# IMPROVING THE LINK BETWEEN THE LEED GREEN BUILDING LABEL AND A BUILDING'S ENERGY-RELATED ENVIRONMENTAL METRICS

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## ABSTRACT

*The US Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) green building rating program has grown from a little known tool for market change to a label and brand relied upon by many of the largest players in real estate. It now serves as an indicator of sustainability and an instrument for environmental management. While LEED-certified buildings tend to offer greater environmental benefits than their conventional counterparts, research and experience shows that the variation in and magnitude of these benefits varies, even among buildings of the same LEED certification level. In light of growing concerns about "greenwashing" and the liability associated with questionable environmental declarations, it is important to ensure that users of LEED and similar certification programs receive a set of benefits comparable to those expected. With a focus on energy-related issues, this research (1) highlights evidence of the inconsistency between the expected and actual benefits of LEED buildings, (2) suggests revisions to LEED's Energy & Atmosphere (EA) section to reduce the variation and magnitude in the energy-related environmental impacts from LEED buildings, (3) quantifies this reduction in variation and magnitude of impacts using Monte Carlo analyses and probabilistic models created specifically for this research, (4) compares carbon dioxide emissions from LEED buildings to the Architecture 2030 Challenge goals and (5) quantifies the importance of scoring LEED buildings on a per capita normalized basis. This research is a follow-up piece to the authors' previous work published in the Journal of Green Building (Wedding and Crawford-Brown 2007).*

## KEY WORDS

green building, USGBC, LEED, Monte Carlo analysis, greenwashing, probabilistic modeling, carbon offsets, green power, Architecture 2030 Challenge

## INTRODUCTION

### *Buildings and the need for environmental solutions*

The high level of material consumption, energy use, water consumption, health effects, air pollution and carbon emissions from the US building industry have been well documented (Lenssen and Roodman 1995; Cole 1999; Uher 1999; Goodman and Walker 2006). For example, the built environment is responsible for approximately 39%–48% of US carbon emissions (Mazria 2003; US Department of Energy 2007a) and 71% of all US electricity use (US Department of Energy 2007b). In addition, projections for population growth and significant additions to the built environment suggest that these impacts are likely to increase substantially in the coming decades. Consider that the US population is predicted to grow by over 88 million people between 2008 and 2050—an increase of almost 30% (US Census Bureau 2008). Moreover, the US is projected to need over 100 billion additional square feet of new residential space by 2030 (Nelson 2003).

### *The USGBC, LEED and the environmental benefits of green buildings*

Green buildings—also known as high performance or sustainable buildings[1]—offer one way to mitigate the current and growing environmental impacts

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from the built environment. And the USGBC—with over 13,000 organizational members, more than 42,000 LEED Accredited Professionals, 20 million hits per month to the USGBC website, and LEED certification programs ranging from homes to neighborhoods to portfolios of buildings—has risen to the challenge. With over 600,000 volunteer hours logged in the consensus approach it has relied on to create the LEED green building labeling programs, the USGBC and its LEED rating system have become the current green standard for the majority of green building and development in the US (USGBC 2007a). Table 1, extracted from USGBC data, highlights the growth of the USGBC and LEED buildings and illustrates that with this exponential growth emerges a second purpose for LEED—to serve as an environmental management tool—in addition to its primary intended role as tool to stimulate market change.

Though LEED buildings can offer positive economic gains, such as reduced operating costs and enhanced asset value, as well as health benefits, including better indoor air quality, the focus in this paper is on environmental benefits. As an illustration of this latter group of benefits, consider that the USGBC LEED point tally of completed projects, as of December 2007—the national database of project details LEED-certified buildings—shows that over 60% of LEED buildings, compared to new non-LEED projects, are designed and constructed to (1) use 100% less water for outdoor uses and (2) consume at least 30% less water for indoor uses, while (3) diverting more than 75% of construction and demolition waste from the landfill (USGBC 2007b).

