, the environment, and the economy. If the shift toward healthy homes is to be primarily consumer and business driven, then informed consumer decision-making is essential.

The marketing strategies of household-product companies reflect a strong interest in capitalizing on consumers' varied ideals of a healthy home. For example, Lysol has recently adopted the slogan "Start Healthing." The message of this campaign is that the best route to a healthy home is the use of Lysol's antibacterial, germ-killing products. In contrast, Seventh Generation (one of the best-recognized "natural" brands) advertises its products as "100% Clean, 0% Toxic." A recent commercial shows children devouring birthday cake off a glass table that has just been wiped down with a Seventh Generation cleanser. The underlying message: would you do the same with a Lysol-cleansed table?

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[7] Conditions linked to endocrine-disrupting chemicals include lowered IQ, diabetes, obesity, and male infertility. See Neslen, "Health Costs of Hormone Disrupting Chemicals."
[8] For example, see Fisk, "Health and Productivity Gains," and Fisk et al., "Demand Controlled Ventilation and Classroom Ventilation."

Clorox has begun promoting the disinfecting power of its conventional, bleach-based products with commercials that lampoon the use of "lavender-scented" natural cleansers. Among household-product companies, a battle is underway not only for consumers' money, but also for their allegiance to a particular approach to cleaning and home-maintenance. These companies are selling not only cleansers, but also different definitions of a healthy home. In the future, we may see similar competitions among sellers of home furnishings and building materials. Health is becoming a selling point for services as well as products: Stanley Steemer now advertises itself as the first carpet cleaner to be certified by the Asthma and Allergy Foundation.

Through advertising and other media, consumers are bombarded with information and misinformation about strategies for creating and maintaining a healthy home, yet there is relatively little information available regarding their attitudes, concerns, and behaviors when it comes to connecting their own housing and health. To begin addressing this gap, we designed a research project focused on four questions:

- First, what is the emerging consensus among scientists and other building professionals about fundamental requirements for maintaining a healthy home?
- Second, to what extent are U.S. households aware of or concerned about these fundamental requirements, and able to achieve a healthy indoor living environment at home?
- Third, what are the challenges (informational, financial, legal, agency-related) to closing the gap between scientific consensus and households' daily experience of healthy housing issues?
- Fourth, what can or should be done to address these challenges?

Historical Background:

The desire for a healthy home is not new, but the nature of our concerns has changed, shifting from basic sanitation and safety to indoor air quality and the health effects of toxic chemicals.

Before modern medicine, environment – including the home – was accepted as an important (arguably the most important) determinant of health. We can even find evidence of healthy housing concerns in the ancient biblical context. The book of Leviticus includes a discussion of buildings: "[the priest] is to examine the mold on the walls, and if it has greenish or reddish depressions that appear to be deeper than the surface…He must have all the inside walls of the house scraped."[9] The Hippocratic writings ("Airs, Waters, Places") contain a detailed discussion of the relationship between location and health: "those [districts] that face east are likely to be healthier than those facing north or south even if such places are only a furlong apart. These districts do not experience such extremes of heat and cold."[10] For medieval physicians, air was one of the six "non naturals" (the others being food and drink, exercise, sleep, excretion, and "accidents of the soul" – or, emotions). The medieval physician manipulated these in treating his patients, creating an individualized regimen designed to support health.[11]

In the 19th century, hospital architecture emphasized the importance of air and ventilation through the model of "pavilion hospitals."[12] Outside of hospitals, "miasmas" (bad air) and sewer gases were concerning to rural and urban dwellers alike. For antebellum settlers in the American South, assessing a region's air and environment were prerequisites to establishing a homestead, as living in the wrong location could lead to disease.[13] But, it was late 19th century sanitary reformers who articulated the first modern link between housing and health: they launched the healthy housing conversation that continues today. Environmental determinism—the idea that a healthy home with fresh air, light, and green space would help cultivate healthy American families—intersected with the agendas of the sanitary reformers and societal concerns about the seemingly unclean living habits of immigrants.[14]

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[9] Leviticus 14:36-41.
[10] "Airs, Waters, Places."
[11] Siraisi, *Medieval and Early Renaissance Medicine.*
[12] Rosenberg, *The Care of Strangers.*
[13] Valencius, *The Health of the Country.*
[14] Lubove, "Jacob A. Riis: Portrait of a Reformer."

Throughout most of the history of the built environment, opening windows was the primary means of ventilation for buildings. Regional architectures (e.g., homes in the South built before air conditioning) reflected the desire to maximize ventilation.[15] It was only with the post-World War II proliferation of chemicals used in everyday life, and the publication of Rachel Carson's *Silent Spring* (1962), that concerned citizens and scientists began to question the increasingly ubiquitous chemical environment. But conversations about air pollution and its health consequences focused almost exclusively on outdoor or "community" air pollution. In the 1970s, as homes became more tightly sealed due to rising energy costs after the OPEC oil embargo of 1973-1974, indoor air pollution was still overlooked. The landmark Clean Air Act of 1970 had nothing to do with the indoor environment, let alone with private homes. Assisted by high-profile events such as the outbreak of Legionnaire's disease and problems with UFFI, indoor air became a newly prominent public health concern only in the early 1980s. Scientific literature on indoor air quality began to expand rapidly, and popular media produced numerous features and news articles on the insidious dangers lurking in the typical American home.

Although he remains largely unknown to historians, as early as 1962 the physician Theron Randolph became one of the first Americans to cite indoor air pollution as a potential health hazard.[16] He suggested that people experiencing persistent headaches, nausea, respiratory and other health problems begin by removing their gas stoves (replacing them with electric), and, if possible, avoid or seal off attached garages, as the products stored there, combined with car exhaust, could easily drift into the home. It is worth noting that gas stoves and attached garages are today still considered major sources of indoor air pollution.[17]

Some healthy housing concerns—lead paint, pests, asbestos—have long histories and remain problems today. Newer concerns of the late 20th and 21st centuries are distinguished by an emphasis on chemicals and their emissions (or "off-gassing"). These chemicals (volatile organic compounds, semi-volatile organic compounds, and phthalates, to name just a few) are used in everything from the construction materials in the structure itself, to flooring, to furnishings, to household cleaners and other products. There is even concern that overuse of anti-bacterial cleaning products may alter the microbial composition of the indoor environment and of human bodies (microbiomes). Research on the microbiology of the built environment is currently expanding. A major theme is that people not only need to be protected from pathogens (as in the case of 'sick building syndrome'), but they also need to

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[15] Arsenault, "The End of the Long Hot Summer."
[16] Randolph, *Human Ecology and Susceptibility to the Chemical Environment.*
[17] For example, see Stratton and Singer, "Addressing Kitchen Contaminants."

be exposed to diverse microbes, especially at a young age. While scientists do not yet understand what constitutes a 'healthy' microbiome indoors, they do know that building design, materials, and operation all play a role in the transmission of microbial communities (for example through ventilation, moisture control, UV light exposure, etc.).[18]

So what *do* we know?: Guiding Principles on Indoor Air Quality

Uncertainty, controversy, and ongoing discovery are standard in any active scientific field, and indoor air research is no exception. Chemicals found in the typical home, their consequences, and their synergistic interactions are the foci of the vast and ever-growing literature on indoor environmental health. Recognizing these intricacies to be beyond the scope of this paper (and beyond our expertise), we looked for a set of guiding principles on indoor air quality to compare and contrast with consumers' attitudes and behaviors regarding their own homes. Ideally, these guiding principles should be accessible to anyone in a policy, industry, or advocacy role who wants to become better informed about healthy housing.

We identified a clear and cogent articulation of the principles of good indoor air quality in a recent article by William Nazaroff, an indoor air scientist at the Lawrence Berkeley National Laboratory and the editor of *Indoor Air Journal*. Nazaroff acknowledged that the rapid pace and specialized nature of indoor air research can make it difficult to find consensus. "The number of chemical species in indoor air of potential concern for human exposure is uncertain," Nazaroff wrote; "a lower bound might be the high-production volume chemicals, which number 2,200 in the US alone. Indoor environmental conditions that influence exposures vary in space and time. Health risks may depend in complex and subtle ways on factors such as the time pattern of exposure, as well as on the age, gender, genetic heritage, and underlying state of health of the exposed persons." Despite this complexity, Nazaroff takes a big-picture approach to indoor air quality and distills decades of research into "four ideas expressed in twelve words, listed in priority order: minimize indoor emissions; keep it dry; ventilate well; protect against outdoor emissions." Below we discuss each principle in more detail.[19]

1. Minimize indoor emissions

The first principle of good indoor air quality is to minimize indoor emissions. Indoor emissions are pollutants originating from inside the home that compromise indoor air quality. Combustion from

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[18] For further discussion, see La Jeunesse, "Wild Frontiers of Healthy Housing Research."
[19] Nazaroff, "Four Principles."

cooking and heating is an important source of indoor pollutants such as carbon monoxide, nitrogen oxides, and particulate matter. Other pollutants, such as volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) come from the "off-gassing" of building materials used in constructing the home, or of materials brought into the home subsequently. Common potential sources of emissions include products such as flooring and paint, furniture, and household cleaners, but also products that are not exclusively housing-related: personal care products like shampoo or nail polish remover, office supplies, and even electronics. Smoking cigarettes or other products indoors is also an important (and preventable) source of indoor emissions. Radon, a cause of lung cancer, is also an important indoor pollutant linked to the geology of specific regions.[20]

Reducing emissions from the sources mentioned above is critical to creating healthier indoor living environments. The problem cannot be solved by improved ventilation alone: since the early days of indoor air research in the early 1980s, scientists have emphasized that no amount of ventilation can compensate for excessive indoor emissions. Indeed, SVOCs are particularly problematic because they are not effectively controlled through ventilation.[21] Furthermore, increased ventilation can lead to higher energy costs, both financial and environmental, so minimizing indoor emissions is a major positive step towards minimizing use of fossil fuels (which can further contribute to indoor air pollution).

2. Keep it dry

Dampness is the enemy of a healthy home for several reasons and is "associated with an increased risk of adverse respiratory outcomes."[22] One very important consequence of excess dampness is the potential for accelerated release of chemicals from building materials, exacerbating what may already be a heavy chemical load inside a home. A damp environment can support the growth of fungi and bacteria, the inhalation of which can cause respiratory problems. While some excess humidity/dampness results from inadequate exhaust and ventilation, unexpected events such as floods, leaks, or burst pipes can rapidly add too much moisture to a home. A recent report by the Institute of Medicine on climate change and indoor air quality emphasized the importance of extreme weather in indoor environmental quality and warned that future climate change-related weather patterns are likely to increase residential flooding, dampness, and mold problems.[23] Because moisture can play a role in

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[20] For an accessible discussion of indoor emissions, see Willem and Singer, "Chemical Emissions."
[21] Willem and Singer, "Chemical Emissions," p. ii.
[22] Nazaroff, "Four Principles," 354.
[23] Institute of Medicine, *Climate Change, the Indoor Environment, and Health.*

exacerbation of asthma, "large health and economic benefits could result from effectively controlling excessive indoor dampness."[24]

3. Ventilate well

This principle connects most directly to the healthy housing movement of the late 19th century discussed above, wherein the emphasis was largely on ventilation (and there were fewer chemical emissions to ventilate or minimize). But no amount of ventilation can compensate for excessive indoor emissions. And there is a major energy component to this problem: "the cumulatively large energy requirements associated with building ventilation are an important constraint on ventilation practice, a constraint that is becoming more stringent with time owing to growing concerns about the environmental consequences of energy use, especially from fossil fuels."[25] The more polluted an indoor environment, the harder a building's HVAC system must work to maintain air quality.

