

Size Matters (a Lot):

The Mistreatment of House Size in Green Home Rating Systems

This paper is a response to the LEED for Homes Pilot program and the article “Small is Beautiful: U.S. House Size, Resource Use, and the Environment” by Alex Wilson and Jessica Boehland ©2005 MIT and Yale University. There are unresolved issues and questions regarding house size in relation to the construction of green homes and the certification systems that attempt to quantify the environmental features of those homes. Although there are other considerations regarding green ratings, such as site considerations, health and indoor air quality, durability, and occupant education, this position paper will focus on the importance of house size considerations and the omission of occupant load ratios, design efficiency, and their connection to resource use within green home ratings. A corrective house size formula, created by the author in collaboration with Vermont Builds Greener (VBG) is offered as one solution to the problem of score weighting for size.

Introduction

The most obvious consumer expectation that would accompany a green home rating system is that the final score of the building is relative to the impact of that home on the environment. It is naturally assumed that homes that score higher are those homes that do the least damage. There is an implication that, using the scores, green home design decisions can be compared side by side clearly showing which choices are environmentally preferable. It turns out that these expectations are largely unfounded because a major determinant in green home rating is being ignored, misrepresented, or underrated: the size of the home.

Overall, size is one of the most significant contributing factors to the resource efficiency, and therefore the environmental impact of a home. Yet, if one were looking for a green home scoring system that fairly reflects house size—or more importantly, the embodied and operational energy of a home that the size indicates—one would be sorely disappointed with most rating systems, including the nationwide pilot of the US Green Building Council’s LEED for Homes. In nearly all green home rating systems, house size is either completely ignored or awarded what amounts to a token score when compared to other, less significant construction strategies in the rating. This leads to a lack of equity in the scoring of different approaches and therefore a lack of equity among the scores of different homes, especially of different sizes. Practically speaking, this creates a situation where small green commitments are awarded equally or greater than dramatic reductions in house size. This is especially a problem because dramatic reductions in size represent dramatic reductions in resource use. But it is also a problem because properly scored reductions in house size can engender affordability in the green home market. Awarding the cost-saving size reduction proportional to its impact limits the small home’s necessity for more costly green options, which controls cost overall. Affordability is the key to opening the green door to low to middle income homeowners, a substantial target market in new home starts.

How important is house size to the environment?

Apparently, en route to a conference on recycled products, Kathleen O'Brien, a well-known green building consultant who has helped develop numerous green building rating programs gave the following advice to her cab driver when asked what he should incorporate into his new house: "If you do one thing, build it small." Limiting her advice to one thing did not evoke talk of energy recovery ventilators, recycled glass tiles, or a site close to a railway station. Kathleen chose size for the subject of her counsel, and as it turns out, that was good advice.

In their 2005 article, *Small is Beautiful: U.S. House Size, Resource Use, and the Environment*, Alex Wilson and Jessica Boehland plainly lay out the importance of house size in relation to resource use. They start by pointing out demographic trends from the US Census. Average house sizes are increasing steadily, from 1,100 ft² in 1950 to 2,340 ft² in 2002. At the same time, household size, or the number of occupants in the home, dropped from 3.67 members in 1940 to 2.62 in 2002. This means that not only are homes becoming bigger, they are housing fewer people while they do their job, leading to a drop in efficiency in the square foot of residence per occupant. Reflecting on Wilson and Boehland's figures, it now takes more materials to house fewer people. Since building materials are largely made from raw natural resources, significantly more resources per person are being consumed for housing today than in 1950. In fact, homes in 2002 required 893 ft² per person of materials as opposed to 290 ft² in 1950.

The article continues by exploring the material use differences between today's large and small homes. In an interview with Gopal Ahluwalia, the director of research at the National Association of Home Builders (NAHB) he estimates that a 5,000 ft² home will use three times the material inputs of a 2082ft² home. While this is conjecture, the point being made is that there are differences as homes get larger, like higher ceilings and more resource intensive finishes, that can lead to material increases that do not match the larger home's better surface to volume ratio.