Similarly, recent research by the New Buildings Institute (NBI) and the USGBC shows that completed LEED buildings use an average of 25%–30% less energy than non-LEED buildings (Frankel *et al.* 2007). The study results indicate that some LEED Gold and Platinum buildings achieve high enough performance to meet the Architecture 2030 Challenge goals for reductions in carbon, but these account for less than 0.1% of new buildings each year.[2] The Architecture 2030 Challenge calls for new buildings today to have a 50% reduced carbon footprint compared to existing buildings, with steady increases in efficiency and renewable energy until reaching carbon neutral new buildings by 2030 (Architecture 2030 2007).

### *Measuring environmental impacts in buildings*

With 75 cities, 23 counties, 17 towns, 27 states, 12 federal agencies, 10 public school jurisdictions, 36 institutions of higher education and dozens of large corporations mandating or incentivizing developers to build LEED buildings (USGBC 2007c), and with dozens of other green building programs, such as ENERGY STAR and Green Globes, the construction and real estate industry is indeed "amidst a surging 'culture of assessment'" (Cole 2006a). At the same time, advertisements and articles in most real estate publications would suggest that every developer, design firm and project is a shining star of sustainability.

As a way to maintain credibility, build brand and project differentiation, reduce liability and potentially attract investors, sellers or other key partners, several organizations, in addition to the USGBC, have begun to create their own set of metrics for building performance—environmental and otherwise. These include academic-government-investor coalitions such as the United Nations Environment Programme Finance Initiative Property Working Group and the affiliated Responsible Property Investing Center, global multi-stakeholder networks such as the Global Reporting Initiative and investor-developers such as Cherokee Investment Partners.

**TABLE 1.** Average annual growth of the USGBC and LEED between 2000 and 2007*

| Indicator | Annual % growth | Total # |
|---|---|---|
| # of USGBC member organizations | 60% | 13,000 |
| Registered LEED building square footage | 180% | 2,900,000,000 |
| Certified LEED building square footage | 80% | 138,000,000 |

*Based on late 2007 USGBC data

Closer analysis of the environmental footprint of buildings has been the topic of numerous academic studies and print commentary. The foci have covered international assessment programs (Uher 1999; Hansen and Dammann 2002; Werner *et al.* 2002; Chung 2005; Duncan 2005; Johnston *et al.* 2005; Malmqvist and Glaumann 2006; Sunikka 2006), the overlap or competition of building assessment programs in the same market (Bosch *et al.* 2003; Malin 2005; Boecker *et al.* 2006; Cole 2006b), the use of environmental indicator systems for the built environment (Uher 1999; CRISP 2002; Werner *et al.* 2002; Dammann and Elle 2006; Malmqvist and Glaumann 2006), the importance of a more integrated approach to building assessment tools (Lützkendorf and Lorenz 2006), definitions of absolute environmental limits and true sustainability for buildings and the construction industry (Lowe 2006; Pearce 2006) and the value and use of quick checklist assessment methods (Gething and Bordass 2006).

Additional related work addresses topics such as the redefining of the objectives of environmental assessments for buildings (Kaatz *et al.* 2006), the significance of the built environment's carbon footprint (Johnston *et al.* 2005; Lisø 2006; Sunikka 2006), the logic (or lack thereof) of the LEED rating system (Eijadi *et al.* 2002; Stein and Reiss 2004; Frangos 2005; Brook 2007; Del Percio 2007), the role of regionalism in sustainable development (Lorch and Cole 2003; Lorch 2006), attempts at international standardization of sustainable building and product assessment (ISO 2006a; ISO 2006b) and efforts to use eco-labels to rate the "greenness" of building and consumer products (ISO 2000; Jordan *et al.* 2003; Rumsey and McLennan 2004; Makower 2006; Probst 2006; Faludi 2007; ISO 2007; Timberland 2007; USGBC 2007d; Atlee and Altes 2008).

Of greatest relevance to this present analysis, a variety of research has assessed the variation in energy use and energy-related impacts from green buildings (Sheltair Group 1999; Bordass 2004; Pless and Torcellini 2004; Scofield 2004; Diamond 2006; Frankel *et al.* 2007; Wedding and Crawford-Brown 2007). Sources of variation in these impacts include (1) the fuel mix at power plants and on electrical grids, (2) the variety of specific LEED credits obtained, (3) the difference in modeled versus actual energy use, (4) building type and (5) the type of renewable energies used on site or purchased from off-site sources. However, no research has yet proposed a comprehensive, quantitative overhaul of LEED's Energy & Atmosphere (EA) category in order to reduce the variation and magnitude of energy-related impacts from LEED-certified buildings. This effort becomes increasingly relevant with recent reports published and initiatives established to address the prevalence of "greenwashing"—i.e., the marketing of certain environmental performance attributes which are accidentally or intentionally inaccurate or untrue (Terrachoice 2007; US Federal Trade Commission 2007; EnviroMedia 2008).