4. Protect against outdoor emissions

Nazaroff writes that the indoor air research community "tends toward myopia in thinking about the causes of indoor air pollution … we regularly fall short of the needed attention to ensure that ventilation air is of suitable quality for its intended purpose. One of the stark manifestations of this problem is the common reference to the outdoor supply air stream in ventilation systems as *fresh."* Urban air is generally more polluted than rural, though not exclusively, as polluting industries may be located in rural areas. The most serious threats to health from outdoor air pollution are fine particulate matter (under 2.5 microns) and ozone.[26]

Summary

While scientists have exponentially expanded their knowledge of indoor air and environmental quality over the last forty years, much remains unknown. Uncertainty and continual progress are inherent to science, yet they need not obstruct changes (in manufacturing, policy, etc.) that will empower and protect consumers, particularly when it comes to reducing indoor emissions. Nazaroff's four principles offer a guide for households, building professionals, industry and policy-makers alike to take steps toward promoting healthier indoor air quality. Replacing toxic building products, furnishings,

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[24] Approximately 4.6 million cases of asthma in the US, at a cost of $3.5 billion. See Nazaroff, "Four Principles," 354.
[25] Nazaroff, "Four Principles," 354.
[26] Nazaroff, "Four Principles," 355.

and household products with safer alternatives is a particularly critical step toward adhering to the principles of good indoor air quality and promoting healthier homes.

Research Strategy

Recognizing that scientific, consumer, business, and policy stakeholders seem to be increasingly interested in healthy housing issues, from the macro (healthy communities) to the micro (chemicals in consumer products) level, we wanted to assess the level of agreement between current scientific consensus and current consumer concerns and actions on healthy homes.

To assess homeowner concerns and behaviors, we collaborated with The Farnsworth Group to design and field an original survey to a panel of US homeowners. The main goals of our survey were to assess: 1) the degree to which homeowners are concerned about healthy-home issues; 2) the types of concerns (both general and specific) that are most and least prominent; 3) actions that homeowners have taken or would like to take, including any obstacles to taking action; and 4) the information channels through which homeowners learn about healthy-home issues. We later conducted a follow-up survey focused on renters, with the goal of comparing their concerns to owners'. Since renters are frequently impacted by the behaviors of their landlords, and have less ability to modify their homes, this follow-up survey included questions to assess the effect of this agency constraint on renters' concerns. Finally, since households often engage the services of professional remodeling contractors to manage more extensive home renovations and repairs, we also conducted a survey of a small sample of general remodeling contractors to gauge their recent experience with 'healthy-home' projects and client concerns. The goal was to assess such factors as their clients' levels of interest in healthy-housing issues, their most popular/frequent projects related to healthy homes, and their level of knowledge/confidence about healthy homes. The details of all three surveys are included in the **Technical Appendix** to this paper.

An important distinction in our design and analysis of each survey was between different categories of healthy-home issues. At a basic level, there are issues of safety, accessibility, and structural integrity of the home. These include problems with foundations or roofs, trip hazards, or even obstacles for aging or disabled residents. In this "basic" category we also included pests, which, to our surprise,

turned out to be a frequently-cited problem in the free-response section of our survey.[27] We distinguished these basic issues from indoor air quality problems that may be less obvious yet still pose health hazards. Many indoor air pollutants can be "invisible" in that they cannot be seen, smelled, or touched; households often remain unaware of them unless they cause physical symptoms, and they may cause health problems only after years or even decades of exposure. Classic examples would be radon, which is only detectable by specialized instruments; formaldehyde, which may give off an odor or cause symptoms only at high concentrations, yet may still be dangerous at low concentrations; and endocrine disruptors such as phthalates. New homes without any apparent odors or problems may contain high levels of volatile organic compounds (VOCs) and other pollutants. This is sometimes true of homes that are tightly sealed for the purpose of saving energy; however, indoor conditions are affected by many variables, including the chemical content and emissions of construction and other materials.[28]

Another emerging category of healthy-home issues is neither basic nor air-quality related, but also warrants attention: indoor environmental quality. This refers to aspects of the home environment such as noise or light. Noise pollution can come from outdoors, as in the case of nearby transportation hubs (airports, railroads, traffic) or industry, or from inside the structure, as often happens with adjacent units in a multi-family building. Depending on the site location and placement of windows, households may feel they do not get sufficient natural sunlight indoors during the day. During the night, excessive artificial light or 'sky glow' can emanate from outdoors and enter the home from outdoor signs and lamps. Water quality—a surprisingly prominent concern among our respondents—is another aspect of indoor environmental quality.

It is important to recognize that a home is a dynamic system, and that the categories described above are interrelated. As an example, consider a house that is poorly insulated/weatherized, lacks adequate heating, or has problems with the integrity of its envelope. Occupants may be compelled to use unsafe space heaters or even their kitchen oven to provide adequate heat, creating not only fire

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[27] Public health reformers of the late 19th century targeted substandard housing (particularly problems with overcrowding, lack of ventilation and light, lack of safe plumbing/sewers, and general sanitation) as a major cause of poor health among immigrants and the poor. Although much research today focuses on chemical and biological hazards in the indoor environment, it is important to recognize that basic housing deficiencies persist. According to information from the 2013 American Housing Survey, basic housing deficiencies (related to plumbing, electrical and heating systems, and structural integrity) impact about 5 percent of households. However, the share was higher among renters (9 percent) than among owners (3 percent). Survey results from two decades earlier further suggest that while owners saw their incidence of problems decline (from 5 percent), renters saw no improvement in housing adequacy. Not surprisingly, low-income households earning roughly the equivalent of the federal minimum wage ($15,000 per year) experienced housing adequacy problems with the highest frequency across tenures.

[28] Less et al., "Indoor Air Quality"; Maddalena et al., "Maximizing Information."
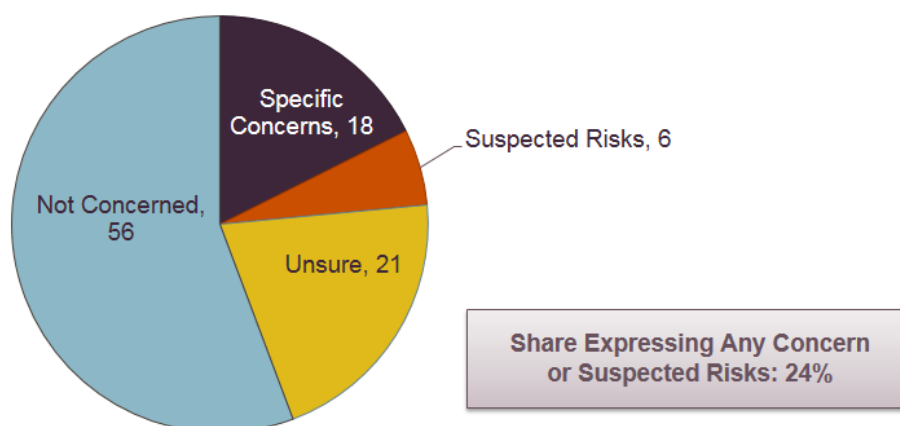
hazards but also indoor air pollution due to combustion. Or, in a home with a persistent pest problem, occupants may be forced to purchase, use, and store potentially toxic pesticides, creating not only additional indoor air pollution but also a poison hazard for children. And finally, location is a crucial influence on indoor environmental quality: it becomes much more difficult to achieve and maintain good indoor air quality when situated near a polluting industry, major highway, airport, etc.

We fully recognize the importance of basic safety issues; addressing these would go a long way toward improving health and quality of life for millions of Americans. Indeed, results from the American Housing Survey suggest that fully 9 percent of renters experienced moderate or severe problems related to plumbing, heating, electric, and basic structural integrity/upkeep as of 2013. However, in this project we were especially interested in consumer concerns about indoor air quality, environmental quality, and the chemical environment. The topic of chemicals at home is currently gaining momentum within the environmental health, healthy housing, and related business communities. In creating our survey, we gave respondents the opportunity to cite any and all of these interrelated concerns, and many cited multiple, competing issues affecting the safety, health, and comfort of their homes.

Survey Findings

Figure 1: Nearly One in Four Householders Expressed Concern About Healthy Home Problems or Risks

Share of Owner Households Expressing 'Healthy Home' Concerns (Percent)

Notes: Sample size is 2,249. Households were asked, "In the past few years, how concerned have you been about your current home negatively affecting your or another occupant's health? This may include but is not limited to concerns related to mold/moisture, indoor air quality, asthma, chemicals in the home, noise insulation problems, light issues or other "healthy housing" issues important to you. "
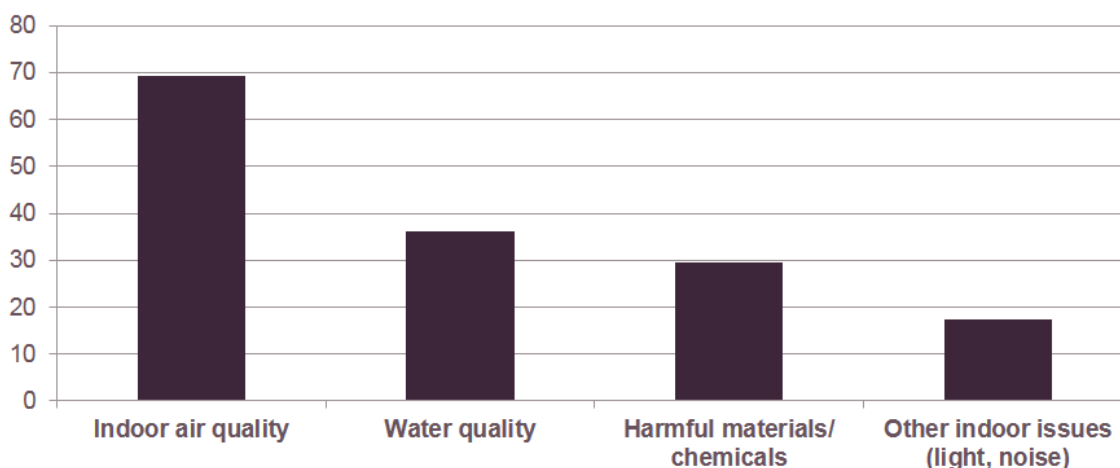Source: JCHS tabulations of Healthy Home Owner Survey, The Farnsworth Group.

Fundamentally, we found that our sample of homeowners had significant concerns about their homes negatively affecting their or another occupant's health. When asked, "In the past few years, how concerned have you been about your current home negatively affecting your or another occupant's health?", nearly one-quarter of homeowners reported some level of concern or suspected risks. Another fifth (or 21 percent) of respondents identified as "unsure" about whether their home could contain health hazards **(Figure 1)**. Even those who are strongly concerned may feel stymied by uncertainty about the best course of action to take when addressing a healthy-home problem. If we include these households, the total combined share of households either concerned or unsure of health risks/problems related to their home was closer to 45 percent. In short, this finding suggests that there is definite interest in healthy housing among homeowners. It also suggests there is a potential market for transparent healthy-housing information, as well as for knowledgeable and trustworthy healthy-home remodelers, contractors, and service providers.

When asked to describe their concerns, the majority of these households, or 70 percent, cited issues related to indoor air quality (IAQ) **(Figure 2)**. Compared to other issues, our results suggest that

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IAQ was by far the leading source of healthy housing concern. The next most cited issue by comparison was water quality, cited by just over a third of concerned households. Concerns about harmful materials/chemicals at home were cited by just under a third of these households. Meanwhile, interest in other emerging indoor issues such as light and noise were least prominent.

