



# How Healthy are National Green Building Programs?

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National Center for Healthy Housing  
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**National Center for  
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## **About the National Center for Healthy Housing**

NCHH is the only national scientific and technical non-profit organization dedicated to creating healthy and safe homes for children through practical and proven steps. NCHH conducts policy advocacy, research and demonstration projects, and training and outreach. NCHH also works with governmental and non-governmental organizations to develop standards and programs and guide their implementation through insurers, lenders, federal and state laws and regulations, community organizations, and the courts.

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# Executive Summary

The green building market has exploded over the last several years, with consumers demanding homes that are healthier for their families, better for the environment, and less expensive to operate (i.e. energy-efficient). Recent studies have shown that people are willing to pay more for a healthy home. A 2007 survey by the Robert Charles Lesser & Co asked buyers about their attitudes toward green building and their motivations and willingness to pay for green homes (RCLC, 2007). Forty-one percent of respondents reported that they cared about and were willing to pay for the health and wellness components of a green building, *even if the costs were not recoverable*. This is compared with 18% for energy savings and 24% for the environment. Ideally, a home should be designed, constructed, and operated in a manner where all building goals are optimized - including environmental, energy, durability, affordability, and occupant health concerns.



In this report, the National Center for Healthy Housing (NCHH) compared major national green building and indoor air quality guidelines with its own set of recommended healthy housing criteria to determine whether these programs adequately protect residents from housing conditions known to affect health status, such as asthma and respiratory disease, unintentional injuries, allergic reactions, cancer, and other health effects from contaminants and allergens. The analysis examined building guidelines produced by both the public and private sectors including: Enterprise Community Partner's *Green Communities Criteria*, National Association of Home Builder's *Green Home Building Guidelines*<sup>1</sup>, the U.S. Environmental Protection Agency's *Energy Star with Indoor Air Package* and the U.S. Green Building Council's *LEED for Homes*.

We compared the selected guidelines with NCHH's healthy housing principles, which also serve as the basis for training delivered through the National Healthy Homes Training Center training and education program. These include keeping homes dry, clean, ventilated, pest-free, contaminant-free, safe, and maintained.

The results show that while all the programs have components aimed at improving resident health, many are missing critical elements. For example, injury prevention is omitted from all of the guidelines and protection from contaminants such as lead, radon, and pesticides are not uniformly covered. Only one program, Green Communities, focuses on affordable existing housing, an important consideration since low-income families are disproportionately impacted by housing-related health problems. Overall, the analysis suggests that green building programs offer a significant opportunity to achieve public health benefits and have the potential to transform the housing market toward healthier building. This report suggests ways to strengthen the occupant health criteria for green building programs so that they may deliver even greater benefits to the families who reside in them.

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<sup>1</sup> This analysis used the guidelines submitted by the National Association of Homebuilders to the American National Standard Institute (ANSI) for consensus standard approval. ANSI approval had not been granted at the time of press.

# Background

## The Connection between Housing and Health

The fact that improved housing means improved health in a general way has been accepted for well over a century (Lowry, 1991). The advent of improved sanitation in the form of indoor plumbing, separation of housing from industrial emissions through zoning, and improvements in housing durability among others all led to demonstrable health gains by eliminating or controlling cholera, typhoid, tuberculosis, and injuries. Such health gains led to the first efforts to regulate housing quality.

As attention has shifted from communicable disease to chronic afflictions, such as asthma, cancer, lead poisoning, injuries, and mental health disorders such as anxiety and depression, the link between housing and health has received new appreciation and investigation. Several reviews of the linkages between housing conditions and health in the modern era have been completed in the past decade. Increased recognition of this link has led to important developments both nationally and internationally (NCHH, forthcoming).



## Housing Regulation and Voluntary Programs

Most communities rely primarily on residential codes to protect occupants from housing-related health and safety hazards. The International Code Council (ICC) publishes building codes, which are recognized by many states and municipalities that regulate construction practices. Although both codes play a critical role in protecting the health and safety of residents, unhealthy and substandard housing continues to result in millions of illnesses and injuries each year in the United States. Housing conditions can lead to increased risk of respiratory infections, asthma, allergies, injuries, toxin exposures, cancer, and death.

New construction and substantial rehabilitation of existing housing units provide an opportunity to decrease residents' exposure to harmful effects from housing conditions. Construction and rehabilitation can help to:

- Prevent moisture intrusion into a housing unit;
- Provide easily cleanable surfaces and systems to help reduce the tracking of contaminants into the housing unit;
- Reduce and eliminate entryways for pests;
- Provide sufficient ventilation;
- Reduce the likelihood of injuries; and
- Reduce exposure to toxins such as radon, volatile organic compounds, and lead.

Rising concerns regarding the need for energy conservation have driven the increasing support for green building programs across the country. This increasing role of green building in construction and renovation practices provides an opportunity to ensure that housing units protect resident health while also conserving natural

resources. These goals can be achieved simultaneously with the promotion of healthy housing standards in conjunction with green building efforts.

More than 120 localities have adopted green building rules for public construction and 12 cities, including Boston, Washington, and San Francisco, have extended the rules to the private sector. Most of these green and healthy building programs include criteria to make housing environments healthier. The purpose of this report is to compare these programs to a core set of healthy homes criteria to determine the programs that offer the greatest protections. The results are intended to help government agencies, builders, architects, and homeowners make informed decisions about the green building programs they select.

