# Metrics for High Performance Affordable Housing

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**Abstract:** This report has been prepared for Lawrence Berkeley National Lab and the Department of Energy as the deliverable for Task Four of the FY2009 FAS Scope of Work, which tasked FAS with developing "industry friendly" metrics for high performance affordable housing and creating a means for visually representing those metrics.

This report defines high performance housing as that which meets specific performance benchmarks or criteria in each of several attributes. A high performance house must be: cost effective, sustainable, safe/secure, productive, functional/operational, accessible, and take occupancy, historical preservation and aesthetics into account in its design, construction, and operation. This report summarizes the best available standards and metrics, makes recommendations on how performance should be defined and measured for each attribute, and offers suggestions on high performance benchmarks for each attribute. In addition, as the goal of this report is to provide a starting point for discussion during the metrics creation process that must follow, this report contains recommendations on the development process and resulting metrics.

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## Introduction and Background

As residential energy prices have risen over the past several years, the monetary resources of many homeowners have been further stretched. This is especially true among low income families, for whom utility bills constitute on average 16% of their income, as compared to a median of 4-5% nationwide—a fact due not only to lower income, but to the energy inefficient nature of much of our nation's older housing stock.[1] Simultaneously, a growing national consensus has emerged around the need to mitigate the effects of climate change by reducing the nation's energy use. As the building sector accounts for 40% of this energy use, to substantially reduce energy use a signification portion of consumption cuts must come from residential and commercial buildings.

Since 2005, the importance of indoor air quality and limiting interior toxic materials has received renewed attention due to the presence of formaldehyde in the Hurricane Katrina relief trailers and the subsequent health problems of occupants. This collection of issues—unhealthy housing, the threat of climate change and need to reduce carbon emissions, and the high cost of utilities for low income families must be dealt with rapidly. The solution to these problems is to create a housing stock that is safer, more efficient, comfortable, and useful for its inhabitants. In short, the solution is to build new houses and retrofit existing houses to be higher performing in terms of safety, sustainability, and utility.

### High Performance Building Legislation and Policy

In 2005 Congress first recognized this need for high performance housing and for a set of standards to define what high performance housing means. This first attempt at addressing high performance housing in the *Energy Policy Act of 2005* (EPAct) defines high performance building as that which "integrates and optimizes all major high-performance building attributes, including energy efficiency, durability, lifecycle performance, and occupant productivity."[2] EPAct also notes that in the future, buildings should continue to comprehensively integrate the best available, arguably cost effective building technologies to advance the state of high performance building.

In 2007, the *Energy Independence and Security Act (EISA)* reiterated the need to develop a high performance building standard and revised the legislated definition. According to *EISA*, a high performance building is redefined as one that "integrates and optimizes on a life cycle basis all major high performance attributes, including energy conservation, environment, safety, security, durability,

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[1] The average age of a residential building in the U.S. in 2007 was 32 years. In 1975 when the average house was built, buildings were frequently constructed with no or minimal insulation, single pane windows, and poor air sealing.
Census Bureau, "Frequently Asked Questions," American Housing Survey, http://www.census.gov/hhes/www/housing/ahs/ahsfaq.html (accessed December 17, 2009).
Department of Energy, "Reducing the Burden on Needy Families," (July 25, 2008), http://apps1.eere.energy.gov/weatherization/reducing.cfm (accessed December 17, 2009).
[2] 109th U.S. Congress, *Energy Policy Act of 2005*, (August 8, 2005) http://www.doi.gov/iepa/EnergyPolicyActof2005.pdf (accessed December 17, 2009).

accessibility, cost-benefit, productivity, sustainability, functionality, and operational considerations."[3] These "performance attributes" were conceived by the National Institute of Building Sciences (NIBS) for the *Whole Building Design Guide*, a resource created to promote high performance building by applying an integrated approach to design, planning, and construction. While *EPAct* focused primarily on a building's energy efficiency and environmental impact, the definition and attributes recommended by NIBS is based on a more comprehensive understanding of the high performance concept, which takes into account occupant needs and quality of life.[4]

Also in 2007, NIBS formed the "High Performance Building Council" to assess all current building standards and suggest to the US Congress and Department of Energy (DOE) tactics to accelerate the development of a high performance building standard. Based on this work, in 2008 NIBS published the *Assessment to the US Congress and US Department of Energy on High Performance Buildings*, a report commissioned by Congress to define each of the eight performance attributes identified in the *Whole Building Design Guide* and *EISA 2007*. However, the project was underfunded by Congress so the resulting report was limited in scope. Failing to even assess all current building standards, let alone clearly define high performance standards and metrics, the report's conclusions were limited to reiterating the need for a "performance metric" and "verification method" to be developed for every attribute. (For a detailed analysis of the "Assessment" and policy recommendations, see Appendix 1.) While there has been some minimal progress by the High Performance Building Council since 2007 in defining high performance building and setting high performance standards, the United States still lacks a definitive set of underlying performance metrics.

## Developing Residential High Performance Metrics

To create a stock of highly performing houses it is necessary to specifically define the attributes of a high performance building. These definitions require a performance metric or set of metrics and corresponding verification method for each performance attribute. As such, the federal government must take the lead in developing these underlying metrics with the participation of private organizations and corporations. Doing so will enable houses to be compared and benchmarked against a nationwide standard. This capability will benefit builders, policymakers, home buyers, and other building industry stakeholders by providing federal guidance on what a high performance house is and is not. In turn, this will likely strengthen the market for high performance housing just as the Energy Star standards and labeling has strengthened the market for energy efficient appliances, windows, and lighting.

To be useful, the developed metrics must be easily understood and applied by all stakeholders. Wherever possible, metrics should be quantifiable and based upon a comprehensive understanding of an attribute's safety, technical feasibility, and performance. Though developing comprehensive underlying metrics for a given attribute may require extensive modeling and analysis, developing these

[3] 110th U.S. Congress*, Energy Independence and Security Act of 2007*, (January 4, 2007). http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=110_cong_bills&docid=f:h6enr.txt.pdf (accessed January 29, 2009).

[4] National Institute of Building Sciences, *Assessment to the US Congress and US Department of Energy on High Performance Buildings,* (2008) http://www.wbdg.org/pdfs/hpb_report.pdf (accessed December 1, 2009).

metrics allows performance standards and benchmarks to be created for residential construction that are predictably high performing, yet still feasible and cost effective.

Performance based standards are preferable to prescriptive standards because, unlike prescriptive standards, which dictate specific materials and construction practices, performance standards allow for innovation and flexibility. So long as the performance benchmark is met and the underlying metrics and equations satisfied, building professionals are able to use non-standard building products, plans, and techniques, a necessity to advance and improve the state of high performance building in the future.

Where mathematically based metrics cannot be created because the attribute is innately subjective, it is still necessary to create a baseline measure of high performance in order to define what high performance means now and in the future. Historical preservation and aesthetics, for example, cannot be measured, but standards for performance can still be created that benchmark minimum and high performance. It is necessary to set standards for qualitative attributes because only by understanding and benchmarking current performance can the tightening and improvement of those standards and targets occur in the future. (For an in-depth discussion of the necessity of quantifiable and comparable metrics, see Appendix 2.)

When developing any metric, it is important to note that construction is highly interconnected and by extension, a building's performance attributes are similarly interconnected; for example, energy use affects not only a home's sustainability, but also its cost effectiveness and productivity. Because of this inherent interconnectivity, designing high performance housing requires integrating the process and allowing all stakeholders, including: architects, engineers, building professionals, building industry labor representatives, interior designers, code officials, and local planning officials to have input and to link their work with that being done by other stakeholders.