Figure 2: Indoor Air Quality and Other Indoor Environmental Problems Drive Homeowner Interest in 'Healthy Housing'

Share of Homeowners Concerned about 'Healthy Housing' who Cited the Following Specific Issue(s) (Percent)

Notes: Sample size is 529. Households that expressed some basic level of healthy housing concern were asked, "Which general category(ies) best describes your concern about the impact of your home on your household's health?"
Source: JCHS tabulations of Healthy Home Owner Survey, The Farnsworth Group.

Next, we surveyed these households with 'healthy housing' concerns to investigate which specific indoor air and other environmental quality issues they felt were the most pressing. **Figure 3** illustrates these results and the list of concerns respondents had to choose from. When asked to select up to three issues that "generate the most concern" for their household, the leading answer by far was managing household dust and/or pet dander (cited by 47 percent of homeowners), followed by managing dampness or moisture (36 percent). Dust, dander, dampness, and moisture concerns affected households in all types of geographic locations relatively equally, with no significant difference in the rate of concern between highly populated, central city locations and less populated, rural areas. Another highly ranked and widespread issue of concern was water quality/purity (25 percent).

Figure 3: Dust and Dampness Generated the Most Concern, Followed by Water Quality and Other Indoor Air Quality Concerns

Share of Homeowners Concerned about Indoor Air & Environmental Quality Issues who Identified the Following Issues as <u>Among their Top Three Concerns</u> (Percent):

Issue	Percent
Managing household dust and/or pet dander	47
Dampness or moisture issues	36
Water quality/purity issues	25
Outdoor pollution surrounding the home	22
Air pollution from indoor cooking/heating	18
Lack of sufficient ventilation	15
Radon gas in the home	14
Excessive dryness of air	12
Chemicals from the building/structure itself	9
Chemicals from interior furnishings	9
Excessive outdoor noise(s)	7
Asbestos insulation	6
Insufficient natural light	6
Lead paint	4
Noise issues within the home	3
Excessive illumination coming from outdoors	3

Notes: Sample size is 465. Households that expressed some basic interest in 'invisible' healthy housing issues were asked, "Among the healthy home issues that concern your household, please select up to three of them that generate the most concern."
Source: JCHS tabulations of Healthy Home Owner Survey, The Farnsworth Group.

Outdoor pollution surrounding the home was the next most prominent concern, selected as among the most concerning issues by 22 percent of households. Households in urban locations were much more likely to be impacted by this issue, with over 70 percent of households in central city locations citing outdoor pollution, compared to only around 40 percent in rural areas. Although not specifically mentioned in our survey, attached garages can be an important source of household air pollution, as car exhaust fumes and emissions from other products (e.g., lawn care) can easily enter the home. As early as 1962, physician Theron Randolph cited attached garages as a major cause of indoor air pollution (followed by gas stoves and forced-air heating). Air pollution from indoor cooking and heating was cited as among the most pressing issues by 18 percent of households. Respondents also cited— though less frequently—lack of sufficient ventilation (15 percent), radon gas in the home (14 percent), and excessive dryness of air (12 percent) as among their top concerns.

Issues cited as most concerning by less than 10 percent of respondents included chemicals from the building/interior furnishings, excessive noise, asbestos, lighting issues and lead paint. This does not necessarily imply that few households were concerned about these issues, but rather that when asked to rank them against other concerns, they very rarely emerged among the top three issues. Indoor

environmental issues such as noise and light have the potential to affect quality of life significantly, but generally receive less attention than indoor air quality problems.[29] Similarly low shares of homeowners citing lead paint and asbestos also raises the question of how many homeowners actually have these problems but are unaware of them. Both of these are problems where the mitigation might be more problematic than the substance itself, possibly also making it easier for impacted households to justify ignoring these issues.
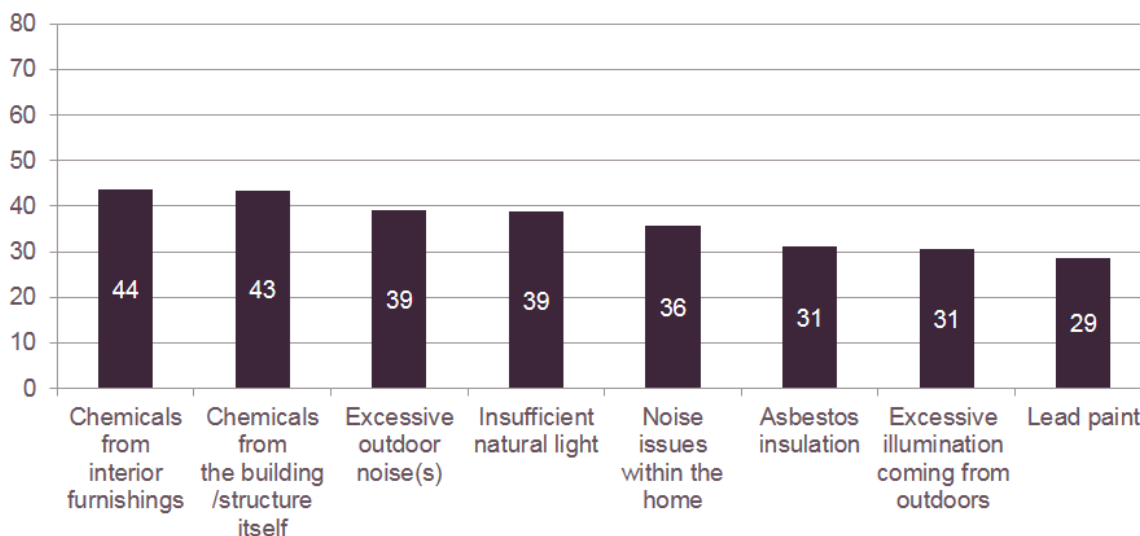
We also asked homeowners to report whether they had *any* concern/interest in each individual issue regarding their current home in recent years. This yielded a similar ranking of concerns, though as expected in every case the share of households indicating some level of concern was higher. Looking at issues cited least often as a "top concern" (by less than 10 percent of households), we found that the baseline rate of *any* concern in these issues actually ranged much higher, between 25 and 45 percent. For example, nearly 45 percent cited concerns over chemicals, and between 35-40 percent cited excessive outdoor noise, noise issues within the home, and insufficient natural light. Issues with the lowest rates of concern (around 30 percent) included asbestos insulation, artificial illumination from outdoors, and lead paint **(Figure 4)**. With the exception of indoor noise issues within the home, city dwellers were significantly more concerned about all of these issues.

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[29] Noise pollution is becoming an increasingly ubiquitous problem in both urban and suburban environments. Although there are many potential adverse consequences of noise exposure, recent studies have looked at relationships between noise exposure and cardiovascular health. For example: Correia et al. Also see Datz, "Aircraft Noise"; Sorensen et al., "Road Traffic Noise"; Halonen et al., "Road Traffic Noise"; Barron, "In Urban War." The intersection of light and human health is another important area of research relevant to creating healthy homes. Specifically, researchers are interested in how different types of light exposure affect the endocrine system and chronobiology. One well-known example of a light-related health issue is the relationship between exposure to sunlight and Vitamin D levels. More recently, some researchers have begun to study the effect of electronic devices such as computers, e-readers, smartphones, etc. on melatonin and sleep behavior. As an example of this research, see Chang et al., "Evening Use of Light-Emitting eReaders." Given the expanding variety of light bulbs and lighting systems for residential use, lighting is an emerging healthy-home issue that industry may wish to follow. For examples of how popular cultural/health trends may affect indoor lighting preferences, see Williams, "The Paleo Lifestyle," and Galbraith, "Can Orange Glasses Help You Sleep Better?"

Figure 4: While Still Emerging, Baseline Concern over Chemicals and other Indoor Environmental Issues Is Already Substantial

Share of Owners Rating Specific Indoor Environmental Health Issues as a source of their Healthy Housing Concern(s) (Percent)

Chemicals from interior furnishings	Chemicals from the building /structure itself	Excessive outdoor noise(s)	Insufficient natural light	Noise issues within the home	Asbestos insulation	Excessive illumination coming from outdoors	Lead paint
44	43	39	39	36	31	31	29

Notes: Sample size is 465. Households that expressed some basic interest in 'invisible' healthy housing issues were asked, "Of the following healthy home issues, how would you rate your level of concern/interest over the past few years regarding your current home?"
Source: JCHS tabulations of Healthy Home Owner Survey, The Farnsworth Group.

Recalling Nazaroff's four guiding principles of good indoor air quality—"**minimize indoor emissions, keep it dry, ventilate well, protect against outdoor emissions**"—it is evident that among the homeowners who expressed concern or awareness of healthy housing risks, many of their top priorities and concerns aligned with these very issues, particularly dampness and outdoor air pollution surrounding the home. Outdoor air pollution can have a paradoxical/ problematic relationship with ventilation, as natural ventilation (opening windows/doors) can let in outdoor pollutants even while occupants try to release indoor ones. In fact, "indoor exposure to outdoor pollutants can easily dominate (or at least be comparable to) outdoor exposure!"[30] If the home relies on mechanical more than on natural ventilation, and is situated in a polluted area, air filtration may help, but has problems of its own as it may require regular, specialized maintenance to perform optimally, or even adequately. The takeaway is that "ventilate well" is easy in theory but sometimes difficult in practice, particularly if indoor emissions are high or the house's location is problematic.

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[30] See Stephens, "Infiltration of Outdoor Pollutants."

Based on these results, it is difficult to assess the degree to which homeowners are aware of and pursuing the first (and most important) principle of both good indoor air quality and, arguably, a healthy home**: reducing indoor emissions**. As **Figure 3** shows, a leading concern among homeowners was indoor air pollution from cooking and/or heating, suggesting many households are aware of indoor emission risks. Cooking is an important source of indoor air pollutants, but the proper installation of an effective range hood can help mitigate this problem. However, most locations in the United States do not have building code requirements for kitchen ventilation.[31]

Though only a small share of respondents prioritized chemicals from the building structure itself and chemicals from indoor furnishings as among their "top concerns," the baseline rate of concern over indoor chemical emissions was higher. In addition, when asked about actions they had taken or would soon take to create a healthier home, more than one-third of concerned households reported using VOC-free paint, removing interior furnishings and carpets posing health risks, and removing toxic cleaning supplies—a possible sign of growing consumer awareness in this area. In order to reduce overall indoor emissions, homeowners and businesses that supply housing materials and furnishings need to be aware of and mitigate both sources of indoor air pollution. Chemicals from building materials, finishings, and adhesives are particularly complicated because they are generally outside of homeowner control and expertise. Selection of these products is largely under the control of builders and contractors, and can have a major impact on indoor air pollution levels.

Homeowner Action and Inaction

Our second major research question asked, "To what extent are households able to achieve a healthy indoor living environment at home?" Based on our homeowner survey, we found that among respondents with healthy-home concerns related to indoor air or environment, nearly 60 percent had taken some sort of action to mitigate a problem or improve indoor health. As this suggests, homeowners are not only vaguely suspicious of indoor health risks but they are taking steps to mitigate these risks. Not surprisingly, as intensity of concern increased (from "suspicious" to "minor" to "moderate" to "major"), so did the likelihood of action. Even among those who merely suspected a health risk in the home, more than half had taken one or more healthy-home actions.