The analysis focuses on national guidelines created by government, non profit or industry associations. These green programs have varying goals, such as energy conservation, improved quality of life, and preventing adverse environmental impacts. The following section provides a summary of the guidelines included in the analysis.

# Summary of National Green Building Programs

## Enterprise Community Partners Green Communities Criteria

Green Communities is a major initiative led by Enterprise Community Partners (Enterprise). Established in September 2004, it is a five-year, \$555 million commitment to create more than 8,500 homes that deliver significant health, economic, and environmental benefits for low-income families and communities. The program establishes green building criteria and provides funding to assist developers in planning and construction. As of January 2008, Enterprise has invested over \$570 million in over 250 developments that will result in more than 11,000 homes that meet the Green Communities Criteria.



Projects developed under the criteria must satisfy all 40 mandatory elements and gain additional points (35 points for new construction or 30 for rehabilitation projects) from optional criteria. The criteria allow flexibility if a particular hardship is demonstrated and an alternative is proposed that meets the intent and accomplishes the same outcome as the criteria. Building projects that

conform to the criteria are eligible for grants, loans, and tax credit equity as incentives. This is currently the only national green building program that requires a minimum number of new homes or apartments to be dedicated to lower-income residents.

The criteria are divided into the following categories:

- Integrated Design Process
- Site, Location and Neighborhood Fabric
- Site Improvements
- Water Conservation
- Energy Efficiency
- Materials Beneficial to the Environment
- Healthy Living Environment
- Operations and Maintenance

Optional criteria are available in Location and Neighborhood Fabric, Site Improvements, Energy Efficiency, Materials Beneficial to the Environment, and Healthy Living Environment. A review panel evaluates each project for grant approval. As part of the grant requirement, the grantee's architect and construction manager must self-certify compliance with the program criteria.

**Mandatory Criteria:** Yes, comprehensive

**Third Party Certification:** No

**Building Performance Testing:** Optional

**Units Certified/Completed as of June 30, 2008:** 11,970

[www.greencommunitiesonline.org](http://www.greencommunitiesonline.org)

## US Green Building Council's Leadership in Energy and Environmental Design for Homes (LEED for Homes)

The U.S. Green Building Council (USGBC) administers the Leadership in Energy and Environmental Design (LEED) program. LEED for Homes is a voluntary initiative designed to actively promote the transformation of the mainstream home building industry toward more sustainable practices. The long-term goal is to recognize and reward the top 25% of new homes, in terms of environmental stewardship. LEED for Homes applies to market rate and affordable homes, as well single family and multifamily homes.

The program has completed its pilot phase and began its full program in 2008. The program includes mandatory and optional green construction practices in the following categories, for a total of 136 available points:

- Awareness and Education
- Location and Linkages
- Energy and Atmosphere
- Sustainable Sites
- Water Efficiency
- Indoor Environmental Quality
- Materials and Resources
- Innovation and Design Processes



Builders receive credits for achieving criterion in each of the eight criteria categories. LEED for Homes has several performance tiers termed Certified (45-59 points), Silver (60-74 points), Gold (75-89 points), and Platinum (90-136 points). The award level point thresholds are adjusted based on home size. A third-party Provider is responsible for determining the LEED for Homes score and the rating.

The costs of participation in the LEED for Homes Program are established by local or regional Providers plus a registration and certification fee to USGBC based on the number of homes or square footage of multifamily buildings ([www.usgbc.org/DisplayPage.aspx?CMSPageID=147](http://www.usgbc.org/DisplayPage.aspx?CMSPageID=147)). The Provider is responsible for the third-party inspection and performance testing services. These verification and rating services generally require approximately 2 to 3 days per home. The costs vary depending on the size and location of the homes, and the number of green measures to be inspected and tested.

**Mandatory Criteria:** Yes, moderate

**Third-Party Certification:** Yes

**Building Performance Testing:** Yes

**Units Certified as of June 30, 2008:** 729

[www.usgbc.org](http://www.usgbc.org)



## National Association of Home Builders Green Building Program

The National Association of Home Builders (NAHB) developed its Green Home Building Guidelines with “mainstream” builders in mind. The guidelines seek to reduce the environmental impacts of housing development by focusing on several key aspects of the building process, which are termed “guiding principles.” The guidelines include a minimal number of mandatory construction practices and optional construction practices under each principle. Unlike several of the other programs, the NAHB program requires point totals in each category (site, water, energy, etc) *and* it assigns Bronze, Silver, Gold or Emerald performance levels in each category.



NAHB’s guiding principles are:

- Resource Efficiency,
- Energy Efficiency,
- Water Efficiency,
- Indoor Environmental Quality,
- Operations, Maintenance and Homeowner Education,
- Global Impact, and
- Site Planning and Development.

NAHB initiated a process for the development of an ANSI standard for green home building construction practices, which is expected to be complete by the end of 2008. The result will be a voluntary green home building standard that can be adopted by local green home building programs or local building departments as a conformance guide. After completion of the ANSI process, the standard will be promulgated as a joint publication between NAHB and the International Code Council.