A comparison of material estimates from two house designs conducted by the author using sample homes from Chief Architect, a residential CAD program, may not confirm Ahluwalia's suspicions exactly, but shows significant reductions in structure and envelope materials. Finish materials, which can vary widely in homes, were not tallied. The two homes, a 1650 ft² 3-bedroom home, and a 4000 ft² 3-bedroom home have decks and garages removed. Homes were chosen with similar shape and overall roof form. Only a few material categories are compared and reductions in these categories did not vary exactly proportional with house size reductions, but were nonetheless significant. If these numbers are carried out to a 50% size reduction, say from 3300 ft² to 1650 ft², one can expect to find between a 35% reduction in concrete, up to a 45% reduction in roofing, roof sheathing and wall framing lumber. Of course, house shapes and designs vary with size, so a more exact correlation will take a comparison of large quantities of similarly constructed homes of various sizes.

	1650 ft ²	4000ft ²	Unit	Reduction
Concrete	35	60.5	Cu Yd	42%
Wall Framing Lumber	5419	11484	Board-FT	53%
Roof Framing Lumber	2886	5498	Board-FT	48%
Wall Sheathing	70	130	Sheet	46%
Roof Sheathing	50	108	Sheet	54%
Roofing	1585	3466	ft ²	54%
Siding	2100	4093	ft ²	49%

Figure 1 House materials related to area.

Wilson and Boehland also reported a significant energy use difference between small and large homes that is nearly proportional to their size difference. With the energy modeling help of Andrew Shapiro of Energy Balance, Inc., using the same REM/Rate software as home energy raters across the country, they determined that a 1500ft² home with the same level of energy efficient construction as a 3000ft² home and in the same locale, used less than half the energy to heat and about two thirds the energy to cool. In all, the smaller home used 48 MMBtu for space conditioning compared to 92 MMBtu for the larger. The house 50% smaller used 48% less energy. Perhaps more interesting is that according to the same study a 1500ft² home with relatively poor insulation characteristics still outperformed the 3000ft² home with good insulation characteristics. The smaller home used 65% of the energy of the larger, despite what would be determined today to be inadequate construction. In short, it is possible to save more energy by reductions in size, than by increases in the quality of energy efficient construction. Size does matter. A lot.

In a comparison of 999 single-family, detached, 3-bedroom Vermont Energy Rated Homes (information provided thanks to Vermont Energy Investment Corporation) size is plotted to projected annual energy use after the homes are subjected to a correction formula to equalize their HERS scores (back to an 80). The trend (figure 2) shows an energy reduction that is largest at the smaller end of the homes, but is significant across the chart.