Figure 5 lists actions taken most frequently by households to make their homes healthier. Again, many of the projects they reported completing most frequently were relatively minor: for example,
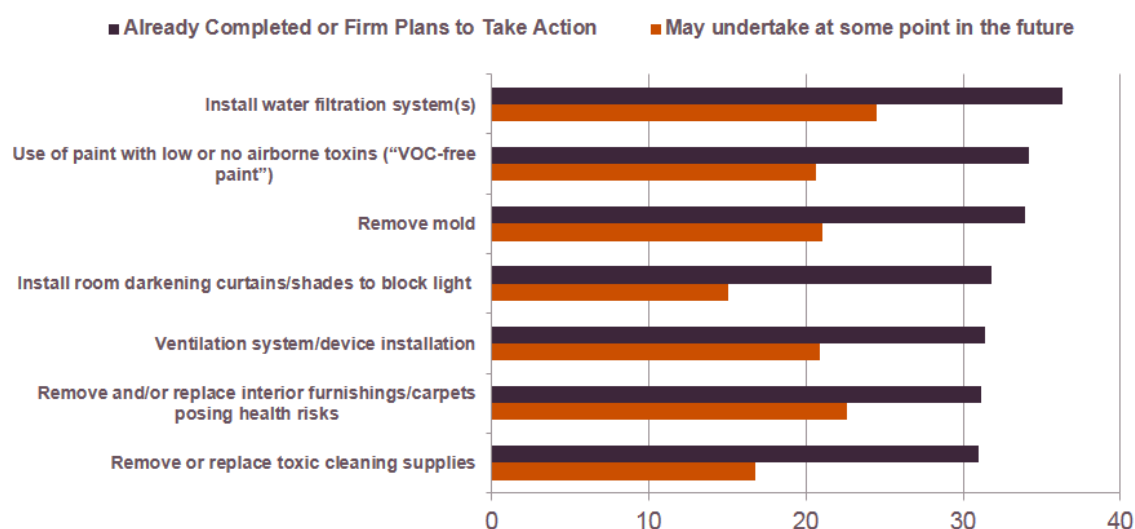
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[31] Stratton and Singer, "Addressing Kitchen Contaminants."

installing a water filtration system, use of VOC-free paint, installing room-darkening shades, and replacing toxic cleaning supplies. Although these relatively easy and inexpensive actions can be described as "low-hanging fruit," they are indeed important steps toward healthier homes, steps that scientific consensus certainly supports. Other popular actions were mold removal, installing a ventilation system or device, and removing/replacing indoor furnishings and/or carpets seen to pose health risks. Each of these activities could be superficial or comprehensive/structural. For example, superficial mold can be removed with topical cleansers while a severe mold problem requires professional remediation. Replacing carpets or flooring is more intrusive and expensive than replacing a few pieces of furniture. While we don't know the extent of these projects, respondents were clearly interested in addressing these issues, and were sometimes taking action.

Figure 5: Healthy Home Initiatives Homeowners Undertook Most Frequently were Typically Low-Cost or Relatively Easy

Share of Homeowners Expressing Intention to Act on Specific Healthy Home Projects (Percent)

■ Already Completed or Firm Plans to Take Action   ■ May undertake at some point in the future

Notes: Sample size is 465. Households that expressed some basic interest in 'invisible' healthy housing issues were asked, "…which of the following healthy home actions has your household performed in the past few years in your current home, or which does your household plan to undertake in the near future?
Source: JCHS tabulations of Healthy Home Owner Survey, The Farnsworth Group.

Yet many households reported significant obstacles, even when they wanted to take action. In our free response section, homeowners often cited uncertainty as a significant impediment to making a change in their homes. This includes uncertainty about the best contractors and companies to handle the project, the actual health payoff of the project, the severity of the risk if no action is taken, and the potential side effects of the action ("will I have to move out?" "will the house be livable while the
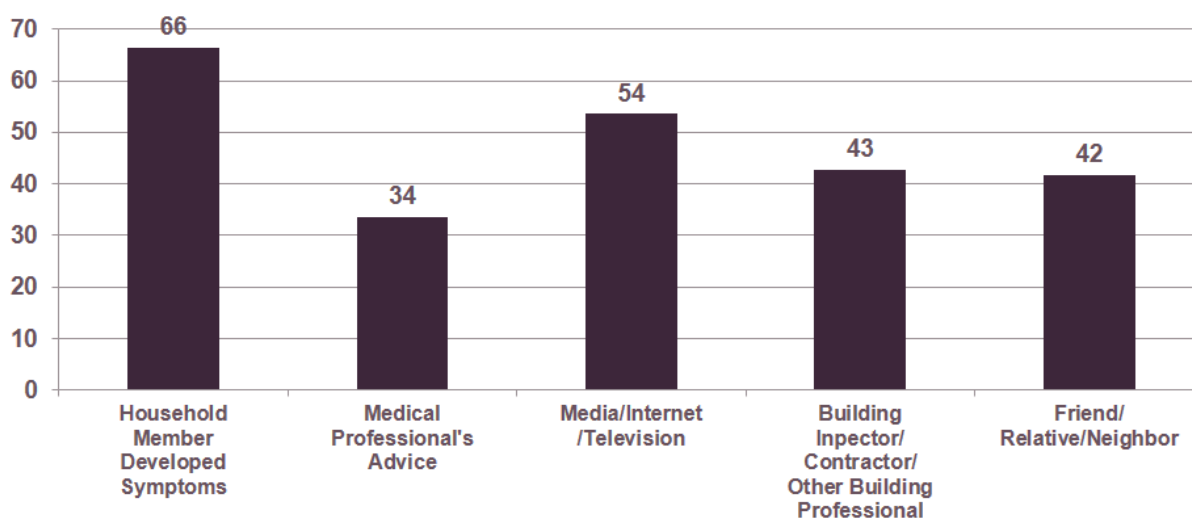
project is completed?"). Other households cited lack of time to research the problem and options for addressing it, a problem compounded by the suspicion that information online, in other media, or in stores is actually nothing more than marketing or advertising.

Paths to Healthy Housing Awareness

Uncertainty among homeowners likely results not only from the sheer complexity of the healthy housing question and the potential for misleading claims, but also from the lack of definitive, comprehensive, and easy-to-access information upon which to base healthy housing decisions. Given this information challenge, we also wanted to understand how homeowners were becoming aware of healthy housing issues. To this end we asked homeowners who took specific healthy housing actions to indicate how the related health issue(s) and/or risk(s) came to their household's attention.

Figure 6: The Ways in Which Issues Came to Owners' Attention were Diverse

Share of Households Expressing Intention to Act on a Healthy Home Project that Obtained Information Through the Following Means (Percent)

Notes: Sample size is 414. Households that expressed some basic intention to act on specific healthy housing projects were asked, "Among the following healthy home actions your household has taken, plans to undertake or would like to undertake, please indicate how the related health issue(s) and/or risks(s) came to your household's attention."
Source: JCHS tabulations of Healthy Home Owner Survey, The Farnsworth Group.

As **Figure 6** shows, homeowners cited a diverse range of information sources. Fully two-thirds of them took action because they developed symptoms they felt were related to their home. The next most frequent channel of information or awareness of healthy housing issues was the internet/ media/ the web. To a lesser extent, friends, relatives, neighbors and building contractors also served as sources

of information on healthy housing risks. Medical professionals scored lower as a source of healthy housing information. While these categories are quite broad, they provide an impressionistic sense of how households become aware of housing problems.

One particularly opportune time for homeowners to invest in improving indoor air quality is during an energy efficiency upgrade. Although it is beyond the scope of this paper to describe the many ways in which energy efficiency and indoor environmental quality are related, it is clear that energy efficiency upgrade/retrofit projects can improve indoor air quality. For example, a tighter building envelope can reduce infiltration of some outdoor pollutants, and a better-insulated house with efficient appliances (or better yet, heating from non-fossil fuel-based energy sources) can reduce indoor combustion pollution.[32] But even as hype over energy efficiency has risen over the past decades, it is not clear that stakeholders—not only homeowners, but also owners of rental properties, policy makers, etc.—are sufficiently aware of this connection. A recent report by the American Council for an Energy-Efficient Economy (ACEEE) on the benefits of multifamily energy retrofits found that improved occupant health, while a documented benefit of many retrofits, is not usually factored into the cost-benefit analyses used in approving or denying energy efficiency projects.[33]

In order to assess homeowners' tendency to factor indoor air quality considerations into their energy efficiency projects, we asked those who were concerned about healthy housing and who completed an energy efficiency project to identify any motivating factors they considered. **Figure 7** shows that while the majority of respondents cited saving money or other financial considerations, less than half cited indoor air quality as "among their motivating goals" for their energy efficiency project. An even smaller share—less than one-quarter—cited reduction of outdoor pollutant infiltration as a motivating goal. Given that both of these outcomes are potential payoffs of an energy efficiency upgrade, it seems more can also be done to educate consumers about the relationship between energy retrofits and indoor air quality.
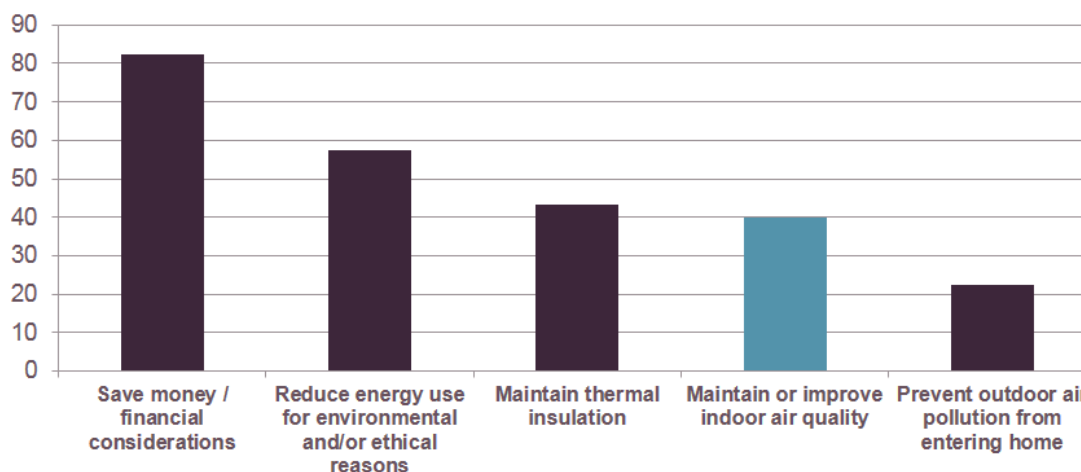
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[32] Stephens, "Infiltration of Outdoor Pollutants."
[33] Cluett and Amann, "Multiple Benefits."

Figure 7: When Retrofitting for Energy Efficiency, Most Households Do Not Pursue Indoor Air Quality as a Motivating Goal

Share of Homeowners Who Completed an Energy Efficiency Project in the past few years who were Motivated by Each of the Following (Percent)

Notes: Sample size is 319. Households that indicated they took action in the past few years to increase the energy efficiency of their home were asked, "In carrying out your energy efficiency project, which of the following were among your motivating concerns? Please select all that apply." Source: JCHS tabulations of Healthy Home Owner Survey, The Farnsworth Group.