**Mandatory Criteria:** Yes, limited

**Third-Party Certification:** Yes

**Building Performance Testing:** Not required

**Units Certified:** Program at inception

[www.nahbgreen.org](http://www.nahbgreen.org)

## U.S. Environmental Protection Agency Energy Star with Indoor Air Package Pilot Specifications

The U.S. Environmental Protection Agency (EPA) developed the ENERGY STAR with Indoor Air Package (IAP) Pilot Specifications to recognize homes equipped with a comprehensive set of indoor air quality measures. IAP is targeted to production builders, which according to EPA are the most rapidly growing sector of the home building industry and are highly influential in home building trends. Homes that comply with these specifications can use “Indoor Air Package” as a complementary label to ENERGY STAR for homes. As a prerequisite for this label, a home must first be ENERGY STAR qualified. ENERGY STAR is a performance-based program, which requires qualified homes to be at least 15 % more energy efficient than homes built to the 2004 International Residential Code (IRC), and include additional energy-saving features that typically make them 20–30% more efficient than standard homes. IAP requires a suite of additional prescriptive measures, including:



- Moisture Control
- Radon Control
- Pest Control
- HVAC Systems
- Combustion Safety
- Building Materials
- Home Commissioning

Like Energy Star, IAP requires third-party verification through the Home Energy Rating System (HERS).

**Mandatory Criteria:** Yes, comprehensive

**Third-Party Certification:** Yes

**Building Performance Testing:** Yes

**Units Certified:** Not Applicable (Pilot Program)

[www.energystar.gov/index.cfm?c=bldrs\\_lenders\\_raters.nh\\_iap](http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_iap)

# Method of Analysis

We compared the criteria of the four national programs to a detailed list of healthy homes measures that are aligned with NCHH's seven healthy homes principles. Those principles involve keeping homes:

- Dry
- Clean
- Ventilated
- Safe
- Contaminant-Free
- Pest-Free
- Maintained

These principles were developed by a broad-based expert workgroup of housing and health professionals as part of the federally funded National Healthy Homes Training Center and Network. The principles reflect the latest in scientific research and best practices related to reducing housing-related health hazards. For more information see [www.healthyhousing.org/training](http://www.healthyhousing.org/training).

Table 1 presents a detailed analysis comparing each program to the NCHH criteria. The left column presents NCHH's recommended criteria for achieving the aforementioned principles. We compared each program to these criteria and assigned a score based on the following scoring system:

Score	Green Program Description
3	Includes <b>mandatory</b> criterion equivalent to NCHH criterion
2	Includes <b>mandatory</b> criterion similar to NCHH criterion
1	Includes <b>optional</b> criterion that is similar to NCHH criterion
0	Does not include similar criterion

Table 2 provides summary grades for each program, both by each healthy homes principle and overall. We established a target score for each category by multiplying the number of criteria under each healthy homes principle by 2.5 (average 2 and 3 of the scores listed above). For example, if half of the criteria in a category scored a 3 (i.e., half criterion were mandatory and equivalent to the NCHH standard) and half scored a 2 (i.e., were mandatory and similar but not equivalent to the NCHH standard), then the program would achieve 100% of the target score. The score of 2.5 acknowledges that some differences in the language for a specific criterion are likely and acceptable.

The overall grade (A, B, C, D) for the program was calculated by totaling the scores for all the criteria across categories. This provides all criterion equal weight in arriving at a total grade.

## Grading Key

A+	>100% of target score, <i>all</i> NCHH criteria included
A	90-100% of target score.

<b>B</b>	80-89% of target score.
<b>C</b>	60-79% of target score.
<b>D</b>	<60% of target score.

This analysis did not assign a weighting factor to each individual criterion because there are generally insufficient scientific data to support such a judgment. The concept of healthy homes involves taking a holistic approach to the home environment by implementing packages of upgrades, which together can ensure the health, safety, and durability of a home.

The review did not consider the costs of the various building standards because none of the standards provide cost estimates. Only the Green Communities Criteria explicitly considers costs. In addition, of the guidelines, only the Green Communities Criteria are directed toward both new construction and rehabilitation activities. Of the guidelines reviewed, the Green Communities Criteria has the broadest application when viewed in this context.

# Results

Tables 1 and 2 show the results of the analysis. The Enterprise Community Partners Green Communities Program ranked the highest among the programs included in the analysis. This is largely due to the fact that the program includes many mandatory criteria for the indoor environment. The LEED-H program includes a mixture of mandatory and optional criteria to achieve even the lowest LEED rating of “certifiable”. It is not possible to assess the mix of criteria that a builder will select to comply with the standard. NCHH conservatively rated optional criteria as a 1, thereby reducing the LEED-H score for all such criteria. The NAHB program relies substantially on optional criteria with a minimal set of mandatory standards. As such the program received the lowest rating.



One reviewer suggested that optional criteria receive greater credit because the flexibility in scoring enables greater program participation. The reviewer also noted that several of the optional healthy homes criteria are pursued by the majority of program participants. The reviewer suggested multiplying the percentage of projects that incorporate the optional measure by the score a measure would have received if it were mandatory as an alternative scoring system. For example, if “landscaping away from a building” would receive a score of 3 as a mandatory element, it would receive a 2.7 if 90% of the program participants selected it as an optional criterion. Although such a nuanced system may reflect a more precise view of the actual compliance with a program’s criteria in a prior year, because programs cannot predict the optional criteria that future projects will select, NCHH felt that these programs could not be scored as highly as those based on mandatory criteria. In addition, NCHH believes that the healthy homes criteria are practical and cost-effective (e.g. avoiding installing carpets in wet areas) and so it is sensible to include them as prerequisites.