This principle of design interconnectivity or whole building design is the foundational principle of the NIBS *Whole Building Design Guide* and is essential to high performance building. Whole building design enables all homeowner uses and needs and all construction steps and practices to be accounted for and integrated into the original building design, thereby lowering costs, streamlining and eliminating waste in the planning and construction process, and producing a more useful and functional structure. Because of the necessity of an interconnected design and construction process to creating high performance buildings, the process of creating metrics to measure high performance is also highly interconnected. For each qualitative and quantitative attribute, multiple professions, industry groups, and associations have a legitimate stake in how the metric is created and implemented. And by working with these teams of stakeholders, the resulting metrics will have both better express whole building design and construction principles and have greater legitimacy within the building community.

This stakeholder partnership is especially important in cases where minimum standards and codes are set by private code development organizations or where a qualitative standard must be created. In these cases the private code development organizations, such as the International Code Council (ICC) and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), develop codes through an American National Standards Institute (ANSI) approved consensus process that draws contributions from member stakeholders. Key stakeholders in the development process include: labor, industry, trade representatives, building scientists, and representatives of other key industry groups.

As products of consensus among such a diverse membership, the codes developed by these organizations tend to be cautious in areas such as accepting new technologies and pushing energy efficiency. To override this caution and create a truly high performing set of standards and codes, it may be necessary for the government to partner with the code organization in developing, disseminating, and passing legislation in support of better, stronger codes and standards.

Likewise, setting qualitative standards requires greater stakeholder partnership as the standards are not based upon an underlying set of mathematical assumptions, models, or technical specifications, but upon the knowledge of a variety of subject matter experts. And for a qualitative standard to be comprehensive and widely accepted, the opinions of all expert stakeholders must be included in the underlying assumptions and consensus.

Thus far, the federal government's vision of high performance housing has been limited to the attributes that reflect the asset rating of the house. All eight attributes mentioned in *EISA 2007* reflect the house's performance without any occupants; however, occupant behavior has a substantial effect upon the actual performance of the house. Most studies of housing and energy performance to date, especially including DOE's Residential Energy Consumption Survey, provide a good overview of household characteristics and energy use, but do not correlate energy consumption with the asset rating of the house and provide little or no data on the effect of occupation on the actual performance of a house.[5] And even the highest performing house in asset rating, if operated in a sub-optimal manner, can use huge amounts of energy and water, contain poor quality air, and hurt the productivity and comfort of the occupants. And so to create a metric that accurately portrays how a house will perform once inhabited, it is necessary to create an occupation metric that accounts for the difference between the modeled performance and actual operational performance of the house.

In the following report, the Federation of American Scientists will analyze existing metrics and standards and identify the best available, where possible. Where there are existing high performance metrics available, FAS will suggest any necessary revisions to these and outline a standard based upon those metrics. In cases where quantitative measurement of the attribute is not possible, but qualitative codes, standards, and legislation exist, the best high performance codes and standards will be identified and, where necessary, amended. In cases where quantitative measure is not possible and no adequate code exists, this report will lay out specific steps and guidelines toward creating a useful, feasible, and justifiable qualitative performance standard. The category of quantifiable attributes will be considered include: cost effective, sustainable, safe/secure, and occupation. The category of non-quantifiable attributes will be considered to include: productive, functional/operational, accessible, and historical preservation and aesthetics.

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[5] Energy Information Administration, *Residential Energy Consumption Survey*, (2005) http://www.eia.doe.gov/emeu/recs/contents.html (accessed December 17, 2009).

## Quantifiable Attributes:

### Cost Effective

High performing houses must above all be affordable, an attribute best quantified by measuring the cost effectiveness of the house and all its components. This is necessary because without affordability and cost effectiveness measures, high performance housing will fail to penetrate the mainstream market and the affordable housing markets, creating a disparity between those who can afford a high performing house and those whose house is less safe, less healthy, less sustainable, and more expensive to operate. Moreover, through market penetration and scaling up of high performance building components, advanced technologies and materials that are currently not cost effective will likely become so in the future, thus allowing for the use of these better performing components.

In each attribute measured, improving performance must be balanced by a consideration of cost effectiveness and where a particular improvement is shown to not be cost effective, a cost effective measure must be substituted. Cost effectiveness calculations must be made by first considering the cost effectiveness of each component, then of the house as a whole. In making this determination a reasonable payback period of no more than 10 years should be input into the calculation, unless the increased cost of improvements is rolled into the mortgage or a long term, low-interest loan. When rolled into a loan, the cost effective payback period should never be longer than the term of the loan or, in the case of a mortgage, longer than the term of a typical 30-year mortgage. It should be noted that creating comprehensive cost effectiveness metrics is not a simple task because each quantifiable attribute will need a separate toolkit.

The best example of a cost effectiveness tool is the BeOpt toolkit, an open source computer program designed by the National Renewable Energy Laboratory (NREL) that calculates the most cost effective building design and energy efficiency packages that meet a given energy efficiency target (with the default being zero-net energy). At present, the energy modeling in BeOpt is imperfect and the program is unable to simulate the effects upon energy use of all building materials and technologies on the market, but BeOpt is the most accurate and comprehensive tool available. Moreover, NREL receives relatively steady federal funding for software development and updates, and so the software will continue to improve in both usability and functionality. The primary advantage of this toolkit is its ability to determine the optimal energy use and efficiency for a specific building, as well as numerous near optimal paths based on different design, technology, and materials options. For the purpose of relating energy and cost, optimal energy use is defined as the point (or points) where the maximum energy efficiency is achieved without increasing the annual cost of a house, which is calculated as the sum of the mortgage payment and utility bills (assuming that the mortgage payments follow the payback schedule for the full course of the mortgage).

To effectively determine cost effectiveness and optimal energy use, the determination must take place during the design phase, before construction commences. In doing so, materials and technology decisions can be made in the most efficient manner possible and they can be fully integrated into the whole house design. As such, FAS recommends performing the optimization calculations during the design phase of construction and optimizing energy by utilizing the BeOpt toolkit. Further, FAS recommends requiring that the BeOpt optimization recommendations be followed for a house to be considered cost efficient in terms of energy use. For the remaining components of sustainability, no toolkit comparable to BeOpt exists and the first step should be for an appropriate government agency (such as the EPA) or national lab to develop similar toolkits, which are then maintained, improved, and housed at that agency or lab. For the purposes of measuring water efficiency and materials sustainability, especially, the creation of a comparable toolkit is both necessary and possible because in both cases there exist numerous high performance components that can be packaged, substituted, and compared to optimize efficiency and meet a desired sustainability goal.

## Sustainable

Improved energy efficiency and environmental conservation are not only the first two high performance attributes mentioned in ESIS and EPAct, they are also key themes throughout both pieces of legislation. As evidenced by these Congressional acts, sustainability is essential to high performance because without this attribute the US cannot create a housing stock that has less environmental impact, is more affordable to operate, and is healthier to live in. This requires considering multiple components of sustainability, including: energy, water, materials, location, and occupancy. For each of these four categories of sustainability FAS has identified benchmark metrics by which to measure housing performance. Or, where not possible to identify a specific metric, recommendations have been made regarding the steps and tools necessary to develop a mathematically and technologically sound methodology for assessing building-level sustainability.