Another angle from which to gauge consumers' healthy-home remediation activities is by investigating the recent activities of residential remodeling contractors. In our follow-up survey of general remodeling contractors who engaged in the 'healthy-home' category, the most frequent items contractors reported installing included non-toxic paints/finishes/adhesives (e.g., low- or no-VOC, formaldehyde-free). Fully 9 out of 10 contractors who engaged in 'healthy-home' activity had installed these items at some point in recent years. The next most popular item, installed by just over 70 percent of contractors, was non-toxic building materials (cabinets, flooring). Other popular projects, with around 60 percent of contractors installing them, included noise insulation, duct sealing to improve indoor air quality, water filtration systems, and dust-reducing techniques during remodeling work. Of course, many other healthy-home projects require specialists, so our survey likely did not capture other activity on specialized issues such as radon testing/remediation and mold removal.

As is clear from the four principles of healthy housing, while air filtration and proper ventilation are critical to indoor environmental health in some situations, they cannot compensate for excessive indoor emissions. Therefore, contractors who make informed selections of non-toxic (or less-toxic) building/finishing materials, and who take appropriate precautions when installing new materials, are

taking important steps toward helping their clients create healthy homes. From this perspective, the higher installation rates for non-toxic building materials and paints/finishes/adhesives are promising. Even so, informed decision-making and materials selection requires knowledge of the chemical content of materials, which requires transparency on the part of manufacturers. Selection of healthier materials also depends on the development of such materials and their ready availability across various markets at non-prohibitive prices. For example, some respondents in our contractor survey reported difficulty obtaining "green" or "sustainable" products in certain areas of the country, especially in the South and in rural areas. Even if these contractors wanted to use such products, they faced obstacles to doing so.

Renters' Healthy Housing Challenges

While our primary survey and analysis focused on the healthy-home concerns and activities of homeowners, it is also important to understand the unique challenges renters face in maintaining a healthy-home environment. More than one out of every three US households rents their principal dwelling, and in recent years this share has grown as households increasingly faced obstacles to homeownership. Renters' healthy housing issues and needs are distinct from those of homeowners for many reasons relating not only to the characteristics of renters themselves and the buildings they inhabit, but also to characteristics of the landlord-tenant relationship. As a result of these factors, renters generally report higher incidences of healthy housing problems.

Since renters do not own the buildings they inhabit, they have considerably less control in managing multiple aspects of their indoor space, including the chemical content of building materials installed, timing of installations/renovations, building upkeep decisions and even indoor waste management. While some landlords inhabit the building they own, most live off site, and as a result have far fewer incentives to make healthy housing improvements whose marginal benefits accrue mainly to the rental inhabitants. Frequently, landlords are motivated to pursue lower-cost materials regardless of potential risks to occupants (especially if risks are longer-term or difficult to prove). For their part, renters themselves face little incentive to pursue or request healthy housing improvements whose cost (in terms of disruption/displacement, the risk of higher rent, etc.) would exceed the benefit they might enjoy. And while renters can certainly move in the face of healthy-home problems, the displacement costs of doing so can be high, especially under tight rental market conditions.

The locations and structural characteristics of rental units also differ from owner-occupied units in important ways that could impact health. Renters are more likely to be located in central city locations, where factors such as air quality, noise and light are likely to have a greater impact than in

suburban locations. Fully 43 percent of renters live in central cities, compared to just 23 percent of owners. Rental units are also smaller on average and are more likely to be located in multifamily buildings. More than 60 percent of occupied rental units are located in multifamily buildings, compared to just 5 percent of owner-occupied units. Problems with ventilation and indoor air quality, but also noise and light, all frequently differ across these physical contexts. Renters in multifamily structures face greater possibilities of indoor air and noise pollution from neighboring units and common spaces than households in single-family homes. Renters also tend to have lower incomes and tighter budgets than homeowners, further limiting their ability to mitigate problems or seek comparable/alternative housing when healthy housing problems arise.

We were not surprised, therefore, to find that in our short follow-up survey of renters, they reported considerably higher rates of concern over healthy housing issues. Whereas around 24 percent of homeowners expressed some concern about healthy housing issues/risks, fully 36 percent of renters did. In general, renters expressed concerns similar to those of owners: managing dust and pet dander, dampness and moisture, and water quality were among their top three concerns. Another 17 percent reported air pollutants, odors, or smoke from a nearby unit as a top concern, issues that occupants of single-family homes do not face. Other noteworthy concerns (approximately 13-14 percent) included: lack of ventilation, outdoor air pollution, excessive outdoor noise, and noise within the building. Concerns about noise and air pollutants were more common among renters in multifamily buildings. Homeowners in multifamily buildings also reported more noise concerns than owners in single-family homes.

We also explored renters' abilities to address healthy housing problems when doing so required action from their landlords. When asked to describe their relationship with their landlord, nearly a quarter of renters concerned about healthy housing issues described their landlords as unreliable, and not looking out for occupant health. Another 44 percent said that they were frequently or occasionally disturbed or harmed by routine property maintenance or other activities by their landlord/management company that compromised the quality of indoor air or their enjoyment of their rental unit. When asked to what extent their concerns were satisfactorily addressed, more than a fourth said the landlord/management failed to address the issue, and another 32 percent described the landlord's response as reluctant. Another 44 percent said a healthy housing concern caused them (or another household member) to move or seriously consider moving from a rental unit. In short, renters who are aware or concerned about healthy housing often felt challenged or impeded by the landlord-tenant relationship when seeking out healthy housing solutions.

In 2011, the American Housing Survey also included a module on the topic of "healthy homes," enabling us to compare the indoor environmental concerns of renters and owners in more detail. Results from the survey confirm that renters experienced a higher incidence of health issues and risks than owners. Overall, a higher share of renters (21 percent) than owner-occupants (17 percent) reported that they were in fair or poor health; this disparity could be due to a number of reasons (both related and unrelated to housing). Renters were also more likely to be smokers or have smoking visitors (19 percent) than owners (12 percent). Yet they also frequently reported a number of other problems relating directly to their place of residence. For example, 6 percent of non-smoking renter households for whom no visitors smoked still had second-hand smoke entering the home either daily or weekly. In contrast, only 3 percent of similar owners experienced this problem. Renters were also more likely to report mold in the last 12 months (5.2 percent versus 2.6 percent of owners), and musty smells (17.8 versus 14.8 percent). And while renters were less likely to have stairs present in their homes, those who did were more likely to report loose, broken or missing railings, broken steps, lack of nonslip coverings, and insufficient illumination for stairs.

In short, renters face healthy housing concerns at a higher rate than owners, and at least some of this disparity likely results from difficulties of the landlord-tenant relationship, as well as from the types of buildings and locations renters inhabit. As we discuss below, renters' unique characteristics and context require distinctive approaches to healthy housing.

Conclusions

1. A significant share of homeowners have healthy-home concerns, driven in large part by indoor air quality but also by other issues, including water quality, chemicals, light, and noise.

Since the first modern discussions of indoor air pollution as a national public health problem began in the early 1980s, indoor environmental health has gained traction as a consumer, scientific, and governmental concern. Our survey showed that roughly one in four homeowners expressed concern about a health hazard within the home. Homeowners in central cities tended to report concerns more frequently. Especially interesting is that out of those homeowners that took action or were planning to take action on a healthy-home project, fully two-thirds reported that a household member had developed symptoms that the family directly attributed to the home (e.g., asthma, other respiratory issues, allergies, headache, rash, chronic stress, seasonal affective disorder, neurological or endocrine system disruption, etc.) **(Figure 6).** Homeowners are not only suspicious about potential health hazards within the home; they are experiencing these hazards first-hand.

Among consumers concerned about health threats within their homes, indoor air quality was by far the most common problem, cited by over two-thirds of homeowners. The highest-ranking indoor air concerns were managing dust and/or pet dander, dampness and moisture, air pollution from indoor cooking and heating, outdoor pollution from areas surrounding the home, and lack of sufficient ventilation. These concerns intersect with the basic principles of good indoor air quality agreed upon by indoor air scientists and discussed earlier in this paper ("**minimize indoor emissions, keep it dry, ventilate well, protect against outdoor emissions**").[34] "**Minimize indoor emissions**" is a far-reaching and powerful strategy if aggressively implemented. Taken to its logical conclusion, it would necessitate the development and use of non-toxic or at least low-toxicity building materials, furnishings, and household/personal products.

To some extent, homeowners are acting on these principles. Among those who expressed concerns about indoor environmental issues, the most popular air quality-related projects completed or planned were use of VOC-free paint, removal/replacement of indoor furnishings or carpets posing health risks, removal or replacement of toxic cleaning supplies, and installation of a ventilation system or device. The first three of these actions all help to reduce indoor emissions, and the fourth should help to ventilate well. Interestingly, among this same group of homeowners, only just under 10 percent

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[34] Nazaroff, "Four Principles."

highly prioritized chemical issues, either from the building/structure itself or from interior furnishings. Obviously, it is much easier to take action on interior furnishings than on structural components such as insulation, drywall, and flooring, all of which have proven problematic in the recent past. It is important that consumers—especially those building a new home, an addition, or undertaking a major construction project—be aware that building materials may have a major impact on indoor air quality, and that a healthy home starts from the ground up.

As reflected in both consumer concerns and scientific consensus, high levels of outdoor air pollution (particularly ozone and microparticles) present challenges in creating a healthy residential environment. Exchange between indoor and outdoor air is fundamental to IAQ, but is beneficial only if the outdoor air itself is healthy. "Fresh air" is often a misnomer. In many communities, outdoor air is polluted by industries and traffic, putting local residents at a serious disadvantage. Homes are not sealed capsules immune to their local, regional, and even global environments. Current conversations about how to promote healthy communities should make outdoor air pollution one of their many priorities. Natural ventilation, such as opening windows and doors, is often the only method of ventilation in older homes. But it is less effective, and potentially counter-productive, when outdoor air is polluted by car exhaust, industries, pesticides, etc.

According to results from the 2013 American Housing Survey (AHS), 9 percent of owners and 20 percent of renters report living close to highways/railroad/airports, while 3 percent of owners and 7 percent of renters report living close to industrial structures or factories. As mentioned in the introduction to this paper, outdoor or "community" air pollution was the sole focus of air pollution control efforts throughout the 1960s and 1970s. While it is a sign of progress that by 1980 the conversation began to shift to indoor environments—where Americans spend 90 percent of their time— the relationship between indoor and outdoor air quality deserves further attention.

The range of heathy home problems affecting households is broad. As other results from the AHS suggest, basic safety and integrity of the building, pest control, and lack of functional plumbing, electrical and heating systems still impact a significant number of households. For many households, the need to address healthy-home concerns is competing with standard maintenance and accessibility concerns. As we will discuss below, it would be ideal if contractors, building managers and homeowners could address indoor environmental health issues in the course of a remodeling project that they might be undertaking anyway.

2. There is a need and demand for clear, unbiased, actionable information related to healthy housing. We are already seeing this develop on multiple scales, from product certifications, to assessment services, to whole-house purchasing options.

The science of the indoor environment is a vast, complex, and expanding field with numerous subspecialties. Scientists are currently researching these and many other questions: Which chemicals and materials pose health threats? Are the effects seen in the long-term (cancer) or short-term (headache, sore throat, respiratory irritation)? How do chemicals interact synergistically, including with other factors in the indoor environment such as heat, humidity, and UV light? What methods of ventilation work best?

Unfortunately, for many chemicals the answers to these questions remain far off. Although scientists have long called for more long-term studies of the health effects of chemicals found in the indoor environment, it is currently not possible to test adequately, and to arrive at definitive conclusions about, each and every chemical that humans are exposed to at home.