Across all the green programs, there is substantial variation in their performance under the *Dry* and *Contaminant-Free* categories with scores ranging from A to D. Several programs received an A under the Dry category (ENERGY STAR IAP, Green Communities, and LEED-H) because they require extensive moisture control practices. The LEED-H program addresses several aspects of moisture control through its Durability Plan requirement. One concern is that it is not possible to assess whether the plan will always include the most important moisture control elements. Nonetheless, because the durability plans are mandatory and will be evaluated as part of program participation, NCHH rated LEED-H’s Dry criteria as similar to the NCHH specific requirements.

Ensuring structures are properly ventilated is particularly important because of the green building mandate to improve energy efficiency by tightening the building envelope. Energy upgrades can benefit occupant health by increasing comfort and reducing unplanned airflows which can result in moisture problems. Mechanical ventilation helps ensure contaminants and humidity are exhausted to the outside and that the home receives clean, fresh air. NCHH has identified the American Society of Heating, Refrigerating, and Air-Conditioning Engineers standard 62.2 (ASHRAE 62.2, 2007) as the industry standard for ventilation for buildings of four

stories or less, which should be included in all green and healthy programs. All the programs, except the NAHB guidelines, include ASHRAE 62.2 as the ventilation performance standard.

The evaluation indicates greater consistency across green programs for the *Pest-Free* and *Maintained* categories. All of the programs included criteria to minimize pest infestations following the least toxic methods (NAHB's criterion was optional and the other programs were mandatory) and to educate homeowners about proper maintenance of their green homes. In contrast, all of the programs included in the analysis overlooked safety (e.g., preventing trips/falls and poisonings), even though the home is the predominant source of unintentional injuries for children in the United States. In addition, the programs missed opportunities to incorporate building finishes that are easy to keep clean (e.g. smooth, cleanable flooring), which help owners reduce allergens and contaminants that may accumulate in a home.

**Table 1: Consistency with Health Homes Principles**

	<b>Enterprise Community Partners Green Communities</b>	<b>ENERGY STAR Indoor Air Package</b>	<b>USGBC LEED Homes</b>	<b>NAHB Green Building Program</b>
<b>DRY (10 Criteria - 25 points)</b>				
Water Heater Catch Pans and Drains	3	0	3	0
Avoid Mold-susceptible Materials	3	3	3	0
Basements and Concrete Slabs Drainage	3	3	2	2
Surface Water Drainage	3	3	2	2
Roof Flashing	2	3	2	1
Continuous Drainage Plane	2	3	2	2
Window and Door Flashing	3	3	2	1
Avoid Heat Loss to Unconditioned Space	2	3	2	3
Landscaping Away From Building	0	0	1	0
Avoid Carpet in Wet Areas	3	3	3	1
<b>TOTAL</b>	<b>24 (96%)</b>	<b>24 (96%)</b>	<b>22 (88%)</b>	<b>12 (48%)</b>
<b>CLEAN (12 Criteria - 5 points)</b>				
Walk-off Mats	0	0	1	1
Smooth and Cleanable Flooring	1	0	0	0
Central Vacuum System - optional	0	2	1	1
<b>TOTAL *does not include optional score</b>	<b>1 (20%)</b>	<b>0 (0%)</b>	<b>1 (20%)</b>	<b>1 (20%)</b>
<b>VENTILATED (7 Criteria - 17.5 points)</b>				
Bath & Kitchen Exhaust Fans	3	3	3	1
Outdoor Air Ventilation ASHRAE 62.2	3	3	3	1
HVAC System Sizing	3	3	3	3
Avoid Air Handlers/Duct Work in Garage	3	3	3	1
Air Filtering	3	3	3	1
No Use of HVAC Use During Construction	0	3	1	1
Ventilate Before Occupancy (unless low VOC products specified)	2	3	1	0
<b>TOTAL</b>	<b>17 (97%)</b>	<b>21 (120%)</b>	<b>17 (97%)</b>	<b>8 (46%)</b>

	<b>Enterprise Community Partners Green Communities</b>	<b>ENERGY STAR Indoor Air Package</b>	<b>USGBC LEED Homes</b>	<b>NAHB Green Building Program</b>
<b>SAFE (5 Criteria – 12.5 points)</b>				
Water Heater Temperature <120 F	0	0	0	0
Locked Medicine Storage Cabinets	0	0	0	0
Shower Grab Bars	0	0	0	0
Smoke Detectors	2	2	2	2
Carbon Monoxide Alarms	3	3	3	1
<b>TOTAL</b>	<b>5 (40%)</b>	<b>5 (40%)</b>	<b>5 (40%)</b>	<b>3 (24%)</b>
<b>CONTAMINANT-FREE (7 Criteria – 17.5 points)</b>				
Low VOC Products	3	0	1	1
Urea Formaldehyde Free Composite Wood Products or Sealed	3	3	1	1
Low VOC Carpet	3	3	1	2
Garage Isolation	3	3	1	2
Smooth Cleanable Low VOC Floors	1	1	1	0
Combustion Venting	2	3	3	1
Radon Test and Mitigation System	3	2	2	2
Smoke-free Policy – optional	3	0	0	0
Use Lead Safe Work Practices - optional applicable only to rehabilitation	3	na	na	0
<b>TOTAL *does not include optional scores</b>	<b>18 (103%)</b>	<b>17 (97%)</b>	<b>10 (57%)</b>	<b>9 (51%)</b>
<b>PEST-FREE (1 Criterion – 2.5 points)</b>				
Rodent Proof Materials	3	3	2	1
<b>TOTAL</b>	<b>3</b>	<b>3</b>	<b>2</b>	<b>1</b>
<b>MAINTAINED (2 Criteria – 5 points)</b>				
User’s Manual for Health Features	3	3	3	3
Homeowner’s Manual for Equipment and Certification	3	2	3	2
<b>TOTAL</b>	<b>6 (120%)</b>	<b>5 (100%)</b>	<b>6 (120%)</b>	<b>5 (100%)</b>