In part to address this issue of varying environmental impacts from LEED buildings, the USGBC has taken several significant steps since this present research began by requiring buildings to now (1) obtain at least two EA credit 1 points above the ASHRAE 90.1-2004 baseline to improve LEED building energy efficiency and (2) reduce building carbon emissions by 50% compared to existing buildings. In addition, USGBC efforts are underway, as of January 2008, (1) to incorporate life cycle assessment (LCA) as a framework for weighting and scoring buildings in new LEED programs and (2) to roll out a carbon offset program in the first half of 2008.

### *The legitimacy of green energy purchases and carbon credits in accounting for a LEED building's environmental footprint*

When quantifying the energy-related environmental impacts of a green building, the use of off-site green energy purchases (e.g., Renewable Energy Credits, RECs) or carbon credits raises considerable debate. A variety of organizations, from the US EPA to the Sierra Club and PepsiCo, have demonstrated their support for green energy purchases as a way to stimulate renewable energy and reduce a building's or organization's indirect emissions due to electricity generation (Hanson and Van Son 2004; PepsiCo 2007; Sierra Club 2007; US Environmental Protection Agency 2007a; US Environmental Protection Agency 2007b). Similarly, numerous organizations—such as Delta, Nike, Dell and Google—proclaim their organizational greenhouse gas reductions via the purchase of voluntary carbon offsets.

However, others criticize the claims of emissions reductions based on the purchase of RECs because of the uncertainty regarding (1) the cause-and-effect relationship between green energy payments (as catalysts) and the creation of new sources of renewable energy on the US electrical grid to displace more polluting, conventional grid supplies (Holt and Bird 2005; Baratoff *et al.* 2007; Gillenwater 2007a; Gillenwater 2007b), (2) the ownership of the emissions reductions from such purchases—whether the owner is the green energy purchaser or the utility plant (Holt and Bird 2005; Holt *et al.* 2006; Gillenwater 2007a) and (3) the quantification of emissions reductions resulting from green energy purchases (Schendler 2006; Gillenwater 2007a; Gillenwater 2007b). In the same way, detractors refer to the widespread use of carbon offsets as a way to "throw money at a problem" or to obtain a "get-out-of-jail-free card" (Linn 2007). Third-party certifications for RECs, such as Greene-e, and carbon credits, such as Green-e or the Voluntary Carbon Standard, can offer additional levels of credibility to these strategies and address some of these concerns.

This lack of consensus on the emissions reductions associated with green energy and carbon offset purchases prompted the US Federal Trade Commission to begin its discussions about the environmental marketing language surrounding these two green strategies on January 7, 2008—a year earlier than planned (US Federal Trade Commission 2007). For the time being, the resolution of this issue remains a concern; it is outside of the scope of this research; and emissions reductions from green energy and carbon offset purchases are assumed to be credible. For a more thorough discussion of carbon markets and the quality of carbon offsets, see Hamilton *et al.* (2006), Kollmuss and Bowell (2007), Trexler Climate and Energy Services, Inc (2006), Capoor and Ambrosi (2007), Environmental Defense (2007) and Hamilton *et al.* (2007).

### *The scope of this research*

This project is a follow-up effort to a related research undertaking entitled "An Analysis of Variation in the Energy-Related Environmental Impacts of LEED Certified Buildings" (Wedding and Crawford-Brown 2007). Accordingly, that project will be referred to as "Phase I." Like this current research, Phase I relied on the creation and use of Monte Carlo probabilistic models, based on empirical data, to simulate nine environmental impacts from LEED buildings and assess the variation in these impacts.