The large number of variables affecting indoor environments underscores the first principle of good indoor air quality: reduce indoor emissions. Since the beginnings of the modern era of indoor air quality research in the mid-1970s, scientists have emphasized that no amount of ventilation can compensate for excessive indoor emissions. This is as true today as it was in 1980. As Dr. Nazaroff has written, "ventilation is inadequate as a means of controlling pollutants whose uncontrolled indoor emission rates are excessive."[35] Two emerging trends suggest that we need to be more aware of this principle than ever before: some "high performing green homes are reaching previously unheard-of levels of airtightness"; simultaneously, there is an "ever-expanding suite of synthetic products and materials used in the construction, finishing and furnishing of homes."[36] Both to meet consumer demand for safer products and to protect public health, there is an urgent need for more and better information on the ingredients of building, finishing, and furnishing materials.

A Berkeley Lab report found that while state and federal regulators have introduced a variety of "home labeling schemes" (such as the EPA's Indoor Air PLUS certification for homes) and that many materials are certified by different organizations as having low emissions, "there is currently no consensus among these labeling and certification systems on the criteria or performance levels that

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[35] Nazaroff, "Four Principles," 354-355.
[36] Maddalena et al., "Maximizing Information," 1. See also Less et al., "Indoor Air Quality."

define low emissions. Emissions data from new materials and products are not consistently available, and databases for US products are either not updated or incomplete."[37] If this inconsistency and lack of information creates obstacles for indoor air researchers and building professionals, the average consumer is likely to be even more confused and overwhelmed, or to become skeptical of certifications in general.

Indeed, our results indicate that consumers face considerable uncertainty in making decisions about their homes, and this may limit their ability to take effective action. Reasons cited for not acting on an issue include: uncertainty about reliable contractors/companies, uncertainty about the actual health payoff of the investment ("Will my child's asthma go away if I replace all rugs with hardwood?"), uncertainty about the reality or severity of the risk ("Is that bit of mold really dangerous? Is it toxic mold?"), uncertainty about the side-effects/consequences of taking action ("What if they discover more mold and I have to move out with the kids—where will we go?"). Another reason cited by some homeowners was lack of time to research options and skepticism about the truthfulness of available information. Consumers are savvy and are rightly suspicious of "greenwashing" and of marketing and advertising that makes health claims.[38] "Greenwashing" is a well-recognized problem in which manufacturers make false or unsubstantiated claims about the safety, health, or environmental benefits of their products or services. This harms both consumer trust and the movement toward rigorous and reliable certifications. There is unmet market demand for verified, meaningful health certifications of building products.

High profile news stories about dangerous materials, such as Chinese drywall in 2009 or the recent debacle over Chinese laminate flooring, likely reinforce confusion and inaction among consumers contemplating home improvements, whether their goal is a healthier home, aesthetics, or both. A proliferation of certifications based on non-existent or conflicting standards is less helpful to consumers than a smaller number of trustworthy certifications based on scientific standards.[39]

Even households that rely on a contractor to make healthy-home decisions may face problems of information. Among general remodeling contractors we surveyed, around 25-30 percent indicated they had installed products or techniques that help achieve healthy-home objectives in recent years. But

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[37] Willem and Singer, "Chemical Emissions," p. iii.
[38] Meany, "Are Your Green Claims Helping."
[39] See Willem and Singer, "Chemical Emissions," p. iii: leading standards include California Department of Public Health Standard Method, section 01350, as well as Green Guard Environmental Institute (GEI) and Scientific Certification Systems (SCS).

of these, only about half indicated they were highly confident advising clients on home improvement projects involving healthy-home concerns. Among the same group of contractors that installed healthy-home products/projects, less than half had heard of training or certification programs; only around one in five had ever participated in such a program. As these results suggest, even contractors who work in the healthy-home category may be in need of further relevant training and quality information. Indeed, like homeowners themselves, many contractors also expressed suspicions of products making health or "green" claims.

One clear area in which greater education may pay dividends in terms of environmental and human health, as well as business, is at the intersection of energy efficiency and indoor air quality/healthy-home issues. Any home renovation, particularly a major one involving heating and AC systems, is a prime opportunity to integrate an IAQ audit and IAQ-improvement measures. But few households indicate that they are aware of these health benefits in completing energy efficiency projects. Remodeling contractors have a potentially major role to play in educating their customers and guiding them to well-informed decisions that can accomplish these interrelated goals.

3. Homeowners obtain information about healthy housing through a wide variety of channels. Therefore, there are many opportunities to provide accurate and actionable information.

Average consumers do not have access to an indoor air science advisor, or to the vast and highly technical literature on indoor environmental quality. Even if they did, the time it would take to sort through and process this information would be immense. Our survey results indicate that homeowners rely instead on a variety of information sources when learning about healthy housing issues. Again, these include empirical evidence from physical symptoms they attribute to the home; internet, television, and other media; a contractor, inspector, or other building professional; and even friends, relatives, or neighbors (Figure 6). Medical professionals were also listed with some frequency, though it is unlikely that a majority of physicians are adequately knowledgeable about indoor air quality or other healthy housing issues.[40] A further study by McGraw Hill Construction confirmed that when making

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[40] A recent report by McGraw-Hill construction found low levels of physician awareness regarding the link between housing and health, with only 32% of general practitioners believing that buildings impact patient health. Among pediatricians, 53% believe in the housing-health connection, and among psychologists/psychiatrists, 40%. Only 15% of physicians reported receiving any information on the housing-health connection. McGraw-Hill's report argues that since physicians receive the majority of their information from medical journals, rather than from the

decisions about their homes, consumers turn to contractors or other building professionals; friends, relatives, and neighbors; and—at a higher rate than the other two categories—the internet and other media.[41] As these results suggest, there are multiple information channels available to consumers in need of clear and accurate healthy housing information.

The construction-related professions have a particularly critical role to play in educating their clients about healthy housing and indoor environmental quality. More than any other information source, they have the most direct knowledge of how houses function as dynamic systems. Some organizations, such as Healthy Housing Solutions, are beginning to capitalize on this expertise by offering courses and training programs through which building professionals can become certified healthy housing inspectors/contractors. These certified individuals perform home assessments and make recommendations. This is not an entirely novel development: for decades there have been professional home inspectors as well as specialists in testing and remediating specific hazards (lead, radon, mold, asbestos). However, emphasis may be shifting to a more holistic approach to a healthy home. As whole-house assessment programs develop, it would be beneficial to track their progress and study their impact on consumer satisfaction in healthy-home improvements and outcomes.

More can be done to help contractors, consumers, and others obtain the information they want about healthy housing. For example, more science-based information on healthy housing and public health risks at home could be integrated into resources used by consumers and professionals who have not traditionally studied housing, such as physicians. More information on indoor environmental quality could be integrated into home-design/improvement resources for consumers (such as magazines, websites, television shows, and online stores). Trade publications for contractors and building professionals could devote more space to the impact of chemicals in building materials. As an example, the resource Smarterhouse.org, from the American Council for an Energy Efficient Economy, integrates information on ventilation, healthy homes, and indoor air quality into its website pages on energy efficiency, retrofits, and appliances. *Home Energy*, a home-performance magazine for building professionals and consumers, includes in-depth feature articles on indoor air quality.[42]

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government, public health, or advocacy organizations that produce most information on healthy housing, the construction industry should address this knowledge gap. See McGraw-Hill Construction, "The Drive Toward Healthier Buildings," 4-5.

[41] McGraw-Hill's 2014 report on this subject found "word of mouth from trusted family members and friends" to be the top source of information. "The Drive Toward Healthier Buildings," 83.

[42] For example, Stephens, "Infiltration of Outdoor Pollutants."

4. The intersection of energy efficiency and indoor air quality provides an important opportunity to educate consumers about the health benefits of an energy-efficient home.

Modern indoor air quality research has always been intertwined with energy efficiency. As energy-efficient construction became a political, financial, and environmental priority in the mid-1970s, insightful scientists began to study how this construction affected concentrations of indoor pollutants, especially combustion products, formaldehyde, and radon. For a period during the 1980s, the media portrayed energy efficiency and indoor air quality as competing goals; consumers might easily have believed they could choose only one or the other. Fortunately, 40 years of research into the relationship between energy efficiency and air quality have demonstrated that, when executed well, energy-efficient building can be synonymous with—and promote—healthy building. As emphasized throughout this paper, an important first step is to recognize that no amount of ventilation can compensate for excessive chemical emissions from building materials, finishings, and home furnishings. Low-toxicity building materials should be synonymous with "green" building and remodeling.[43]

As a recent ACEEE paper on multifamily retrofits found, the potential health benefits of energy efficiency are under-represented and underappreciated in standard cost-benefit analyses, leading to lack of awareness among decision makers at municipal and state levels.[44] These benefits also do not appear to be as obvious to consumers as they should be. Again, we found that about 40 percent of homeowners undertaking an energy efficiency project and concerned about healthy housing cited improving indoor air quality among their motivating considerations. This was far below the 80 percent who cited saving money as their main goal. Many variables influence the relationship between a home's envelope tightness, energy efficiency, and indoor environmental quality; this relationship should not be oversimplified or oversold. However, more could be done to raise consumer awareness of the multiple (non-energy) benefits of energy-efficiency projects.

Homebuilders and organizations are actively integrating healthy-home principles into green building designs and standards. Nationwide examples (for new homes) include Energy Star Homes with Indoor Air Package, the U.S. Green Building Council's LEED for Homes, and the National Green Building Standard, which is a joint project of the National Association of Home Builders and the International

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[43] For example, LEED version 4.0 will offer credits for optimizing materials selection in order to reduce toxic chemical emissions, as well as for disclosing the ingredients of building materials.
[44] Cluett and Amann, "Multiple Benefits."

Code Council. The National Center for Healthy Housing evaluated these programs to determine how well they align with selected principles of healthy housing ("dry, clean, ventilated, safe, contaminant-free, pest-free, maintained, verified/certified").[45] None of the programs scored highly across all categories; most scored very well in some and very poorly in others. Of course, many small businesses and individual architects and contractors are building and remodeling homes using the principles of green building and healthy housing (and have been doing so for decades), and the NCHH study is not comprehensive. However, it reminds us that large gaps remain between meeting energy efficiency standards and meeting healthy housing standards in the same home. Energy efficiency upgrades/retrofits are an ideal time to assess and act on indoor environmental quality concerns.

5. Renters and owners need to be approached differently. Incentivize owners and developers of rental property to invest in healthy housing, which is likely to intersect with green building priorities.

Across nearly every measure of healthy-home risks and problems, including basic housing adequacy measures, renters scored as worse off than owners. Renters are not only more likely to live in inadequate housing, but they also expressed concerns about the health impact of their home at a higher rate than owners. In addition, renters face housing cost burdens at a higher rate than owners, raising further questions about their relative ability to afford healthy-home remediation (or the costs of moving to a new unit). As of 2014, nearly half of all renter households paid more than 30 percent of their household income for housing, versus just a fourth of owners. Lack of disposable income left too many renters with far fewer resources each month for other purchases, including those that may support occupant health at home. At an extreme, over 40 percent of the concerned renters we surveyed reported that at some point, a healthy housing concern caused them to move or to seriously consider moving from a rental unit. Renters obviously face a lack of attractive options when landlords are not willing or able to mitigate health problems in rental buildings.

The clear inequities documented between owners and renters in their housing quality and adequacy measures likely results not only from their differing financial resources, but also from the agency dilemma faced by rental occupants (relative to those who own/manage the units they occupy). While owners have the autonomy (even if not the money) to make decisions regarding building materials, flooring, techniques (dust mitigation, pesticide application, etc.), and permanent indoor

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[45] National Center for Healthy Housing, "How Healthy are National Green Building Programs?"

furnishings (cabinets, countertops), renters rarely exercise such control. Lacking control over the timing of remediation or construction, families and individuals who rent—particularity those with infants or young children—may find themselves unable to avoid untimely exposure to toxic chemicals, dust, noise, smoke, etc.