**Table 2: National Green Program Health Grades**

Health Principles	Enterprise Community Partners Green Communities	EPA Indoor Air Package	USGBC LEED For Homes	NAHB Green Building Program
DRY	A	A	B	D
CLEAN	D	D	D	D
VENTILATED	A	A+	A	D
SAFE	D	D	D	D
CONTAMINANT-FREE	A	A	D	D
PEST-FREE	A+	A+	B	D
MAINTAINED	A+	A	A+	A
OVERALL GRADE *	B+	B+	B-	D

\* Based on total score across all criteria in comparison to 85 target score

**Grading Key**

<b>A+</b>	>100%, <i>all</i> NCHH criteria included
<b>A</b>	90-100% of target score.
<b>B</b>	80-89% of target score.
<b>C</b>	70-79% of target score.
<b>D</b>	<70% of target score.

# Recommendations

As consumers learn more about the impact of their homes on their health and well-being, demand for green and healthy housing will increase. Surveys show that consumers who purchase “green homes” cite health as a key motivator (RCLC, 2007). Yet not all green building programs are created equal. Key opportunities for improvements are highlighted below.



## Dry

Dampness, moisture and mold in homes have all been linked to increased risk of respiratory problems (NAS, 2000), yet many homes in the US have moist conditions. The 2005 US American Housing Survey reports that approximately 10% of US homes reported some moisture problems. It is estimated that dampness and mold in homes contributes to approximately 21% of asthma cases in the United States (Mudarri and Fisk, 2007). Thus, moisture reduction in homes provides an opportunity to improve the respiratory health of occupants.

New construction and substantial rehabilitation of buildings offers the most efficient opportunity to ensure the building envelope is constructed in a way that sheds moisture and allows buildings to dry out when they do get wet. Simple improvements that could be made to several programs include:

- Requiring landscaping to be away from the building foundation unless plantings are drought resistant and require no watering.
- Avoiding the use of mold susceptible materials in areas likely to get wet (entry ways, bathrooms).

## Safety

Approximately 18,000 injury deaths and 12 million non-fatal injuries occur each year in residential settings (Runyan et al. 2005). None of the green housing programs reviewed included criterion to address potential safety issues. This may be largely due to the main focus of most green building programs on resource efficiency and sustainability rather than on occupant health specifically. However, recommended healthy housing principles related to safety can play complimentary roles in improving occupant health while also decreasing resource utilization. For example, setting water heater temperatures at 120 degrees Fahrenheit will reduce the risk of scalds and burns while also decreasing energy use. High-risk groups including children younger than 4 years old, the elderly, and individuals with physical or mental disabilities account for nearly 90% of individuals burned by hot tap water. Water heater temperatures set above 120 degrees Fahrenheit have been demonstrated as a primary residential deficiency associated with scalds (U.S. Department of Housing and Urban Development, 2006). Other criterion can reduce residents' risk of falls and injuries, which result in substantial hospital visits for the young and elderly. Recommendations to improve safety include:

- Providing lockable medicine cabinets.
- Installing grab bars in bathrooms.
- Setting the water heater at 120 degrees Fahrenheit.

## Contaminants and Cleanable Homes

Radon can be found in any home and is the leading cause of lung cancer among non-smokers. EPA recommends radon resistant construction in areas of the country with a likelihood of high radon levels. Second hand tobacco smoke is also a risk to occupants; it exacerbates and can cause asthma, lung cancer, sudden infant death syndrome (SIDS), and other health effects. The National Academy of Sciences has demonstrated a causal relationship between second hand smoke and both the exacerbation and development of asthma in young children (NAS, 2000). Smoking bans have been demonstrated to be effective in significantly reducing exposure to second hand smoke, thus providing one method through which green building programs could help to reduce occupant exposure to second hand smoke. In addition to reducing fire risks, non-smoking units have the additional benefit of reducing maintenance costs associated with specialized cleaning and repainting.



Contaminants, pollutants and allergens can all be tracked into a home or be found in homes at levels that have adverse health risks. One safeguard to enable owners to reduce exposure to such substances is to make the home as “cleanable” as possible. All programs in the analysis missed opportunities in the “clean” category. Many of the healthy housing principles related to cleanable surfaces may help green building programs minimize cost and resource utilization. For example, providing walk-off mats and smooth, cleanable flooring may decrease the frequency with which maintenance personnel need to replace flooring surfaces, thus conserving resources. Compared to carpeting, smooth and cleanable flooring options may decrease long term costs since carpeting may need replacement as often as every five to seven years in heavy use areas. Recommendations to reduce contaminants and provide cleanable surfaces that are absent from several programs include:

- Requiring active sub-slab depressurization (ASD) as system in all new construction to help with a variety of contaminants including radon and volatile organic compounds found in the soil.
- Providing optional credits for multi-family units that choose to be smoke-free properties.
- Requiring track off mats and adequate shoe storage.
- Providing optional credits for the installation of central vacuums.