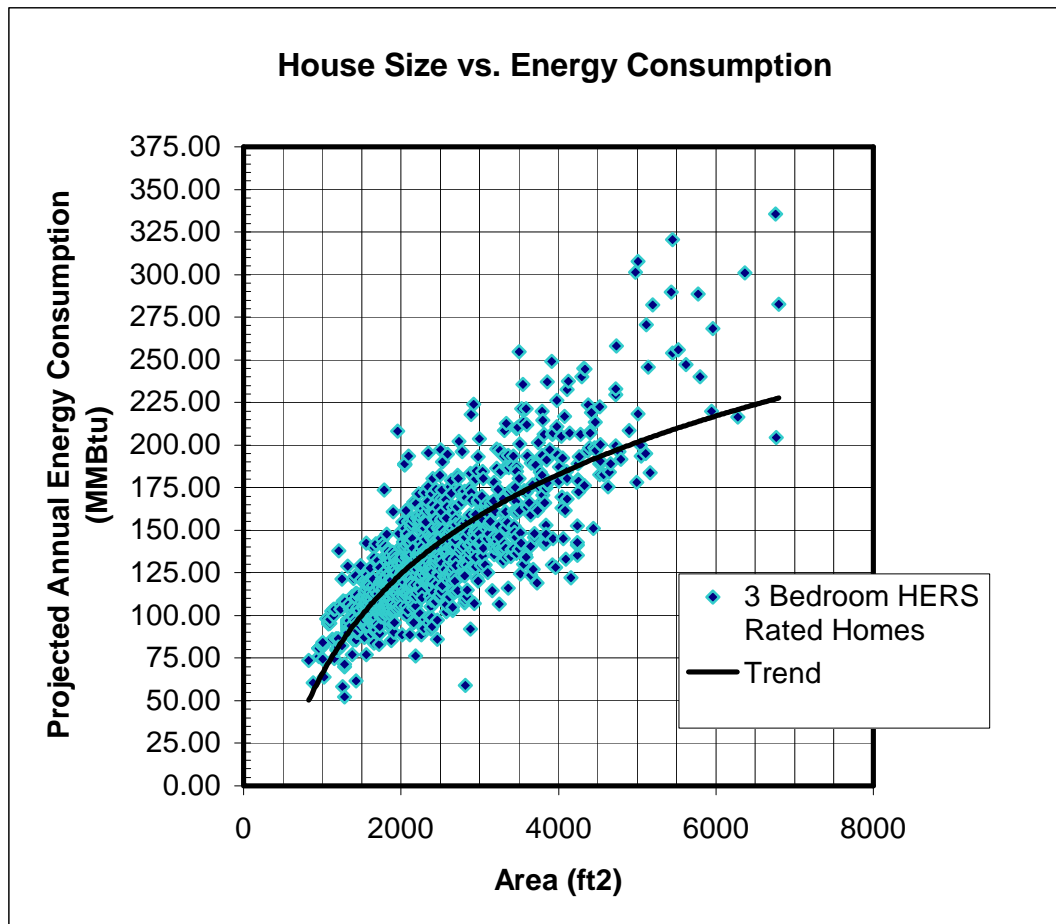


Figure 2 House size vs. energy consumption

Although a comprehensive case study is lacking, it has been presented and is well accepted by design professionals that smaller homes use fewer materials in their construction and maintenance, and cost significantly less in energy to heat, cool, ventilate and light. So, it is safe to report that smaller houses are more efficient at housing their occupants, and that dramatic reductions in size are accompanied by dramatic reductions in material and energy use.

How is house size scored?

Built Green Colorado, the largest, one of the oldest, and often touted as the most successful green home rating systems in the US, awards 10 points for a home that is under 2000ft², and an additional 5 points if the home is under 1500ft². There is no mention of bedrooms. In their guide to their checklist, BGC explains both point categories for size reduction thus: “The overall environmental [impact] of a house is, intuitively, proportional to its size. Built Green[®] chooses not to penalize those builders whose homes are larger than this threshold, but does reward those homes with a smaller environmental “footprint”. Reward might be an overstatement. Other strategies that are awarded 10 points in Colorado’s program: Awnings (5 points) and a whole house fan (5 points); limiting duct leakage to less than 10% of design flow (10 points); the installation of a tankless water heater with an EF of .82 (10 points); the installation of Energy Star refrigerator (4 points), Energy Star dishwasher (4 points), and a gas cooktop with electronic ignition (2 points). There are numerous other combinations possible that equal ten points. None can boast the energy or material savings of a significant size reduction. Seventy points are required to receive BGC certification. *No* reduction in size can earn you more than 21% of these points.

LEED for Homes, though one of the more equitable systems regarding size, awards a maximum of 10 points for a 50% size reduction from the national average (i.e. reducing a 1900 ft² 3-bedroom house to a tiny house of 900 ft²). These ten points represent 33% of the threshold points, which seems fair at first glance, until it is compared with the points available for other, less significant approaches, also worth 10 points, such as the combination of using high efficiency plumbing fixtures, minimizing landscape watering, and using permeable paving materials. In short, LEED for Homes values a reduction in size that has been shown to represent nearly a 50% energy savings over the life of the building and reductions in materials that may also approach 50% or more as worth the same as a permeable driveway, a few ultra-efficient plumbing fixtures and a low water demand landscape plan. Other ten-point combinations are similarly startling. This is hardly equitable across the scoring and hardly an incentive to build small, despite the benefits.

Generally, green home rating systems divide their checklists or score sheets into sections or, more accurately, categories of green strategies. These categories often include site issues (i.e. proximity to services), health issues (i.e. IAQ), water efficiency (i.e. low flow fixtures), energy efficiency (Energy Star compliance), material substitutions and reductions (i.e. using recycled content materials), and education (i.e. owner manuals). Some ratings require the builder to address a certain number of strategies in each category; most have mandatory requirements in each category. Determining the total number of points, the certification threshold, how many points are available in each category, and how the categories are weighted against each other is less than scientific. The number of points and the weighting systems in general are often dependent on votes, input from industry professionals, and review committees. To date, no standardized or scientific methods have been developed, short of LCA, that can weight scores or categories against each other to determine what is mandatory, what minimal amount of measures

is substantial enough to be called green, or how each strategy or credit compares to the next. While much discussion, purpose, and decisiveness surround the categories and points, these artificial divisions of point categories are anything but accurate.