### Energy

In 2008 the residential housing sector consumed over 22 trillion BTUs of energy, which accounts for approximately 20% of all energy use in the US.[6] Much of this residential energy use is wasted by inefficient appliances and fixtures, leaky windows and doors, and uninsulated or underinsulated building envelopes. By increasing the energy efficiency of both new and existing homes the US has the potential to save billions of dollars on utility bills, trillions of BTUs of energy, and create a higher performing, more comfortable housing stock. However, the full potential of energy efficient new construction and retrofits cannot be realized without a standard measure by which to judge the efficiency of a building; fortunately, this standard scale already exists in the form of the Home Energy Rating System (HERS) Index, created by the Residential Energy Services Network (RESNET). On this Index the HERS Reference Home, being a house built to the *2006 International Energy Conservation Code* (IECC), is assigned a score of 100 and a net-zero energy house a score of 0. This index can be utilized to standardize the measurement of relative energy efficiency of standards, codes, and benchmarks, enabling an accurate analysis of which energy efficiency programs and measures are truly the highest performing.

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[6] Department of Energy, *Buildings Energy Data Book,* (October 2009) http://buildingsdatabook.eere.energy.gov/ (accessed December 1, 2009).

The minimum HERS rating required for a building to be certified by different high performance building programs is as follows:

- Energy Star in IECC climate zones 1-5 must rate an 85 or lower;
- Energy Star in IECC climate zones 6-8 must rate an 80 or lower;
- Energy Star Pacific Northwest in Oregon and Washington rates from 75-85;[7]
- The Department of Energy Builders Challenge must rate a 70 or lower;
- LEED must rate a 40-70 depending upon the level of certification;
- The National Association of Home Builders (NAHB) Green Standard must rate a 60-100 depending upon level of certification.

FAS recommends setting the Builders Challenge benchmark of 70 as the high performance benchmark for energy efficiency because it has been proven feasible and cost effective using affordable, easily available methods and technologies. While not the program with the most stringent energy efficiency target, meeting a score better than 70 generally requires utilizing advanced technologies that are not proven to be cost effective or that have high upfront costs—not ideal or feasible for the affordable housing market. As such, at this time, setting a benchmark at a HERS score of 70 balances the need for a high performance house to be energy efficient and cost effective. In the future, as the state of the building industry develops, it will be necessary to tighten the benchmark as lower HERS scores become cost effective and FAS recommends readjusting the benchmark to align with the Builders Challenge Program goal, which seeks to be cost effective at the net-zero energy benchmark by 2020.

## Water

As with energy efficiency, it is necessary to calculate the water efficiency of a house in terms of its relative asset rating, which includes fixtures, appliances, and leakage rates relative to similar houses. At present, the best existing model for measuring the water efficiency of a building is Version 1.0 of the National Water Savings analysis model created for the EPA WaterSense program. The EPA WaterSense program is a prescriptive water efficiency certification program with a goal of reducing interior water use by 20% over a standard house and exterior landscaping water use by 30%.[8] The model calculates water efficiency in terms of end-use water consumption (EUWH) and the number of fixtures and appliances for each end-use, adjusting the use for variables such as the age and size of the house, number of occupants, and household income. The baseline water usage is derived from the Residential

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[7] Energy Star Northwest follows a prescriptive path designed to be 15% more efficient than the Oregon State 2008 Residential Specialty Code on Energy Efficiency (Chapter 11). Early Remrate modeling of a house built exactly to the prescriptive standard (for both gas and electric) yields HERS score in the range of 75-85 range. Energy Star, Range calculated from REMRATE Reports provided by Shaun Hassel of Advanced Energy.
Northwest Energy Star, "Single Family Homes-Oregon," *Northwest Energy Star Homes Requirements,* (June 2008) http://www.northwestenergystar.com/downloads/OR_2009_BOP.pdf (accessed December 17, 2009).

[8] The outdoor water use calculation is derived from the Landscape Water Allowance calculator, which estimates water savings per square foot compared to a standard turf grass lawn in a particular climate.
Environmental Protection Agency, "Revised WaterSense Water Budget Approach," (May 8, 2009) http://www.epa.gov/watersense/docs/home_waterbudget508.pdf (accessed December 17, 2009).

End Uses of Water (REUWS) report by the American Water Works Association Research Foundation, which sets 1998 as the base year for water consumption.[9]

From this model, a metric similar to the HERS Index can be created, placing the 1998 water consumption baseline standard at 100 and a zero-water house at 0 (with 0 being defined as the point where the house has no interior water waste, reuses all interior water, uses no more water that a set maximum volume, and uses no exterior water except that which can be collected from precipitation).[10] By utilizing the same scale and end goal as the HERS Index, wherein the scale is 0-100 and lower is better, this "Residential Water Efficiency Index," is less likely to encounter barriers to understanding and adoption by those involved in the residential building industry and residential water market.

At present, for a house to be become WaterSense certified it must achieve a 20% savings, which would be equivalent to an Index score of 80. Water efficiency feasibility and cost effectiveness studies show this 20% to be a conservative goal that lies well within the normal range of cost effective improvements.[11] Water conservation recommendations from the Pacific Institute for California and the BASIX program in New South Wales, Australia set a conservation goal of a 40% reduction in overall water usage; however, this 40% goal (an Index score of 60) has yet to be proven cost effective and requires both active homeowner water conservation and large scale water collection, storage, and filtering measures. Based on this data, FAS recommends setting a benchmark of 30% water savings for both the interior and exterior—an Index score of 70. This indoor water benchmark optimizes water efficiency by being both higher performing than the existing WaterSense benchmark and technologically feasible with existing, inexpensive, water conservation and water loss prevention measures.[12] In addition, the 30% exterior water savings goal must take into account the differing climates and precipitation throughout the country as well as the differing watering needs of turfgrass lawns in these different climates.

For multiunit residential housing, measuring water consumption and creating a usable metric requires taking indoor water use measurements on a per unit basis by metering each unit, rather than measuring the residential building or complex as a whole. Additionally, acquiring useful measurements requires a

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[9] Michael McNeil et. al., *WaterSenseProgram: Methodology for National Water Savings Analysis Model Indoor Residential Water Use*, (Berkeley: Lawrence Berkeley National Lab, 2008) http://escholarship.org/uc/item/1qw7n2nh (accessed December 17, 2009).

[10] While the HERS scale measures net energy efficiency, which is calculated in terms of the annual net energy flow, the Residential Water Efficiency Index would measure exterior water efficiency and use and interior water efficiency. Note that as water cannot be sent from the home directly to the community water supply as this water (even if treated) is considered graywater and not fit for human consumption, there can be no measurable net water flow. As such, in most climates achieving a 0 rating is not technologically feasible as at a minimum, water for human consumption would need to be brought in.

[11] For example: The Pacific Institute, *Waste Not, Want Not: The Potential for Urban Water Conservation in California,* (2003) http://www.pacinst.org/reports/urban_usage/index.htm (accessed December 1, 2009).

[12] Simply following all of the prescriptive measures in the WaterSense program and the basic water conservation and technology adoption measures recommended by the Pacific Institute will yield a water savings of at least 30%, a figure that the Pacific Institute's estimates to be cost effective, being less expensive on both an individual and societal level that acquiring new sources of water or developing advanced water remediation technologies over the next 20 years.

form of water “smart metering” to determine how each unit uses water. Without this knowledge there is no mechanism for acquiring reliable data on how residents use water, benchmarking water usage, or incentivizing water efficiency and water efficiency upgrades.