## Ventilation

Providing clean fresh air is essential for a healthy home. Scientific evidence suggests that inadequate ventilation adversely affects health by increasing respiratory problems as well as moisture problems. All the programs, excluding NAHB, require compliance with the ASHRAE 62.2 standard, including the affordable housing built under the Green Communities program. This ventilation specification should be a required element of all green programs and technical resources must become more accessible to assist owners and builders in meeting it.

## Future Research

In developing the recommended healthy homes criteria and the underlying healthy homes principles, we have attempted to reflect current knowledge and best practices and to incorporate criteria that are feasible to implement (e.g. can be broadly adopted) and will contribute to health improvements. There is a need for additional research to identify how much each factor contributes to the occupants’ overall health status.

Additional research and evaluation is also needed to understand the overall impact of green building on occupant health. Preliminary results of an NCHH evaluation of a green affordable housing development in Minnesota indicate that:

- Families are more comfortable in their green homes;
- Families report that their homes are easier to clean; and
- About one-third report that their health and the health of their children is better.

NCHH applauds the national and local organizations that have developed green building programs to help conserve our nation's energy and natural resources, protect the environment, increase our access to nature, and protect families from environmental health threats. These programs offer new opportunities to create more livable and sustainable communities and underscore the relevance of the built environment to our health and well-being. NCHH hopes this review will promote more widespread acceptance and support for these programs and will spur a greater commitment to resident health as these programs evolve and new programs emerge.

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# Appendix 1

## National Center for Healthy Housing’s Recommended Healthy Homes Criteria

CRITERION	REFERENCE
<b>Dry</b>	
<p>Water Heater Drains and Catch Pans: For conventional hot water heaters and equipment that condense water (e.g., air conditioner, dehumidifier) install drains or catch pans that capture overflow or leaks.</p>	<p>LEED ID 2.1; GC 7-8a</p>
<p>Avoid Mold-Susceptible Materials in Wet Areas: Do not install mold-susceptible materials such as vinyl wallpaper, paper-faced gypsum board, and unsealed grout in wet areas. Use highly durable, moisture-resistant materials in tub/shower enclosures (cement board, fiberglass-reinforced board).</p>	<p>EPA 1.11; LEED ID 2.1; 5.8; MR 4.1; NAHB 903.1; GC 7-10a, 7-10b</p>
<p>Basements and Concrete Slabs: Provide proper drainage to the lowest level of concrete. Waterproof exterior of below grade foundation walls. Provide continuous crushed stone under footings or provide pipe through footing for drainage of any accumulated water under slab to drainage. Install a capillary break of 4 inches of clean or washed gravel (0.5-inch or greater), placed over soil. Cover with a 6-milimeter (mil) polyethylene sheeting moisture barrier, with joints lapped one foot or more to prevent moisture from migrating from the soil through the slab to a living or storage area. On interior below-grade walls, avoid using separate vapor barrier or a below-grade vertical insulation that can trap moisture inside wall systems (e.g., polyethylene sheeting, vinyl wallpaper or foil faced). Raise paper covered gypsum board ½ inch above concrete slabs.</p>	<p>EPA 1.3, 1.4, 1.7, 6.2; LEED EQ 1.1; NAHB 903.2.1,903.2.2, 903.3 GC 7-11a</p>
<p>Surface Water Drainage: Divert water drainage away from the building by directing gutters and downspouts to flow onto splash blocks or a proper drainage system. Slope new and rebuilt walkways, stairs, patios and thresholds away from the buildings. Best practices include a grade of 0.5 inch per foot, or approximately a 4 percent pitch. EPA recommends a 2 percent pitch (0.25 inch per foot) for hard surfaces such as patio slabs, walks and driveways. Provide drain tile at footings, level or sloped to discharge to outside grade (daylight) or to accessible sump pump. Top of drain tile pipe must always be below level of where bottom of concrete slab or crawl space floor will occur. Pipe shall be surrounded with min. 6 inches of ¾ inch washed or clean gravel that is fully wrapped with fabric cloth. Use a sealed sump pump system. Drainage system not required in pure sand.</p>	<p>EPA 1.1, 1.2, 1.5, 1.8, 1.15; LEED EQ 1.1; LEED SS 4.2, 4.3; LEED Durability Checklist; NAHB 602.3.2, 602.5, 602.6; GC 7-12</p>