The goal of this current research, henceforth termed "Phase II," was to analyze the effects of suggested improvements to the Energy & Atmosphere section of LEED on the variation and magnitude of the energy-related environmental impacts from LEED buildings, as observed in Phase I. Suggested alterations to LEED are detailed in the following sections (see Table 3). Justification for the feasibility and benefit of each alteration is also discussed. Simulated carbon dioxide emissions from models based on LEED buildings, before and after the suggested changes, are also compared to Architecture 2030 Challenge goals. The importance of scoring a LEED building based on the number of employees, i.e., rewarding distinction based on *per capita* normalized impacts, is also illustrated. Finally, the authors propose initial steps to operationalize these suggested revisions to LEED and offer discrete steps for future research on this topic.

## METHODS

### *Defining environmental impacts*

Despite the current prominence of climate change concerns and the seemingly one-pointed focus on carbon emissions, with over 130 million Americans living in areas of non-attainment with one of more of the US EPA's criteria pollutants, it seemed appropriate to broaden the scope of energy-related impacts (US Environmental Protection Agency 2002). Accordingly, for this study, energy-related environmental impacts refer to nine end points of concern: emissions of carbon dioxide, nitrogen oxides, sulfur dioxide, mercury, and particulate matter; the generation of solid waste and nuclear waste (high level and low level); and water consumption.

These include power plant and/or on-site combustion-related environmental impacts attributable to building energy use. Impacts here should be thought of as environmental loadings (e.g., $CO_2$ emissions) rather than subsequent effects (e.g., an increase in global temperatures). Dispersion modeling to and within media, assimilation into the environment (e.g., biochemical transformation), as well as organismal uptake and corresponding health effects (i.e., risk assessment) are outside the scope of this research. Moreover, the focus is on regional and global impacts rather than site-related energy use impacts (e.g., carbon monoxide).

Impacts in this project also focus on operational energy use (e.g., for heating and cooling), not embodied energy consumption (e.g., upstream energy consumption in material extraction and transportation of products). One exception may be water consumption from hydroelectric generation, which can certainly be considered an upstream impact. Upstream impacts were excluded in this analysis in part because of the uncertainty and debate about the quantification and contribution of these impacts to total impacts. Some suggest that embodied energy impacts constitute a relatively small percentage—approximately 5%–10%—of a building's life cycle energy use (Lazarus 2003; International Energy Agency 2004). Other research (Deru and Torcellini 2007) and databases such as the US National Renewable Energy Laboratory's (NREL) US Life Cycle Inventory (LCI) indicate that pre-combustion impacts of energy use can account for 27% of a building's total emissions related to energy use on average, with a low of ~4% and a high of ~99% depending on the impact (e.g., carbon dioxide emissions from coal use or sulfur dioxide emissions from natural gas, respectively) (Deru 2008). Furthermore, these data on pre-combustion have only been reported at the national and NERC interconnection level; as described later, an estimation of LEED building impacts on a smaller geographic level than this is desired.

### *Simulating impacts from LEED buildings*

To understand whether the suggested alterations to LEED reduce the variation and magnitude of the energy-related environmental impacts from LEED buildings that were found in Phase I, it would have been best to take actual measurements from many LEED buildings in many regions of the country—in theory, from those that used the current LEED framework and from those that used the revised LEED program as proposed later in this research. However, obtaining such data from actual buildings was not feasible for the current study given that (1) no buildings are, of course, certified under the altered LEED scenario suggested in this research and (2) obtaining data on a large sample of impacts to create statistically significant results requires significant resources and time. Instead, the authors created unique probabilistic models which were used to perform Monte Carlo analyses and simulate 1,000s of LEED buildings and corresponding impacts for each model type (e.g., solid waste generation per square foot per year from LEED Silver office building).

For this research, it is assumed that a building's modeled energy use equals its actual energy use, though this is not always the case. Phase I illustrates the additional variation in impacts caused when this is not considered as the default assumption (Wedding and Crawford-Brown 2007). A study of 21 first-generation LEED buildings showed that the ratio of actual energy use divided by modeled energy use varied from 0.18 to 2.25, even though the mean was 0.99 (Diamond 2006). The much more comprehensive NBI/USGBC study of completed LEED buildings showed that, on average, actual energy use intensity (EUI) was approximately equal to designed EUI. However, this ratio was 0.93, 0.83 and 1.12 for LEED Certified, Silver and Gold/Platinum buildings, respectively, and the correlation between the two ($R^2$) was only 0.33. In fact, 30% of buildings performed significantly better than expected while 25% used more energy than modeled (Frankel *et al.* 2007).