### Materials and Resources

The third quantifiable element of the sustainability attribute is materials and resources. Key considerations of materials sustainability are minimizing building waste, increasing the amount of recyclable or easily renewable materials used, and reducing the volume of building materials used—especially in the case of materials with a high embodied energy or high content of unhealthy or environmentally damaging chemicals or materials. Embodied energy consists of all the energy inherent in a raw input, expended in acquiring the raw inputs, and expended in processing those inputs into a finished product. As such, it is frequently used as a parallel measure of the carbon emitted in creating a product, which is a highly useful calculation, assuming the larger sustainability goal is to quantify carbon output for the purpose of reducing that output. However, the embodied energy calculation stops when the finished product leaves the manufacturing plant and does not consider the energy expended in transportation and disposal or the life expectancy of that product. To understand the full energy, and therefore carbon, cost of a material one must perform a lifecycle analysis to account for all energy use from acquiring the raw material until its disposal or reuse at the end of its useful life. And when the lifecycle analysis of each of a building’s materials is multiplied by the volume of that material and then aggregated with the total of every other material’s lifecycle energy cost, the result is a building’s total lifecycle energy cost. This sum allows that building to be compared with other similar buildings through a quantifiable and standardized means.

Currently there are numerous tools available to determine the embodied energy of each of dozens of building materials, such as concrete, metals, and biological materials from different sources (i.e. lumber, oriented strand board, and straw); when multiplied by the volume of material used, these tools yield data on the embodied energy of the material as it left the source site or manufacturing plant. However, these tools lack the capability to measure the factors necessary to create a full lifecycle analysis.

As such, a web-based tool is needed that analyzes energy costs of building materials over the full life of the material. Additionally, users should be able to easily manipulate variables such as location of the construction site and building methods used (to determine waste) so that a full lifecycle energy analysis can be carried out and actual energy use determined. At the individual building level, this functionality will allow users to compare the relative sustainability of different materials and make more sustainable and energy efficient materials decisions. On a broader scale, this tool will allow for comparisons between different houses by means of a relative embodied energy metric and corresponding benchmark. The metric will require complex modeling to determine the lifecycle energy use of building materials not only separately, but in combination with other materials and in different conditions. FAS recommends that this online tool be developed immediately and that it be housed, maintained, and operated by DOE or one of the national labs as an open-source software application that is accessible to those in the building community and to consumers seeking to make informed decisions.

## Location

The final aspect of the sustainability attribute is location efficiency. At present the vast majority of houses built in the US require residents to drive a car to access essential services and goods, to commute to work, and to seek entertainment. This statement is given credence by the fact that in the first six months of 2008 less than 10% of the US population took some form of public transportation on any given day, despite the cost of regular unleaded gasoline being on average $3.41, the highest average gasoline price (in both real and nominal terms) in over 30 years.[13] Locational high performance consists of building the house on a site with easy access to reliable public transportation and with access to essential services by walking or biking in designated spaces (such as sidewalks and designated bike lanes). Location efficiency has the potential to dramatically decrease the miles driven by residents, thereby decreasing energy use and carbon output, reduce traffic during peak periods, and save the residents money.

The Center for Neighborhood Technology has created one method for calculating location efficiency, referred to as the Housing and Transportation Affordability Index (H+T Index). This index calculates transportation as a product of auto ownership, auto use, and public transit, and household income and size.[14] The inputs are derived census data, the 2001 National Household Travel Survey (NHTS), and the 1995 Transit Connectivity Index. For the purpose of the Affordability Index, the transportation cost is then added to the housing cost, and together the two define the relative affordability of a neighborhood or site for a particular family at their specific income level. For the purpose of using these data to calculate location efficiency, houses would only meet the location efficiency benchmark at a point where the transportation costs account for no more than 15% of the median income for that particular census block. The benefits to defining location efficiency through the formula in this Index are that it relies on publically available data, the data easily interface with interactive maps, and the data and corresponding maps already exist for 55 metropolitan areas and are projected to be expanded in 2010 to 337 metropolitan areas that collectively account for 80% of the US population. The disadvantage to this method lies in that because the emphasis of the Index is the monetary cost of transportation to the resident, public transportation costs are factored into total transportation costs in the same way that expenditures on cars would be considered. To be truly useful in measuring location efficiency as an

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[13] For the first six months of 2008, daily ridership averaged 30.3 million people for all forms of public transportation, including rail, bus, van, and ferryboat. The U.S. population during this period is estimated to have been over 304 million.
Department of Transportation, Bureau of Transportation Statistics, *Transportation Statistics Annual Report,* (Washington, DC: 2008) 107.
Census Bureau, "Population Finder: United States," http://factfinder.census.gov/servlet/SAFFPopulation?_submenuId=population_0&_sse=on (accessed December 17, 2009).
Energy Information Administration, "Retail Gasoline Historical Prices," http://www.eia.doe.gov/oil_gas/petroleum/data_publications/wrgp/mogas_history.html (accessed December 17, 2009).

[14] Center for Transit Oriented Development and Center for Neighborhood Technology, "The Affordability Index: A New Tool for Measuring the True Affordability of a Housing Choice," *Market Innovation Brief,* (Washington, DC: The Brookings Institution, January 2006) http://www.cnt.org/repository/AffordabilityIndexBrief.pdf (accessed December 17, 2009).

attribute of sustainability, the method of inserting public transportation costs into the equation would need to be reconsidered. In addition, factors such as walkability, bikeability, and proximity to essential services and jobs must necessarily be inserted into the calculation to create a picture of location efficiency that accurately portrays not just the monetary costs of a particular location, but environmental costs as well.

An alternative to this method of calculating location efficiency is the location efficient value, a factor currently used in calculating Location Efficient Mortgages.[15] The Location Efficient Value (LEV), a factor of the Location Efficient Mortgage calculation, is the best method by which to define and determine location efficiency. The Location Efficient Mortgage is calculated as:

[(Principal + Interest + Taxes + Insurance) - LEV]/Income.

In this equation the LEV is a function of neighborhood (referred to as the zone) and transport choice. To derive the LEV function, the calculation takes into account the expected annual travel demand per household and the expected automobile ownership of households in the immediate vicinity of the proposed purchase;[16] when the appropriate mortgage information and prospective buyer's income and family size are inserted into the formula, the equation yields the total additional amount of money beyond the main mortgage that a home buyer can borrow based on the house's location efficiency. The primary disadvantage to this method is that the largest input is odometer miles, which must be self-reported and cannot be obtained from public records or census data as with the H+T Index. As such, obtaining the LEV for each metropolitan area and the zones within that area requires interviewing thousands of homeowners, which is time consuming and somewhat expensive. Because of this, expanding the LEV database to additional metropolitan areas beyond the four where it is currently applied (Seattle Chicago, San Francisco, and Los Angeles) is likely to take longer and cost more than expanding the H+T Index. However, this method is the most accurate way to determine location efficiency on the scale necessary to make an accurate location efficiency determination.

To provide an example of how the LEV factors into the location efficient mortgage, the median household income in the US in 2007 was $50,233. For a family of 4 with a median income looking to purchase a house in downtown Seattle, WA, the LEV ranges from $93 to $447, assuming an interest rate of 6.778%, good credit, and a down payment of at least 3%.[17] This equates to an additional borrowing power of from $39,097 to $52,401, depending upon location (with the lowest LEV being in zone 279 and highest in zone 325). All of the Seattle area is a positive number, which is a result of the city's better public transportation availability, fewer cars per household, higher density, and shorter commute distances than is average in America. However, in many suburban and rural areas and in some cities,

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[15] Center for Neighborhood Technology, "About," *H+T Affordability Index*, http://htaindex.cnt.org/about.php (accessed December 17, 2009).

[16] Expected automobile ownership and annual travel demand are themselves derived from several key variables, including small area's net residential density, frequency and type of transit service and its connectivity, household size, household income, and distance to employment.
Center for Neighborhood Technology, "Testimony of Scott Bernstein," (June 11, 2009) http://www.cnt.org/repository/bernstein061109.pdf (accessed December 17, 2009).