Size reduction strategies and points are often relegated to the materials category of the ratings (though size clearly effects water and energy use as well). Green home rating administrators will argue that size reduction points (or any penalties for largeness) are just another credit or green measure, because size only effects the materials category. When the HERS rating methodology is scrutinized, it becomes clear that the energy category also needs to be subjected to size point corrections (1). Water use, in landscaping and leakage in bathrooms, is also affected by size. Smaller homes with smaller roof areas create less runoff from gutter downspouts. As smaller homes require smaller volumes of paint, pest control chemicals, and cleaning products, size has an impact on health-threatening chemical use. The eventual dismantling or destruction of the home represents a smaller amount of construction debris. Yet size continues to be downplayed in terms of rewards.

This is not surprising. Although representation within most green home rating authoring committees, including LEED for Homes and Built Green Colorado, is industry-wide, there really are few, if any, industry champions of the smaller home. Contractors, architects, engineers, manufacturers, bankers, realtors, and material suppliers all benefit economically from larger homes (even with green material substitutions and alternative building strategies), not from smaller homes (with their material reductions and building avoidance strategies). Barring consumers with small budgets and niche markets there are no motivating factors for industry professionals to encourage small homes. This is clearly reflected in the green home rating systems and the lack of published studies on house size and environmental impact. The size of a home, despite intuition and data that shows how significantly it relates to resource use, is evidently neither a major factor nor a major interest in the minds of the authors of green home ratings.

HERS

VBG and LEED for Homes both use the Energy Star labeling of a home as an indication of the energy efficiency, or energy use of the home. Energy Star uses the Home Energy Rating System (HERS) as a testing method. Here is a description of HERS from their website:

A HERS rating is an evaluation of the energy efficiency of a home, compared to a computer-simulated reference house *of identical size and shape as the rated home that meets minimum requirements of the Model Energy Code (MEC)*. The HERS rating results in a score between 0 and 100, with the reference house assigned a score of 80. From this point, each 5% reduction in energy usage (compared to the reference house) results in a one point increase in the HERS score. Thus, an ENERGY STAR qualified new home, required to be significantly more energy-efficient than the reference house, must achieve a HERS score of at least 86.*

...Results of these tests, along with inputs derived from the construction plan review, are entered into a computer simulation program that generates the HERS score *and the home's estimated annual energy costs*.

From the HERS website, italics mine.

Since HERS uses a computer-simulated reference house of identical size and shape to determine the score for the house being rated, efficiency on an occupant basis, size basis, or bedroom basis is ignored. Also, although the home's annual energy costs are estimated by the program, it is not included in the score. Using this method, a 12,000 ft², 2-bedroom home built to meet MEC, and scored with HERS, can receive the same score as a MEC compliant 1100 ft² 3-bedroom home irrespective of the size, the number of occupants, or more importantly the expected annual energy requirements. Therefore MEC and HERS cannot be used to measure the ecological impact, but only the level of improvement of a home. They are scoring the level of energy efficiency, but of the construction methods rather than the actual structure.

Homes that use a significant amount of energy can achieve the same score as a smaller home that uses far less, because they both incorporate higher insulation levels, or better air sealing methods. In fact, in certain circumstances a large home can achieve a *higher* score than a small home that uses far less energy because the larger home incorporates more energy efficient construction techniques, even though it uses much more energy annually. Simply stated, the HERS score rates the performance of the construction methods, not the actual home. Despite, as stated above, reductions in size can have significant effects on the amount of energy consumed in the home, there is no consideration of size in HERS, as the comparison to a house of similar size and shape *cancels out* the consideration of size.

Thus a size factor is required to equalize the score from HERS and to take efficiency into account, since the efficiency of a home is not about BTU's per square foot, but about BTU's per occupant, or at least BTU's per home.

It is important to note that within the HERS rating system is recorded the number of bedrooms, the total square footage of the home, and the projected annual energy use. These can provide useful ratios for green home ratings: total square footage per bedroom (estimating material efficiencies per occupant), and total energy use per bedroom (estimating energy use per occupant).

Size Correction Factors

VBG and LEED for Homes have two different approaches for considering the size of the home and accounting for the size with a score, though both agree that energy use and material use needs to be rewarded for the smaller than average house and penalized for the larger than average house.