CRITERION	REFERENCE
<p>Roof Flashing: Minimize and properly flash all roof penetrations and construct effective eaves. Where feasible, extend eaves (ideally 18 inches to 2 feet, climate conditions permitting) to keep water away from the building. Provide step flashing at intersections of roof and walls with the exception of continuous flashing at metal and rubber membrane roofs. Use metal “kick-out” flashing at the end of roof/wall intersections to direct water away from wall.</p>	<p>EPA 1.8; LEED EQ 1.1; NAHB 602.1, 602.2, 602.12; GC 7-12</p>
<p>Drainage Plane: Install continuous drainage plane fully sealed at all penetrations that directs water away from wall assemblies.</p>	<p>EPA 1.5; LEED EQ 1.1; NAHB 602.9; GC 7-12</p>
<p>Window/Door Flashing: Effective flashing on all rough openings, including membrane flashing on bottom of all rough openings for windows (pan flashing) and doors using adhesives compatible with drainage plane materials and window and door head casing flashing. Ensure proper installation of windows and doors to protect moisture-sensitive materials from rainwater intrusion.</p>	<p>EPA 1.6; LEED EQ 1.1; NAHB 602.12, 704.6.1; GC 7-12</p>
<p>Heat Loss: Reduce moisture problems caused by unnecessary heat loss into and out of the unconditioned space. No non-airtight recessed light fixtures in insulated ceilings.</p>	<p>EPA 1.10, 1.13; LEED EQ 1.1; LEED Durability Checklist; NAHB 701.4.5.4, 704.2.2</p>
<p>Landscaping Away From Building: Plan landscaping so that mature plantings will be at least 24” from house. Avoid planting trees where root systems can penetrate the foundation and plumbing.</p>	<p>LEED SS 2.5</p>
<p>Avoid Carpet in Wet Areas: Avoid wall-to-wall carpet in wet areas including bathrooms, kitchens, utility rooms, basements, or entryways.</p>	<p>EPA 1.11; LEED ID 2.1; NAHB 901.5 GC 7-4</p>
<b>CLEAN</b>	
<p>Prevent Track In: Install permanent walk-off mats, provide track off system, or design to accommodate track off mats. Provide sufficient storage area for shoes and boots to encourage removal when entering building.</p>	<p>LEED EQ 8.2; NAHB 901.13</p>
<p>Smooth and Cleanable Flooring: Do not install carpet in at least one bedroom. If feasible, install smooth and resilient flooring in all rooms.</p>	<p>GC 7-17b</p>
<p><i>Central Vacuum – Optional: Strongly recommend installation of central vacuum system with exhaust to the outdoors.</i></p>	<p>EPA 4.21; LEED EQ 8.2; GCI 7-17B; NAHB 902.10 GC 7-17b</p>

CRITERION	REFERENCE
<b>VENTILATED</b>	
<p>Bath and Kitchen Exhaust Fans: Except for exhaust fans ducted to multiple bathrooms, install Energy Star-labeled local exhaust bathroom fans per ASHRAE 62.2 that exhaust to the outdoors, are equipped with a humidistat sensor or timer, and have rates of at least 20 cfm continuous (50 cfm intermittent). For kitchens with gas cook tops and/or gas ovens, install power-vented Energy-Star labeled fans or range hoods per ASHRAE 62.2 that exhaust to the exterior and have rates of 5 air changes per hour or 100 cfm intermittent.</p>	<p>EPA 4.6; LEED EQ 5.1, 5.2; NAHB 902.1 GC 7.5a, 7.5b, 7.5c</p>
<p>Outdoor Air Ventilation: Adequately ventilate all living areas by following ASHRAE 62.2 or as a rough rule of thumb providing 15 cubic feet per minute of fresh air, per occupant, either via the HVAC system or through natural ventilation.</p>	<p>EPA 4.5; LEED EQ 4.1, 4.2; NAHB 902.5; GC 7.6a</p>
<p>HVAC System Sizing: Size HVAC systems to prevent short-cycling of heating or air conditioning and ensure adequate dehumidification (ACCA Manual J and S).</p>	<p>EPA 4.1; LEED EQ 6.1; LEED EA 6.1; NAHB 701.4.1; GC 7-7;</p>
<p>Avoid Equipment in Garage: No air handlers or duct work in garage. Exhaust ducts allowed if leakage is limited to &lt;5%.</p>	<p>EPA 4.3; LEED EQ 10.1; NAHB 901.1.2; GC 7-12</p>
<p>Air Filtering: Install air filters rated at MERV 8 or higher, and ensure that air handlers can maintain adequate pressure and air flow, OR Install Ductless Space Conditioning System</p>	<p>EPA 4.7; LEED EQ 7.1; NAHB 902.7;</p>
<p>No HVAC During Construction: Avoid use of HVAC equipment during construction, mask HVAC outlets during construction, and clean HVAC ducts and coils before occupancy.</p>	<p>EPA 4.7; LEED EQ 8.1; NAHB 902.9;</p>
<p>Ventilate Before Occupancy: Ventilate before occupancy unless low VOC paints and materials are specified. For the period between finishing and occupancy, ventilate the building at the highest rate the ventilation system can produce for a period of three days.</p>	<p>EPA 7.2; LEED EQ 8.3;</p>
<b>SAFE</b>	
<p>Water Heater Temperature: Set water heater temperature at 120 degrees Fahrenheit.</p>	
<p>Cabinet Locks: Install medicine storage cabinets with locks homes that may be occupied by young children.</p>	