[17] Institute for Location Efficiency, "Location Efficient Mortgage," http://www.locationefficiency.com (accessed December 17, 2009).

the LEV would be a negative number, thus disqualifying a borrower from obtaining a Location Efficient Mortgage.

FAS recommends that the minimum high performance baseline benchmark be set at the point where the LEV equals zero. This benchmark is recommended because at this point where the LEV becomes positive and the borrower qualifies for a Location Efficient Mortgage, the house's location is predicted to yield sufficiency lower annual travel demand and automobile ownership costs to offset the additional mortgage expenditure. Above this minimum standard of qualifying, a relatively higher LEV indicates better transportation and connectivity and fewer miles driven. This metric is highly useful as it creates a standardized value (the LEV) by which relative efficiencies can be measured and compared not only within a single city, but nationwide.

## Safe/secure

While safety and security can be defined differently by every person and are in many ways subjective, certain aspects of the building safety and security attribute are quantifiable and can be definitively measured and benchmarked. In a residential building, the safety of the occupant is primarily a consideration of life safety and health, with healthiness being primarily a measure of indoor air quality and life safety being a measure of the building's structural soundness, suitability for a particular region, and features that inhibit damage from hazards and enable easy access to and exit from the building.

### Indoor Air Quality

At present, the baseline standard for indoor air quality is defined by ASTM E2267-2004 "Standard Guide for Specifying and Evaluating Performance of Single Family Attached and Detached Dwellings-Indoor Air Quality". More recently, *ANSI/ASHRAE Standard 62.2 2007* "Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings" sets higher performance standards for ventilation, building envelope, and moisture control than those defined in ASTM E2267. As the highest performing air quality code to date, *ASHRAE 62.2*, which is both a prescriptive and performance based standard, should be followed in all residential construction. This standard focuses on whole house ventilation, local exhaust, and especially source control to maintain healthy air quality. All ventilation and exhaust calculations, materials and appliance performance requirements, and moisture control calculations and standards in *ASHRAE 62.2* should be met by all residential buildings. In addition, all residential buildings should comply with the moisture control requirements of the 2009 International Energy Conservation Code. And while *ASHRAE 62.2* is the highest performing standard at present, neither this nor any other standard specifies interior pollutant limits. However, in order to ensure high indoor air quality, it is necessary consider specific pollutant limits when creating standards and their underlying metrics.

Therefore, FAS recommends setting specific pollutant limits and creating a set of performance based metrics based on those pollutant limits. Pollutant limits for most leading airborne pollutants are currently expressed in the National Ambient Air Quality Standards. This set of standards, which specifies the maximum pollutant levels at which human health is not adversely impacted, was created by the Environmental Protection Agency (EPA) in compliance with the Clean Air Act. To date, standards have been set for:  carbon dioxide ($CO_2$), particulates (coarse and fine), ozone ($O_3$), lead (Pb), carbon monoxide (CO), nitrogen dioxide ($NO_2$), sulfur dioxide ($SO_2$), and radon (Rn).

During the design phase of the house, modeling assessments of interior pollutant levels should be carried out that include all interior components of a proposed design (including interior finishes such as flooring, paint, and cabinetry).  Parameters for the modeled test should be that the house, when sealed to be airtight for 24 hours and mechanically ventilated at both optimal and suboptimal levels (including no mechanical ventilation), no pollutant should rise above the benchmark level.  In addition, the modeling should be carried out to show that when operated at both optimal and normal performance (including source pollutants) no pollutant would rise above the baseline level over a period of one year.

The software necessary to model indoor air quality has already been developed by the Environmental Protection Agency (EPA) and this software, Simulation Tool Kit for Indoor Air Quality and Inhalation Exposure  (IAQX Version 1.0) should be utilized in modeling indoor air quality.  However, in order for the software to reflect the high performance indoor air quality metrics recommended by this report, the software would need to be adapted to reflect the latest research in indoor air quality.  In addition, the software would need to have the added capacity of outputting a single number that reflects the modeled indoor air quality of that house as compared to a benchmark number and other, similarly-sized houses (similarly to how REMRATE software outputs a HERS Index score).  This software should be maintained and updated by the EPA.[18]

Based on National Ambient Air Quality Standards recommendations, the benchmarks are set as follows:

- $CO_2$:  1000 parts per million (ppm);
- particulates (<2.5 micrograms):  15 micrograms/$m^3$;
- particulates (<10 micrograms):  150 micrograms/$m^3$ (24 hr);
- $O_3$:  0.074 ppm;
- Pb:  0.15 micrograms/$m^3$;
- CO:  9 ppm;
- $NO_2$:  0.053 ppm;
- $SO_2$:  0.03 ppm;

In addition to these pollutants, limits must also be set and corresponding metrics created for radon and formaldehyde, as both of these are proven human health hazards.

- Radon: less than 4 pCi/L.[19]  Where radon-resistant construction is required by the local municipality or where a house has been designated as at a moderate to high radon risk either by local data or designation as Zone 1 in Figure AF101, *2009 IRC,* Appendix F Radon Control Methods should be followed.
- Formaldehyde: 0.01 ppm.[20]

[18] Environmental Protection Agency, "Indoor Air Quality Modeling," (January 10, 2007) http://www.epa.gov/appcdwww/iemb/model.htm (accessed December 17, 2009).
[19] Environmental Protection Agency, "Radon," http://www.epa.gov/radon/ (accessed December 17, 2009).
[20] "Formaldehyde: IDLH Documentation," (August 16, 1996) http://www.cdc.gov/niosh/idlh/50000.html (accessed December 17, 2009).

To be considered high performing in indoor air quality, modeling and subsequent quality control assessments would need to find each pollutant at a concentration equal to or lower than the minimum baseline.  In addition, the house would need to meet the indoor air quality criteria for moisture control and ventilation as described above.  Altogether, the pollutant, moisture, and ventilation modeling could be used to create an indoor air quality index similar to the HERS Index, with the baseline equivalent to a 100.  This calculation would be a complex formula derived not simply from adding up pollutants; despite its complexity, it is necessary to have a standard measure of indoor air quality.  Both the software adaptations, and the specific numerical inputs and calculations for an indoor air quality index should be undertaken by DOE and EPA, with the input of a working group of experts.

### Other Health: Daylighting and Ultraviolet Rays

Related to indoor air quality and healthiness is the necessity of limiting residents' exposure to damaging, potentially carcinogenic ultraviolet (UV) rays.  As such, to be considered high performing all fenestration products that are part of the conditioned building envelope should block at least 98% of solar rays in at least the UVA and UVB spectra (as calculated by NFRC 200).

Research has also shown that people tend to be the most productive and function best (especially at written tasks) with an adequate amount of natural light.  Defining adequate natural lighting as daylighting between 500 and 2,500 lux,[21] a high performance residential building should provide natural lighting within this range for all rooms within the house intended to be used primarily for working-related or fine motor tasks such as:  operating a computer, reading, writing, paperwork (including homework), and working with tools.  Types of rooms that should be designed to have proper daylighting include: studies or dens, kitchens, and living, family or great rooms. Bedrooms, bathrooms, and stand-alone, single-purpose dining rooms would not need to meet this standard; however, where one or more walls of any of  room is more than 50% open to a room where the daylighting standard applies, that room should also meet the daylighting standard.  In addition, all fenestration products that are part of the conditioned space should have Solar Heat Gain Coefficient of less than 0.40, as determined by the National Fenestration Rating Council via their NFRC 200 procedure, and a U-factor of no more than 0.50 (the maximum allowable under the *2009 IECC*).