VBG uses size to determine a preliminary score (after assuring that the VBG requirements are met) from a chart that is related to the average house size in Vermont. After looking up their home's gross floor area on the chart (minus any home business floor area), the applicant must select enough additional approaches to bring their total score above the threshold for certification. In VBG this threshold, or minimum score, is 100 points. As recognition of the difficulties and effectiveness of building small homes, a home that is ½ the state average size (2300 ft² for a 3-bedroom) will score 100 points on the size chart if it also meets all of the requirements of the program. As the home gets larger it scores less until it reaches the state average, where it scores zero. Homes larger than average score negative points until they are double the average size where they score -100 points. This method has the effect of allowing the occupant to "pay" for increased size with more green approaches.

The VBG size chart is based on the following logic: Any home that meets all VBG requirements and reduces its resources by halving the state average floor area should be allowed minimal

certification by awarding it 100 points. A home that is $\frac{1}{4}$ the state average scores 200 points. A home that is twice the state average scores -100 points. A curve approximating the increasing difficulty of creating smaller homes was created in a committee along with the increasing point penalty for creating larger homes by placing points on a grid. A polynomial equation was created in Excel to match the points (with a resulting $R^2=1$) and this equation was used to create a point chart by incremental bedroom allowances. Incorporating bedroom allowances allowed an approximation of occupant loads or structure efficiency, allowing homes with more bedrooms to have more floor area for a given score.

LEED uses a similar chart, related to the national average size home, but embedded within the program and worth a maximum of 10 points for smaller than average homes. Since the threshold is 30 points, a small enough house can get $\frac{1}{3}$ of the way to certification through reductions in size. Homes that are larger than average deduct 1 point for each incremental increase in size, ad infinitum. As in VBG, increments differ based on the number of bedrooms.

See the attached chart for differences between VBG and LEED for Homes size corrections.

Affordable Green Homes?

According to an Environmental Building News article on affordable options in green building, there are a number of green building strategies that cost the same or less to implement than their not-so-green alternatives. The widest reaching among these are renovating older buildings, integrating the planning and design process, and, of course, building smaller. Green building has a reputation for being more expensive—and it's no wonder: building green homes using the type of material substitutions, advanced technologies, sophisticated insulation and sealing methods, and third party testing that are promoted in LEED for Homes and other ratings almost always costs more money at the outset. Some of these green strategies do save money in the long term, but affordability in green housing becomes difficult when point structures favor cost prohibitive methods over reduction and avoidance. Building smaller, on the other hand, can create a significant savings in capital expense while simultaneously reducing resource consumption. As Sarah Susanka so eloquently points out in her books, cutting size can free up money for a higher quality product overall. Include in this quality product those green strategies that otherwise could not be afforded by the middle to low-income homeowner, and size reductions become a gateway to affordability and increased green building strategies. When ratings strongly encourage size reductions they encourage affordability while realizing dramatically reduced environmental impacts. The most economical and environmental green strategy is to build less.

It is also important to acknowledge that as house size and the relevant budget increases, often so does the ability of the owner to afford green strategies that cost more to implement. Bigger homes can afford more green options, and they should incorporate more green options, as they are using more resources per occupant to do the same job.

Sales of Susanka's book "The Not So Big House" (and related books) have shown that Americans do have an interest in building smaller, though national trends and the US Census show house sizes increasing steadily (and household size shrinking concurrently). Green home rating systems now have a unique opportunity to create systems that rate according to the efficiency of the structure and thereby provide an incentive for homes to be built smaller. This is not, as some have mused, social engineering. It is not a matter of forbidding large houses. Choices to build larger homes will be made, but the integrity of green home rating systems is at stake. No one takes a rating seriously if it produces green-rated (Mc)mansions. If the choice to build a large green home was accompanied by the prospect that *proportionally* more green

strategies would need to accompany the use of more materials and energy, there would truly be an incentive to use fewer materials and build more energy efficient buildings: those that use less energy for a given number of occupants.

Not only can size (depending on how it is scored) be an economic leveling agent that allows for low-cost green homes, but, size alone, according to the VBG rating system, is enough to qualify a home for green status, provided that the home meets the program requirements or prerequisites. It is important to note that the requirements for VBG are numerous and fairly comprehensive, as compared with most other rating programs, such as LEED for Homes. LEED for Homes would need to change their requirement structure to offer the same olive branch to lower income homeowners.