As consumers and organizations push for greater transparency regarding the content of building materials, as well as for the development of safer products, how will the average renter benefit? Since renters have less control over the materials and practices used in building and maintaining their homes, rental housing concerns need to be addressed in a fundamentally different way than those of owner-occupied homes. Solutions on the rental side would need to take into account the unique nature of the landlord-tenant relationship, including the differing incentive structures for each party. Disclosure of indoor air quality hazards, especially those in building materials and furnishings, would need to take place at multiple levels, not only to the property owner, but also to existing and prospective tenants. Without attention to their unique situation, renters stand to benefit less than homeowners from progress in healthier building materials and practices.[46]

The growing market for energy efficient housing may set a precedent for how healthy multifamily solutions might take hold. Recently numerous articles and trade publications have heralded the good business sense of pursing energy efficiency. As a recent McGraw Hill study suggests, multifamily builders find that customers are willing to pay more for "green" units.[47] While energy efficiency also saves on energy bills, healthy-home advancements in rental properties can potentially increase resident retention and satisfaction—both of which are of economic benefit to the rental industry. Better indoor air quality, ventilation, and less noise from neighboring units (more privacy) are all goods that consumers clearly value. Given the ongoing and rapid development of research in healthy housing, as well as the tendency of consumers to seek out information through media, the tea leaves suggest that demand in this area is likely to grow in the future. As awareness of healthy housing research and risks grows, renters will likely increase their demand for healthy housing attributes. The rental property owners who can get out in front of this trend may be better poised down the line to capitalize on the growing demand for health-conscious home environments.

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[46] The National Healthy Housing Standard, published in May 2014 by the National Center for Healthy Housing and the American Public Health Association, is an important step toward providing a common set of guidelines for owners of rental buildings wanting to prioritize healthy housing. See http://www.nchh.org/Portals/0/Contents/NHHS_Full_Doc.pdf.
[47] McGraw Hill Construction, "Green Multifamily and Single Family Homes," 5.

Even so, rental property owners that market to the health-conscious renter will still face unique challenges. How can a rental property reliably signal to potential renters that it has good indoor air and environmental quality? How can landlords protect the quality of indoor air when units are handled by the same HVAC system, and they cannot easily monitor occupant behaviors such as smoking? While local rental codes provide some assurances that landlords remain responsible for basic safety issues, they typically do not regulate chemical risks such as off-gassing flooring, paints, toxic glues and insulation. Chemical standards may ultimately be needed not only in the realm of building codes, products and healthy-home improvements, but also in the rental industry to ensure properties can provide healthy housing benefits and protections to renters. Green certification programs such as LEED already incorporate some healthy-home elements in their multifamily certifications, such as LEED 4.0's upcoming materials/health credit. As research uncovers further indoor risks, especially in the realm of indoor air quality and chemicals, building certification programs could integrate similar healthy housing standards.

It would be advantageous to collect more information and data, both qualitative and quantitative, on the impact of initiatives for healthier rental housing. Initial studies suggest that renters are willing to pay more for healthier homes, and landlords/owners/developers may stand to benefit from increased tenant satisfaction, including from investments that combine energy efficiency and health goals. However, to make compelling arguments for healthier rental housing, we need more information on tenant satisfaction as a result of specific energy- and health-related investments. ACEEE recommends that more data be collected on tenants' health-related satisfaction following an energy efficiency retrofit. This would help build a stronger evidence base for difficult-to-quantify, non-energy benefits, which would make possible stronger arguments for investing in energy efficiency in multifamily buildings.

6. Transparency regarding chemicals in building and consumer products is a critical step toward informed decision-making and healthier homes.

Frank Silver was an early proponent of healthy housing through chemical disclosure. In February of 1986, the chemical engineer from West Virginia urged his colleagues and friends to join him in a letter-writing campaign to Robert T. Stafford, chairman of the Senate Committee on Environment and Public Works. Silver wanted to generate support for two proposed pieces of legislation: the Chemical Notification Act and the No-Fragrance Mail Act. Silver considered the spraying of highways with pesticides to be "as dangerous as bad brakes on a car." He wanted signs to be posted "before, during,

and after the use of chemicals everywhere." This policy was to include not only highways but also outdoor spaces like lawns, beaches, parks, and forests; public buildings such as restaurants, hotels, and stores; hospitals and schools; and finally, new homes. Here the Chemical Notification Act contained an especially interesting stipulation: "a list must be given accompanying the deed of all chemicals and substances used in building the house to pass to each subsequent owner with the deed…. Every place chemicals are used, Americans have the right to know and thus make their own decision as to whether or not they wish to avoid the exposure."[48] Although Silver's ideas about transparency have gained traction since the 1980s, his bills never became laws.

Silver was a friend and supporter of the physician Theron G. Randolph, one of the first Americans to identify indoor air pollution as a health hazard. Randolph treated countless patients for chemical sensitivity and found that symptoms were often resolved through simple measures such as replacing a gas stove with an electric one or reducing the number of chemicals stored and used in the home. Although Randolph was ostracized by his colleagues in the medical profession during his prime working years, his concerns about the toxicity of the chemicals that permeate daily life—and especially his attention to indoor air pollution—have gained traction and are now so standard as to be unremarkable. But the Chemical Notification Act—at least in the full form endorsed by Frank Silver—clearly never caught on.

Even in the absence of legislation on disclosure, increasing interest in environmental health from multiple stakeholders is prompting new, non-regulatory approaches to increasing transparency and disclosure. For example, retailers and manufacturers across multiple business sectors—including not only building materials but also apparel, electronics, and household products—are taking concrete steps to eliminate harmful chemicals, or looking for ways to increase disclosure of both supply inputs and products for sale. Multiple stakeholders are increasingly recognizing that it is not only safer, but even makes good business sense to avoid or disclose the use of toxic chemicals, whether to prevent future litigation, get ahead of pending regulation, improve brand reputation, or simply to innovate. Driving this trend is growing customer demand for transparency regarding product ingredients, particularly for chemicals either known or suspected to have adverse health consequences.

In the household and personal product industries, some companies are beginning to pay close attention to public sentiment regarding chemicals, and to take action to ensure continued consumer

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[48] The No Fragrance Mail Act prohibited mailing anything perfumed through the U.S. mail: "Fragrances in the U.S. mails are an abuse and forc[e] Americans, without a choice, to be exposed." The two proposals had been sent to the Committee by Robert C. Byrd, Senate Minority Leader at the time.

trust. They recognize that this trust is more important than waiting for scientific consensus, and justifies the removal of potentially unsafe ingredients. SC Johnson has a particularly comprehensive chemicals policy. The company's chief sustainability officer explains the business advantages of prioritizing consumer concerns: "By listening to input such as public sentiment, we can get out ahead of other concerns as well, such as perceptions that, while not science-based, are so powerful they could hurt trust in certain products. By including these types of insights ... we can potentially make moves before our competitors do—if they are solely looking at the science—and that's another advantage."[49]

Johnson and Johnson had a similar response to concerns about diethyl phthalate (DEP): "Despite DEP's strong safety record, we understand that because it is so tied to other phthalates in the public discussion, the best way to keep your confidence is to not use it at all. To give you peace of mind, all our baby products worldwide are now phthalate-free, and will remain so." The company has a similar policy on triclosan: "Despite triclosan having a long and extensive history of safe use, we want you to have peace of mind. So we have set a goal to phase out triclosan in our beauty and baby care products."[50]

When one or more leading companies in an industry take this precautionary/responsive approach, others may follow so as not to be left behind. Colgate-Palmolive is a third major personal/consumer products company to see safer substitution as a smart business strategy: "We continuously monitor and evaluate the safety of our ingredients, and we actively engage with outside experts and resources to understand emerging science and deepen our knowledge. We seek the facts so that we can make the right decisions. Where we see opportunities regarding ingredients that are raising consumer questions, we substitute with other safe ingredients that provide the same or better benefits without sacrificing quality. Through this ongoing effort, we no longer use, or are on our way to eliminating, some of the ingredients currently raising consumer questions."[51]

With consumers growing more aware of indoor air quality and healthy-home issues, as well as the integration of materials health into LEED 4.0 and the growth of other healthy-building programs such as the Living Building Challenge, we are likely to see a growing market for building materials with known ingredients and with Health Product Declarations. As discussed below, the architectural firm

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[49] "The Choices We Make," SC Johnson 2014 Public Sustainability Report, 10, http://www.scjohnson.com/en/commitment/report.aspx (accessed Aug. 7, 2015).
[50] Johnson and Johnson Co., Safety and Care Commitment, http://www.safetyandcarecommitment.com/ingredient-info/other/phthalates; http://www.safetyandcarecommitment.com/ingredient-info/other/triclosan (both accessed Aug. 17, 2015).
[51] Colgate-Palmolive, Sustainability Report, http://www.colgate.com/Colgate/US/Corp_v2/LivingOurValues/Sustainability_v2/Colgate_Sustainability_Report_Performance_2015.pdf (accessed Aug, 7, 2015).

Perkins+Will is already making the use of such materials a priority. Manufacturers with notable disclosure/health initiatives include Interface (carpet), Construction Specialties, and Shaw Industries. Owens-Corning was the first in its industry to pursue Material Health Certifications for insulation, with four certifications so far. Owens-Corning also has two products with Cradle to Cradle Certification, and others certified with GreenGuard, GreenGuard Gold, and as formaldehyde-free.

The following list details recent types of private initiatives already underway which aim to promote healthier building and housing through increased transparency of product content. These range from initiatives that have sprung up to assess manufacturers' and retailers' claims, to efforts of retailers and manufacturers themselves to clarify the contents of their products or signal commitment to meeting consumer demand for safe products.

Disclosure and Transparency Strategies Underway

Assessment tools for building products:

Consumers and companies who want to assess whether certain building products contain known health hazards now have a growing number of options. One leading example is the Pharos Project, an online database created and maintained by the Healthy Building Network, a non-profit whose mission is to "transform the market for building materials to advance the best environmental, health and social outcomes."[52] This tool allows subscribed users to look up individual products and learn whether they contain documented health hazards, which are categorized according to their effects ("cancer," "gene mutation," "respiratory"). This resource can help architects, designers, builders, and interested consumers to make informed choices. Other projects currently working to help manufacturers create safer products by assessing chemicals and identifying alternatives include GreenScreen, Cradle to Cradle, and the Environmental Protection Agency's Design for the Environment (DfE) and "Safer Choice" programs.

Precautionary product lists:

The architecture firm Perkins+Will has developed a website project called "Transparency," intended as a resource for building owners and others in the design and construction industry. The site contains a "Precautionary List" of products either known or suspected to pose health hazards, as well as a list of asthma triggers and flame retardants in the built environment. All of these lists are continually updated. The Transparency website also contains a growing library of resources on health and the built

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[52] https://www.healthybuilding.net/content/pharos-v3 (accessed July 18, 2015).

environment. Perkins+Will has compiled its list from publicly available government and academic research, with the exception of its flame retardants list, which is based on the work of the Green Science Policy Institute.