### Life Safety/Structural Integrity

The structural integrity and life safety requirements for residential buildings differ greatly depending upon building material, type of housing, and location within the country.  To date, a number of high performing codes have been developed that address safe building practices and these codes, when followed, produce generally structurally sound buildings that are adapted to the differing structural needs of different regions.  The most comprehensive codes currently available are the international codes (or I-codes) written by the ICC.  These prescriptive standards and codes integrate the latest knowledge on issues of structural safety, building safety, and engineering and FAS recommends using a

[21] John Mardaljevic, *Climate-Based Daylight Analysis for Residential Buildings:  Impact of various window configurations, external obstructions, orientations and location on useful daylight illuminance*, (Leicester, UK: Institute of Sustainable Energy and Development) http://www.thedaylightsite.com/filebank/Climate-Based%20Daylight%20Analysis%20for%20Residential%20Buildings.pdf (accessed December 17, 2009).

house built to the latest adopted I-codes (specified below) as the minimum high performing benchmark, except where otherwise noted. As the I-codes are prescriptive rather than performance based, wherever stated the appropriate American Society of Civil Engineers (ASCE) calculations from *SEI/ASCE 7-05* "Minimum Design Loads for Buildings and Other Structures" should be used to determine the necessary minimum structural design and load requirements for a building.

This report recognizes that not all structural integrity standards apply universally throughout the country and that for these cases specific regional or local strength and loading calculations will need to be made. The recommended high performing building code for each category of structural integrity/life safety category is as follows:

**General structural integrity:** The *2009 International Residential Code (2009 IRC)*. Calculations for loading design should be based off of the *ASCE 7-05* "Minimum Design Loads" Chapters 1-4. The *2009 IRC* should also be referenced for safety features including means of egress and escape, guards, and alarms and sprinkler systems.

**Fire:** The *2009 International Fire Code (2009 IRC)*.

**Snow:** Houses located in areas with a ground snow load of greater than 5 lbs/$ft^2$ and less than 20 lbs/$ft^2$ as determined by figure R301.2(5) of the *2009 IRC* should be built in accordance with Chapters 5, 6, and 8 of the *2009 IRC* . Snow loading requirements for houses located in regions with a ground snow load of 20 or greater lbs/$ft^2$ or where the local code specifies that calculations must be performed should be designed using the *ASCE 7-05* "Minimum Design Loads" Chapter 7. For houses located where the ground snow load is 70 lbs/$ft^2$ or greater the load should be calculated using *ASCE 7-05* "Minimum Design Loads" Chapter 7 and the house design must be signed off on by a certified engineer or designed in accordance with accepted engineering practice. Houses with a ground snow load of less than 5 lbs/$ft^2$ do not need to account for snow loading in structural design.

**Wind:** Houses should meet the minimum load for the Wind Zone in which the house is located, to be determined by using the Wind Zone Map found in Figure E301.2(4) of the *2009 IRC*. All houses in an area designated Special Wind Region, Hurricane Susceptible Region, with a basic wind speed 50-year mean recurrence interval of 90mph or greater, where *2009 IRC* Table 301.2.5.1 indicates a modified wind speed of 90mph, or where local jurisdiction requires must be designed using the *ASCE 7-05*, "Minimum Design" Chapter 6 loading calculations and constructed to withstand at least the minimum calculated wind loads. All other houses should meet the minimum loads described either in Table R301.2(2) or *ASCE 7*.

**Flood:** Table R301.2(1) of *2009 IRC* should be used to determine whether residential buildings are in a flood hazard zone. If a house is located within flood hazard zones A, V, or D, then the flood loading standards, as calculated by *ASCE 7* "Minimum Design Loads" Chapter 5 should be met. Performing flood load calculations and building residential structures to R301.2.4 Floodplain construction (a 2009 IRC prescriptive standard) is recommended, but not required, for houses located in zones B, C, and X.

**Seismic:** Buildings located in Seismic Design Zone A as defined by the *2009 National Seismic Hazards Maps* from the US Geological Survey and the *IRC 2009* Figure R301.2(2) should meet all general structural provisions, but do not need to meet any special seismic loading provisions. Zone A buildings are those with .17g or less, with g being the acceleration of a falling object due to gravity. Buildings located in moderate Seismic Design Zones B and C, being those buildings with between .17 and .50g, should meet the minimum seismic loading provisions of *2009 IRC* as defined in R201.1.1.1 Seismic Design Category C. For high seismic hazard Design Zones D through E, being those with .50g or greater and including Zones $D_0$, $D_1$, $D_2$, and E, structures should be designed to meet at minimum the seismic loads as calculated in *ASCE 7* Chapters 12 and 13.

## Occupation

The goal of high performance occupation should be for the house to operate at or beyond its asset rating. Occupation particularly affects water and energy efficiency, materials durability, indoor air quality, daylighting, and solar infiltration—optimal occupation can ensure that the house performs to its highest capability in each of these categories. And while the occupation attribute cannot be built into the house and measured at the time of the house's completion, educating occupants and providing them with a homeowners guide and information on how to optimize a house's high performance attributes are the best means of ensuring that the house performs to its full potential. Homeowner education should include: how properly to use and operate the sustainable features of the house, how to limit energy and water use, how to maintain high indoor air quality and thermal comfort, and best practices for maintaining the house—especially emphasizing the durability of components and materials in the house.

In addition, the homeowners guide that accompanies each house and is tailored to that house should include diagrams, pictures, and easy to understand text to aid occupants in maximizing that house's performance. Topics covered should include: optimal operating of all technology and appliances; best practices for necessary and recommended maintenance; cleaning and maintaining the interior to retain healthy indoor air quality and limit toxic pollutants; the location of various features in the house such as studs, electrical wires and circuits, plumbing pipes and mains, and blocking; and additional outside resources the occupant may need (such as information on how to contact the local recycling and hazardous waste disposal provider, sign up for the renewable electricity package from the local utility, and access the online Home Energy Saver tool from Lawrence Berkeley National Lab).

Each local education program, whether run by a real estate company, builder/developer, or municipal or state government, should be nationally certified and based on a nationally approved homeowner education program. At present the *NAHB/ICC Green Building Standard* requires that a Green Building receive a minimum number of points for "Operation, Maintenance, and Building Owner Education" (from a minimum of 8 points for bronze-level to 12 points for emerald-level certification). To meet the "Operation, Maintenance, and Building Owner Education" minimum a house must come with a homeowners manual, which lists green features and contains product manufacturers' manuals or datasheets. In addition, the house must have a building construction manual that contains a narrative on the importance of green building, lists the green attributes of that building, and contains warranty, operation, and maintenance instructions for all equipment, fixtures, appliance, and finishes in the house. This standard has the most comprehensive operations and maintenance manual requirements of any standard and should be emulated when creating the national homeowners guide.

Earthcraft Homes, a regional sustainable building program, requires that the builder, utility, or 3rd party certify utility bills against a baseline for at least 2 years; give the homeowner a manual that summarizes energy systems operations and irrigation operations; provide recycling bins for newspapers, magazines, and at least one other material; provide information on local recycling and hazardous waste disposal; and provide the homeowner with a checklist of environmental features included in their house.[22] And many local, state, and regional programs, such as the Built Green program in Washington State require simple homeowner education measures such as providing the homeowner with an operations and maintenance guide.

In addition to the homeowners manual topics listed above, the manual required for high performance occupation certification should include all of the features required in the Earthcraft manual as well as comprehensive operations and maintenance information such as that required by the *Green Building Standard*.