Note on Occupant Loads vs. Size

Size is actually only an indicator of a structure's impact. Ultimately it is the efficiency of material and energy use in the home that is important. While size is a good indication of those material and energy efficiencies, occupant loads or occupant ratios takes this one logical step further. A house can be seen as a conglomeration of parts that operate together to form a conditioned space that creates shelter for a number of occupants. Dividing materials embodied in the home or the annual energy use (or any resource use for that matter) by the number of occupants creates a ratio of resource use per occupant, arguably the most accurate consideration of how efficient a home is in performing its function as shelter. After all, with cultural expectations of what a home is, the numerous decisions affecting construction, and differing patterns of use, it is the occupants who are ultimately accountable for environmental impact, not the home itself. The size of a home changes each occupant's "ecological footprint." As the home gets larger, using more resources and land to house the same number of occupants, their footprint gets larger.

For simplicity's sake, since the occupants can change multiple times in a homes life, and the home is the entity receiving the certification, the method of assessing efficiency that is most equitable is to measure the material and energy use per bedroom.

As homes with the same number of bedrooms get smaller, they have lower occupant loads in materials and energy use. Conversely, as homes get larger they have higher occupant loads. If homes were rated by occupant loads, size correction factors would become unnecessary.

Final Thoughts

Size is an important consideration in green home rating systems, as it accounts for a nearly proportional amount of resources consumed by the home in its function as a shelter. The logic that is used to award points for size can determine if small green homes are affordable, and the extent to which large green homes must incorporate more green features to meet threshold scoring. Determining occupant loads on the environment or the structure's efficiency at housing occupants is the real goal to establishing the impact of a home, and to allow comparison between homes and their green rating scores.

It is this author's recommendation that LEED for Homes incorporate two changes to their rating scheme to properly reward house size reductions:

1. Change the size point scores to more closely reflect the reductions in energy use (specifically heating) and the reductions in materials that accompany reductions in size. A careful study of total materials related to house size across the US must be conducted. Assure that material and energy reductions (in actual quantities, not percentages) are

- awarded proportionally appropriate scores when compared to other more expensive, but less effective green strategies.
2. Consider house size scores first, such that if enough reductions are made in size (a 50% size reduction that represents a 33-50% savings in total resources) the home does not need to do much else to be LEED certified, save the requirements. Assure the public that homes of increasing size must do proportionally more to be certified to compensate for the higher energy and material use *per occupant*.

Stringent requirements may be required if small homes are allowed to earn all of their green rating points from size alone, but strong incentives are needed to encourage size reductions that result in significant energy and material savings, and disincentives are needed to dissuade homeowners from building inefficient structures as homes that might serve better as warehouses or event halls.

Definitions

HERS—Home Energy Rating System is used by most green home rating systems to establish green compliance in the energy use category.

Embodied Energy – The amount of energy attributable to a material or assemblage of materials that would include the energy expended in extraction, processing, manufacture, transportation, installation, and disposal.

Operational Energy – The amount of energy attributable to the operation of a structure, including energy used for lighting, heating, cooling, ventilation and plug loads.

Life Cycle Assessment (LCA) --A systematic set of procedures for compiling and examining the inputs and outputs of materials and energy and the associated environmental impacts directly attributable to the functioning of a product or service system throughout its life cycle.

House Size – the total square footage of the residential portion of a structure, conditioned or unconditioned, not including the area attributable to a home office or other home-based business.

Occupant Load Ratio– The total of one or more resource uses of a structure divided by the number of occupants.

Threshold Points – The minimal number of points required for certification in a green home rating.

MEC—The Model Energy Code, maintained by the International Code Council, addresses residential energy requirements and is the basis for energy code requirements of many states for new home construction. Compliance with MEC is also the basis for a score of 80 in HERS.

About the Author

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Sources

Small is Beautiful: U.S. House Size, Resource Use, and the Environment
Alex Wilson and Jessica Boehland
2005 MIT and Yale University.

Building Green on a Budget
Feature - *Environmental Building News* May 1999

The Not So Big House: A Blueprint for the Way We Really Live
Sarah Susanka

Building Green?
Questions Beget More Questions
Green Living
Summer 2006

Integrating LCA into Green Building Design
By Shannon Lloyd, PhD, Anne Landfield, and Brian Glazebrook
Building Design and Construction
November 2005

VBG Checklist
BSR

Rating System for Pilot Demonstration of LEED for Homes
USGBC

Analysis of Energy Consumption, Rating Score, and House Size
Duncan Prahl and Eric Newhouse
The Pittsburgh Papers
2003 EBN