Product Labelling

In the building products sector, a prominent transparency initiative is the Health Product Declaration or HPD, a new standard format for disclosing the contents of building materials. The HPD originated from a series of conversations among building designers, owners, contractors, specifiers, material researchers, and non-profit organizations. Recognizing that the proliferation of "overlapping and sometimes conflicting reporting formats" was a hindrance to businesses and customers alike, the group created a standard format "to support consumers' informed decisions about the products they purchase and their impact on human health, and to reduce the burden on product manufacturers juggling multiple types of information requests and reporting formats."[53] The inspiration for the HPD was the Environmental Product Declaration (EPD), which is a standard way of quantifying a product's environmental impact, from the extraction of raw materials, to energy use, to emissions affecting air/soil/water, to waste.

The development of the HPD is overseen by the non-profit HPD Collaborative. Any interested manufacturer/company can download the standard for free from the HPD Collaborative's website. This document guides the user through sourcing product ingredients, collecting information from suppliers, and compiling the HPD. The intent is to make it easier for manufacturers to organize and share this information, using the same format for all or most audiences. For example, use of the HPD will be one of the approved pathways for developers to capture LEED version 4.0's credits for materials disclosure and optimization.

Merely disclosing product contents will not, of course, lead directly to healthier homes. Just as a 'Nutrition Facts' label discloses the ingredients in a packaged food, but does not classify the food as healthy or unhealthy, an HPD does not classify products as safe or healthy. Transparency is a necessary, but not sufficient, means to selecting safer products.

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[53] Health Product Declaration Collaborative, "A Brief History," http://www.hpd-collaborative.org/about/, (accessed October 30, 2015).

7. In the absence of stronger regulation of chemical and other environmental risks, private sector businesses should prioritize safer materials and products.

US industry largely operates on a 'risk-based' approach, meaning that new products are generally introduced into the marketplace unless and until they can be proven to be health hazards and regulated by law. But even when development of regulatory structures is underway, enforcement of laws is not only costly but often slow-moving. An example are regulations on formaldehyde-containing wood composite products, which are still under development and not currently enforced.[54] Under these conditions, at-risk households cannot rely on regulations alone to protect them from chemical emissions at home.

This system contrasts with a 'hazard-based' approach that would permit innovative new consumer products only if their safety can be verified. The hazard-versus-risk distinction is used often in discussions of environmental health. Hazard refers to the inherent properties of a chemical/material/product that make it dangerous; something can be a hazard even if no one will ever come into contact with it. Risk is the probability that the material will harm someone; risk assessment takes into account the likelihood of exposure, duration of exposure, and pathways through which someone could be affected (inhalation, ingestion, skin contact). The chemical industry generally takes this approach, arguing that restriction and regulation should be based not on inherent properties of the chemical itself, but on the likelihood of exposure. In the absence of a hazard-based approach to developing and supplying safe building and household products, the supplying of such products will fall largely to private sector/businesses wanting to make them a priority.

Recent examples of private businesses prioritizing safe materials include Home Depot's and now Lowe's and Menards' recent decisions to stop the sale of phthalate-containing flooring. Such **'retailer gatekeeping'** is a potentially powerful strategy, both in keeping toxic materials out of homes and in incentivizing manufacturers to develop safer products.[55] The non-profit organization Safer Chemicals Healthy Families is working through its Mind the Store Campaign to monitor toxic products, encourage consumer activism, and push for greater retailer responsibility.[56]

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[54] The Toxic Substances Control Act (TSCA) gives the EPA authority to set restrictions related to chemical substances, including formaldehyde. However, at the time of this paper's writing, the EPA was still developing a regulation to set limits on how much formaldehyde can be released from composite wood products, such as hardwood plywood and medium-density fiberboard. Additional details are available at http://www2.epa.gov/formaldehyde/facts-about-formaldehyde#howcan (accessed Nov. 20, 2015).

[55] Vallette, "The End Is Near."

[56] See http://saferchemicals.org.

While retailer gatekeeping happens at the latest stages of the supply chain, the practice of **green chemistry** takes place in the earliest stages of production—during research and development—making it even more integral to private industry development of safer materials and products. Although modern concern about chemicals, the environment, and human health can be traced to the early 1960s (with the publication of *Silent Spring*) and followed through the landmark environmental legislation of the 1970s, the field of green chemistry was formally established as an academic discipline in 1997, when the University of Massachusetts–Boston established the first green chemistry Ph.D. program. In 1998, Paul Anastas and John C. Warner published the first textbook of green chemistry, *Green Chemistry: Theory and Practice.* Its "Twelve Principles of Green Chemistry" remain the guidelines of the green chemistry movement, which has expanded to universities and research and policy institutes around the country. The Pollution Prevention Act of 1990 was the first piece of American legislation to prioritize pollution prevention ahead of pollution control, and helped lay the foundation for the advancement of the green chemistry movement.[57]

In prioritizing safer materials and products, private industries will need to continue integrating green chemistry best practices and objectives into their business models and research programs. With higher future demand from consumers for safer products and low-risk chemical contents, businesses that demonstrate their commitment to safe chemistry may have an edge in the competition for consumer loyalties. Educational institutions and even governmental programs can play a valuable role in this process, providing additional training and research resources that can support and feed into private industry initiatives that produce public benefits.

Ultimately, greater private industry commitment to safer materials and products along all stages of the supply chain will help consumers and building and remodeling industry professionals to achieve the goal of reducing indoor emissions, the first principle of good indoor air quality. Healthy-home products and services are not only safer, but they can be good business. As our survey results indicated, there is a base level of demand for and interest in healthier home products and services. Ideally, in the long run "healthy" home improvements will not have to compete with other priorities and expenses, but rather will be integrated with energy efficiency and other upgrades, as a natural part of maintenance, renovation, etc.

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[57] American Chemical Society, "History of Green Chemistry." Also see American Chemical Society, "12 Principles of Green Chemistry," and Michetti, "Exploring the Role of Green Chemistry."

Summary

This is an exciting time in the world of healthy housing. A wide spectrum of stakeholders, including consumers, architects, government agencies, NGOs, and scientists, is becoming increasingly wary of chemical-laden home environments. From the micro-level of eliminating specific chemical risks, to the macro-level of creating not just healthy homes but healthy communities using the principles of active design, there are many ways to make both single- and multi-family housing healthier while also making it more energy-efficient and sustainable.[58] An even broader definition of healthy housing could also include considerations of housing affordability, as summarized in a recent report by the Center for Housing Policy.[59] As we learn more about chemicals in building materials and products for the home, and invest in the development and implementation of safer alternatives, it is also important that stakeholders not forget about older but persistent hazards, both chemical and structural: lead paint; trip hazards; pests; inadequate insulation, heating, and cooling; lack of accessibility for aging or disabled residents. These problems continue to disproportionately affect low-income and minority populations.

Ultimately, integrated healthy housing solutions will come from a range of diverse stakeholders, including not only governments and non-profits, but also private businesses and multi-national corporations. The latter have a potentially vital role to play in pushing forward standards for healthy-home building products and practices not only in the US, but also internationally. According to the World Health Organization, 4.3 million people die each year from exposure to household air pollution, and nearly 3 billion people still use "inefficient and highly polluting" solid fuel stoves for cooking and fuel. If urban and apartment living continue to increase in popularity, preventing problems through planning and thoughtful construction or retrofits would go a long way toward preventing new indoor air and environmental quality problems before they occur. Meanwhile, promoting and increasing access to quality and timely information on the content and risks of chemicals in products will be essential. Increased disclosure and access to clear information will not only help businesses to reduce risk, but also enable consumers to educate themselves and satisfy their demand for safer products and building practices.

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[58] Active design aims to "build in" more physical activity into everyday life. For example: residential communities that encourage walking and stair-climbing by providing safe, well-lighted, and appealing pathways and stairwells.
[59] Maqbool, Viveiros, and Ault, "The Impacts of Affordable Housing on Health."

Further Resources

Training programs for contractors, such as Healthy Housing Solutions, train and certify building professionals in assessing indoor air quality and other issues.[60] A related offering, **healthy-home assessment programs for consumers**, such as Healthy Housing Solutions' healthy-home checkup program, cater to homeowners (and presumably renters) wanting to assess their indoor air quality and other issues.[61]

Advocacy and integrative action programs:

There are many governmental and quasi-governmental efforts, at federal, state, and local levels, that are currently working to eliminate household health hazards, particularly for children and economically disadvantaged populations. A leader in this area is the National Center for Healthy Housing (NCHH), a Maryland-based nonprofit organization that advocates for policies supporting healthy housing, including the prevention of childhood lead poisoning. The NCHH recently collaborated with the American Public Health Association to produce America's first National Healthy Housing Standard, a valuable guide for property owners wanting to make healthier housing a priority. The NCHH also functions as a consumer-accessible clearinghouse for information on toxic building materials and other healthy housing topics.

The Green and Healthy Homes Initiative (GHHI) aims to "break the link between unhealthy housing and unhealthy children" by integrating weatherization, energy efficiency, lead control, and healthy housing efforts.[62] In 2008, the White House Office of Recovery and the Council on Foundations enlisted the GHHI to lead rehabilitation efforts for low-income housing. GHHI has offices in Baltimore, Washington, D.C., and Providence, and currently operates in 17 American cities with plans to expand.

Technical Appendix

This appendix section describes three surveys from which we gathered many of our findings. All three surveys were a joint collaboration between the Joint Center for Housing Studies and the Farnsworth Group. The main survey was designed to study homeowners interested in healthy-home issues, and was fielded in the spring of 2014. Drawing from a nationwide panel of homeowners, 2,249

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[60] See http://healthyhousingsolutions.com/hhtc/.
[61] See http://healthyhousingsolutions.com/service/healthy-home-checkup/.
[62] See http://www.greenandhealthyhomes.org/about-us/history-and-mission. .

homeowners were selected to achieve representation across specific variables such as incomes. presence of children, and level of education. From these, we identified a subsample of 529 homeowners concerned about indoor air and environmental quality issues at home. The distribution of all the homeowners by income, education and presence of children matched results from the 2012 American Community Survey (ACS) relatively closely. For example, around a third of the homeowner households we surveyed indicated that they had children, and this closely matches the share from the ACS of 34 percent.

The follow-up survey of renter households was fielded in the summer of 2014. This survey was based on a panel of renters which, while not built to be fully representative nationally, was designed to be unbiased toward any specific demographic. From this panel, we collected a sample of 820 renter households, and of these we identified 254 renters concerned about indoor air and environmental quality issues at home. Among the 820 renters sampled, the distribution of household by income reasonably matched the ACS distribution. The renters also exhibited similar levels of educational attainment to the national population of renters, although the share of respondents without a high school diploma was underrepresented (3 percent versus the ACS's 16 percent). More problematically, most of the renter households sampled—82 percent—did not have children under the age of 18 living in the household. This share is significantly higher than the real share from the 2012 ACS (65 percent). The distribution of renter households sampled by age was also skewed relative to the actual population of renters: Our sample showed an age distribution heavily skewed towards older adults age 55+, while the actual distribution of renters by age from the ACS shows a large concentration of renters 25 to 44 years old.

Since these key demographic variables were significantly different from the national profile of renter households, we re-weighted the renter sample to match 2012 ACS distributions of renter households by age. This fixed the distribution of renters by age, and also improved the distribution of renters by presence of children, i.e., it resulted in 28 percent of renter households having children (up from 18 percent, and closer to the ACS's 35 percent). The intention in re-weighting was to make the sample more representative of actual renters so as to avoid any skewedness in our results.

Finally, the survey of general remodeling contractors was conducted in early September of 2014, drawing from a nationwide panel of remodeling contractors. From these, 350 remodeling contractors were selected who indicated that they installed remodeling projects and/or products related to healthy-home/indoor environmental quality in recent years.

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