It should be a priority of the federal government, particularly the Department of Energy, with assistance from a national lab and the National Institute for Standards and Technology (NIST), to create a high performance housing homeowner education program. Within the scope of this work, the federal government should be responsible for outlining necessary and recommended content for homeowner education, creating checklists and explanations or descriptions of all material that must be covered, writing and disseminating supporting materials and references, developing a template homeowner/occupant manual and making it available to users in a digital format so that it can be easily altered for each specific projects, and marketing and providing marketing tools for the program. In addition to this brief homeowner education program, the federal government should also create a supporting day-long training program for the personnel who will be educating homeowners. The training should be available both in person and in an interactive virtual world and web-based environment so that real estate agents, builders, developers, and municipal or state building officials throughout the country can be trained in how to educate consumers and new homebuyers about optimal occupation and the benefits of high performing housing.

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[22] EarthCraft House, "Building an EarthCraft House and Low-rise Multifamily Technical Guidelines," 49-50, http://www.earthcrafthouse.org/documents/ech_tech-guidelines-complete.pdf (accessed December 17, 2009).

## Non-Quantifiable Attributes:

The productive, functional/operational, accessible, historic preservation, and aesthetics attributes cannot be quantified so no mathematical metric can be derived to measure high performance. However, qualitative measures of these attributes and the factors that contribute to these attributes can be, and in some cases have been, developed. For each of these attributes FAS offers recommendations on the factors that should be considered in analyzing performance and identifies next steps for developing a related standard to measure high performance.

### Productive

Productivity is not generally considered to be a key attribute of a residential building except in cases where the house is also used for commercial or business purposes. However, the house does play an essential role in the connectivity and workplace productivity of residents. To be considered high performing, FAS recommends that a house have broadband internet with wireless support so as to enable the residents to have full connectivity and the ability to use web-based tools for training, work, education, and other applications and to promote telecommuting. Additionally, as a great deal of time is generally spent in the home, residential buildings play a key role in the healthiness of occupants and their ability to work consistently and productively, without medical absences. As such, productivity should be measured by calculating a house's health and occupant safety, which can be achieved by requiring houses to meet the high performance standards for natural lighting, indoor air quality, and life safety previously discussed in the safety/security section.

### Functional/operational

As an attribute of high performance, functionality is difficult to define as each occupant has different uses for a space and a different perception of what a functional house should be. As such, FAS recommends that high performance functionality be defined as adaptability, wherein the building can be easily and inexpensively transformed throughout its useful life. In this way a house can meet the changing needs of the occupants throughout their lives without requiring either moving or expensive remodels; for example, installing blocking by the shower and behind the toilet will allow grab bars to be installed at a later point and selecting kitchen counters with adjustable height will allow the occupants to easily alter the surface based on the working height of each user. The basic guidelines for adaptability are covered in the ANSI A117.1 Standard for Accessible and Usable Buildings and Facilities; FAS recommends that the high performance standard for accessibility be based on this ANSI standard, which is further discussed in the Accessible attribute below.

### Accessible

Beginning with the *Americans with Disabilities Act of 1990*, extensive legislation has been created regulating and setting standards for accessibility and adaptability for commercial and public buildings. The most up-to-date of this legislation is based on the *2003 ICC/ANSI A117.1 Standard for Accessible and Usable Buildings and Facilities*, which is the most comprehensive accessibility standard available. As the majority of this standard applies to public and commercial rather than residential buildings, some standard provisions need not be followed and may actually limit the utility of the house for the residence for the majority of users.

To be considered high performing, residential buildings should adhere to some key components of *ICC/ANSI A117.1* so that the house can continue to be useful and accessible to occupants throughout their lives and situations with only minor retrofits. To this end, FAS recommends that to be considered high performing in the attribute of accessibility, the house meet the following standards.

From Chapter 3: All of the Building Blocks standards should be met to enable grab bars to be easily and inexpensively installed at a later point in the house's occupation.

From Chapter 4: Accessible Routes—the house should meet the General, Accessible Routes, Walking Surfaces, Doors and Doorways, and Private Residential Elevators standards. In addition, excepting cases where the house and at least one main entrance are at ground level and require no stairs to access, the house should have space next to at least one exterior doorway to fit a ramp that complies with the Section 405 Ramps section. For multi-unit, multistory residential buildings, the building should also meet the Curb Ramps, Elevators, and Limited-Use/Limited-Application Elevators standards.

From Chapter 5: General Site and Building Elements—single family homes should meet the Handrails, Windows, and Stairways standards, where relevant. For multi-unit residential buildings, the Parking Spaces and Passenger Loading Zones standards should also be met in addition to meeting the standards required for single family homes.

From Chapter 6: Plumbing Elements and Facilities—single family houses should meet the Shower Compartments standard on size, fixtures, and door width; in addition, there should be adequate space and structural support for a grab bar as specified in the Section 609 Grab Bar section. For multi-unit residential buildings, where the element or facility is in a public area of the building not owned or rented by an individual occupant, the residence should meet the Washing Machines and Clothes Dryers, Drinking Fountains, Toilet and Bathing Rooms, Water Closets and Toilet Compartments, Urinals, and Lavatories and Sinks standards.

From Chapter 9: Built-In Furnishings and Equipment—where applicable due to built-in furnishings and equipment having been designed and built into the house, the General, Dining Surfaces and Work Surfaces, and Benches built-in standards should be followed.

And for multi-unit residential housing, all units should conform to the "Type B" dwelling unit specifications as required in the *2009 International Building Code (IBC)* and at least 20% of all units (with a minimum of one unit) should conform to the "Type A" dwelling unit specifications.

## Historical Preservation and Aesthetics

Both historical preservation and aesthetics are entirely subjective attributes for which no quantifiable metric can be created and for which there is no high performing code or standard on which to model high performance residential housing benchmarks and goals. In addition, meeting the goals of historic preservation often requires a trade-off between historic preservation and meeting energy efficiency and other sustainability attributes. For example, in many historic neighborhoods wood-framed windows are the preferred option to retain the architectural cohesion and integrity of the neighborhood; however, wood framed windows tend to have lower R-values than the current generation of fiberglass windows. As such, in developing this metric its impact upon other high performance attributes must be carefully considered and weighed.

Because of the subjectivity and lack of precedent, FAS recommends that NIBS or a related federal body immediately convene and adequately fund a joint working group to consider both attributes and to begin creating high performance guidelines and standards that address these attributes. While specific historical preservation and aesthetic decisions for a building must be made at a local level, the goal of these standards should be to guide local jurisdictions in creating standards that best serve the needs of their local stakeholder community.

The working group should be highly inclusive and follow the ANSI procedures for decision making to the greatest extent possible. However, for the guidelines and standards created by the group to achieve large scale buy-in it is essential that the working group to be driven, directed, and controlled by key technical experts and stakeholders with either a high degree of influence or a substantial, interested membership. Necessary participants in and drivers of the working group include: the Historic Preservation Society (HPS), the American Institute of Architects (AIA), the Advisory Council on Historic Preservation (ACHP), and the National Park Service (NPS). As standards for these attributes will be adapted and developed at the local level, that local perspective must be included in the national standard development process and so it is additionally recommended that a small number of city-level historical preservation officials be invited to participate in the working group.

## Graphic Representation of High Performance Metrics

Once the metrics have been developed the federal government must create a nationally recognized graphic representation or “label” of high performance building that fulfills the following functions: exhibits the performance of the house as a whole system, the performance of the house in its individual attributes, can be used to compare between the performance of different houses in a standardized and objective manner, and which definitely defines and benchmarks what a high performance is and is not.