CRITERION	REFERENCE
<p>Grab Bars: Install grab bars inside and outside showers in housing units that may be occupied by persons over 55.</p>	
<p>Smoke Detectors: Provide smoke detectors per code AND hardwired with battery backup.</p>	<p>Codes typically require smoke detectors hence all standards are scored as having achieved similar criteria; hardwired devices with battery backup not typically required.</p>
<p>Carbon Monoxide Alarms: Install one carbon monoxide (CO) alarm outside of each separate sleeping area in homes with combustion appliances. Install additional alarm on interior wall of attached garage.</p>	<p>EPA 5.3; LEED EQ 2.1; GC 7-13; NAHB 901.12;</p>
<b>CONTAMINANT-FREE</b>	
<p>Low VOC Paint and Products: Use low-volatile organic compounds (VOC) paints and primers. Use low-VOC sealants and adhesives. If carpet used, use tack strips to lay down carpets whenever possible.</p>	<p>EPA 6.2; LEED MR 2.2; NAHB 901.9; GC 7.1, 7.2, 7.4</p>
<p>Urea Formaldehyde Free Composite Wood: Ensure any composite wood used, (including interior panel products, exposed particleboard, MDF) is free of added urea formaldehyde, or sealed with a low-VOC, water-based sealant or laminate. Wire shelves are appropriate as an alternative.</p>	<p>EPA 6.1; LEED MR 2.2; NAHB 901.6, 901.7, 901.8; GC 7-3;</p>
<p>Low VOC Carpet: If using carpet, install Carpet and Rug Institutes Green Label Plus certified carpet.</p>	<p>EPA 6.3; LEED MR 2.2; NAHB 901.5; GCI 7-4;</p>
<p>Garage Isolation: Install detached garage OR tightly seal shared walls between garage and conditioned spaces with: continuous air barrier, tightly sealed door from living space to garage, air sealing of all penetrations, walls, ceilings and floors, and minimum 100 CFM exhaust fan rated for continuous exhaust with automatic timer control to run for a pre-set period of time when garage door opens and closes.</p>	<p>EPA 5.5, 5.6; LEED EQ 10.1, 10.2, 10.3, 10.4; NAHB 901.3; GC 7-13;</p>
<p>Smooth and Cleanable Low VOC Flooring: Use smooth and cleanable environmentally friendly flooring products such as: linoleum, laminate, ceramic tile, bamboo, cork, wood (especially salvaged wood), rubber or other low VOC emitting products.</p>	<p>EPA 1.11, 6.1; LEED MR 2.2; GC 7-10, 7-17A;</p>

CRITERION	REFERENCE
<p>Combustion Equipment: Ensure all combustion fueled equipment in conditioned spaces is vented to the outside and either sealed-combustion, direct vent, power-vented, induced draft, or aerodynamically de-coupled from the indoor air. No un-vented fireplaces OR all fireplaces and solid fuel heating must have tight-fitting doors and dedicated outside combustion air. Non-closed combustion systems must be aerodynamically de-coupled from the indoor air.</p>	<p>EPA 5.1, 5.2; LEED EQ 2.1, 2.2; NAHB 901.2.1; GC 7-8b</p>
<p>Radon Protection: If home is located in EPA Regions 1 or 2, or local data suggest that there is a radon risk, design and install radon mitigation system, and perform short term radon test. Radon test all homes after completion and before occupancy.</p>	<p>EPA 2.1, 2.2; LEED EQ 9.1, 9.2; GCI 7-11b, 7.6; NAHB 902.8</p>
<p><i>Smoke-free Policy - Optional: Implement and enforce a “no smoking” policy in all common and individual living areas of all buildings. Common areas include rental or sales offices, entrances, hallways, resident services areas, and laundry rooms.</i></p>	<p>EPA 5.4</p>
<p><i>Lead Safe Work Practices – Optional: Use lead safe work practices when sanding, cutting, scraping, drilling or in any other way disturbing painted surfaces in homes built before 1978, unless lead testing documents that the paint is not lead based. Follow Lead-Safe Work Practices. Follow 24 CFR 35 for federally owned or assisted properties. Follow the Lead Paint Field Safety Guide for all other properties.</i></p>	<p>GCI 7-16</p>
<p><b>PEST-FREE</b></p>	
<p>Seal Pest Entry: Seal all wall, floor and joint penetrations with rodent proof materials and low VOC caulk if appropriate. Apply boric acid in holes and cracks likely to experience cockroach problems.</p>	<p>EPA 3.1, 3.2; LEED SS 5; NAHB 3.3.1 (w/o rodent-proof and boric acid provisions); GC 7-15;</p>
<p><b>MAINTAINED</b></p>	
<p>Users Manual: Provide a “User’s Manual” for the house, including written operation instructions for the house, maintenance schedule, maintenance instructions, equipment literature, equipment warranties.</p>	<p>EPA 7.3; LEED AE 1.1; NAHB 1001, 1002; GC 8-1, 8-2</p>

CRITERION	REFERENCE
<p>Homeowners Manual: The builder shall provide the home buyer with a Homeowner's Manual / binder that includes:</p> <ul style="list-style-type: none"> <li>• Healthy Home/Indoor Environment Certificate; and</li> <li>• The completed checklist of Healthy Homes features; and</li> <li>• The product manufacturer's manuals for all installed equipment, fixtures, and appliances.</li> </ul> <p>A walkthrough of the home before closing, that is at least 60 minutes in duration. The walkthrough should include:</p> <ul style="list-style-type: none"> <li>• Identification of all installed equipment, and</li> <li>• How to use measures and operate the equipment in their Healthy Home appropriately; and</li> <li>• How to maintain the measures and equipment in their Healthy Home properly.</li> </ul>	<p>EPA 7.3; LEED AE 1.1; NAHB 1001, 1002; GC 8-1,8-2), 8-3</p>