This label must be user friendly and simple to understand, it must differentiate between the quantitative and qualitative attributes of the house, and it must be based on widely accepted metrics and standards wherever possible. In addition, the label must include a “high performance home” certification similar to Energy Star certification, where achieving the certification indicates that the house or product has been independently verified to have met all the government-approved high performance benchmarks. Attributes included in the main graphic should be: energy, water, materials, location, functional/accessible, indoor air quality, and safety.

Occupation, while a quantitative attribute, should not be included in the label as education is a primary component of the occupation asset and that education (especially house or site-specific education) is unlikely to occur until the point of sale, which occurs after the label is most useful to a homebuyer.

The federal government should require that all new houses be independently tested and verified for performance and then labeled, though only those meeting the high performance benchmarks would receive the high performance certification. Labeling all houses allows buyers to compare the relative attributes of different houses and, even when not purchasing a high performance certified house, the buyer would be able to select a house that performs well in specific attributes that meet their needs or wants (for example, meeting the need to limit monthly operating costs through high energy and water efficiency).

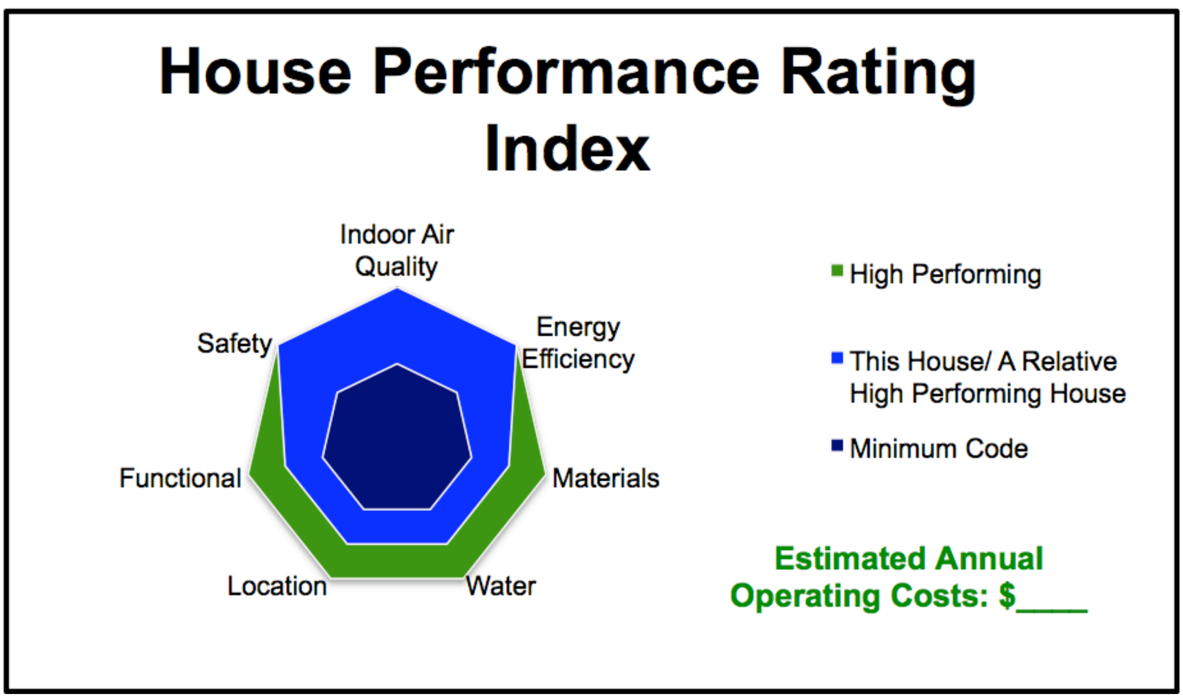
The primary audiences for the label are: consumers and homebuyers, real estate agents, and builders and developers.

Implementing a national building labeling scheme based on these high performance metrics and attributes will improve consumer awareness of high performance building and how it benefits the consumer, the nation, and the environment. Recognizing this, the goal of this improved awareness and understanding is to yield a response similar to that of the Energy Star label, where the label has not just improved consumer awareness of energy efficient products, but actually created and grown markets for certified products.

For real estate agents, the label will increase the visibility of building performance issues and educate agents about the high performance attributes and their benefits to occupants. The label, by providing a simple, standard method of comparing houses, will also aid real estate agents in marketing house performance by providing an objective tool for comparison. Moreover, as consumer and agent awareness of high performance issues grows via the label, the emerging market will provide the opportunity for agents or agencies to specialize in selling high performance houses.

The creation of national high performance metrics and an accompanying label will allow builders and developers to design, build, verify, and then certify high performance housing that is recognized as such. A national measurement standard certification program will aid builders and developers by helping them to improve their own building practices and choices by offering them guidance, stability, and resources. And by improving consumer awareness of why high performance building is beneficial and why the higher upfront price tag is cost effective over the long term, the label will likely grow the market for high performance housing, which will in turn decrease the cost of and increase the availability high performing products.

The label prototype below demonstrates the attributes that ought to be included on the label. In addition, the prototype shows the necessity of including a graphic representation not only of that particular house's performance, but of the high performance benchmark and the minimum code, which will allow users to easily compare each house in relation to the minimum code and benchmark as well as to other houses. The label should also include an estimated annual operating cost of the house based on the house's asset rating (including water, energy, transportation, materials maintenance or replacement, and indoor air quality technology maintenance). This operating cost estimate, while not accounting for individual occupant use variance, will allow the consumer to see how a high performance house is cost effective by reducing operations costs.



## Recommendations for Immediate Action

For widely accepted and quantitatively valid metrics for high performing affordable housing to be developed and adopted, the discussion on metric creation must be opened up to key stakeholders. DOE, NIBS, or a relevant federal department should immediately begin multi-party stakeholder discussions on metrics, using the metrics in this report as a starting point. These discussion round-tables must include appropriate government representatives, private code making organizations, subject matter experts, and representatives of major building and labor associations.

Based on the discussions and the input of a working group, where necessary, the federal lead should further develop the definition of each attribute; begin designing a methodology to analyze every quantifiable attribute for which a rigorous and useful metric does not yet exist; and fund the development of open source software tools to easily and comprehensibly analyze materials life-cycle costs and water use. The capability of the software to perform cost-benefit analysis, optimize financial, energy, and carbon savings, provide near optimal alternatives, and analyze the water or materials as a holistic system is essential. In addition to or as part of these analytical tools, the federal government must develop and back publicly available and open source software that produces an index rating for these attributes so as to enable a house's performance to be compared to other houses and to a model baseline.

The process of creating good, quantifiable metrics and tools must recognize that that the ultimate goal of this process is to create a nationally recognized set of codes and standards to define and promote high performance, affordable housing. Upon completion of the metrics, the federal lead should partner with the ICC, ASHRAE, NAHB, the Department of Housing and Urban Development (HUD), and key stakeholders to create model high performance guides and standards based on the metrics; in doing so, the resulting guides and standards will have a wide base of support for improving the safety and performance of affordable housing.

These codes should, in turn, be used to create a mandatory national high performance residential building labeling scheme that will allow all buildings to be quantitatively assessed relative to both a benchmark and similar buildings. Through this system, policymakers, building professionals, and the public would be able to better understand the true performance of our new housing stock, using its performance as a baseline for future improvements. Moreover, mandatory labeling would increase public awareness and understanding of high performance building and likely lead to a demand-driven market growth for houses with high performing attributes or high performance certification. However, the creation of codes, standards, and high performance labels and certifications is dependent upon first creating quantitative metrics by which to assess and analyze performance. Developing metrics must be the first step in the process improving the availability of high quality, affordable housing in the United States; the government, with industry stakeholders, must immediately undertake this first step.

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