Each probabilistic model consists of algorithms that convert building data and features to estimates of environmental impact on a "per square foot per year" basis. Models were based on empirical data, such as the USGBC LEED point tally, and data from trusted sources, such as US Energy Information Administration (EIA) Commercial Building Energy Consumption Survey (CBECS) database (2003a), the US LCI database, the US Department of Energy's (DOE) Office of Nuclear Energy and NREL. LEED v2.0 and v2.1 projects from the USGBC point tally were used for this research because (1) over 95% of the ~750 completed LEED projects as of December 2007 were from these versions and (2) Phase I, which serves as the baseline for measuring reductions in variation and magnitude for impacts from building using the altered LEED scheme, also used these versions. While LEED v2.2 is now in use, the relationships between impacts presented here likely holds true for these projects, too, though impacts could tend to be lower from LEED v2.2 projects.

The models incorporate 14 of the total 64 categorical total LEED points or approximately 22% of all credits, including EA credit 1 "Optimize Energy Performance" worth 10 points, EA credit 2 "Renewable Energy" worth 3 points and EA credit 6 "Green Power" worth 1 point. These credits were chosen because of their relative impact on a building's energy footprint and because these were deemed to be the most suitable credits in the EA category for use in probabilistic modeling, given the availability of data, which were used in this research. Model results were verified by ensuring that the mean, minimum and maximum EUI for the simulated LEED and base case, non-LEED buildings were comparable to those based on CBECS data, the NBI/USGBC study and a limited number of actual LEED buildings from the USGBC website. Simulated impacts from these models then served as the basis for comparing the variability in and magnitude of Phase I LEED building impacts versus Phase II LEED building impacts. Tests also confirmed the repeatability of model results; successive simulation results typically only deviated by less than 5% for parameters used in this research, such as the coefficient of variability, median and standard deviation. For more details on these probabilistic models and other methods from Phase I, see Wedding and Crawford-Brown (2007).

### *Creating an altered LEED rating system*

Table 2 below highlights the results of the sensitivity analyses from Phase I and indicates the parameters which caused the most variation in LEED building impacts. A value of "78% in the "Top 3" column for "LEED EA credits 1 and 2" indicates that for 78% of the nine simulated impact categories such as sulfur dioxide emissions (i.e., 7 of the 9 categories), this parameter was among the top three sources of variation in the model for LEED office buildings. Because parameter #1 in Table 2 caused such a high degree of variation, other parameters such as EA credit 6, green energy purchases, do not show up in this table.

However, with parameter #1 brought under control, EA credit 6 plays a larger role in LEED buildings' impacts. In addition to insights from this table, additional sources of information for amendments to LEED's EA category draw from (1) the consideration of pros and cons in other green building programs, such as Earthcraft House, (2) analyses of model simulations in Phase I, which highlighted the consistently broad range of impacts regardless of LEED certification level and (3) close scrutiny of the USGBC LEED point tally, which illustrated similarly wide variations in EA point totals for LEED certified projects with little regard for varying certification level.

The resulting suggested changes to LEED's EA category are highlighted in Table 3. The focus is on a tiered approach, where requirements for performance increase as projects move up towards the LEED Platinum certification level. While this does limit flexibility, the authors argue that there are three reasons which merit this trade-off: (1) the importance of the predictability of a LEED building's environmental impacts, (2) the significance of absolute instead of

**TABLE 2.** Sensitivity analysis showing the four most important parameters in creating variation in the nine energy-related environmental impacts of LEED buildings

| | | All Buildings | | Educational Buildings | | Office Buildings | | Residential Buildings | |
|---|---|---|---|---|---|---|---|---|---|
| | | Ranking as the Most Significant Sources of Variation | | | | | | | |
| Overall Rank | Parameter | No.1 | Top 3 | No.1 | Top 3 | No.1 | Top 3 | No.1 | Top 3 |
| 1 | Air emission, waste generation, and water consumption factors | 78% | 78% | 78% | 78% | 78% | 78% | 78% | 78% |
| 2 | LEED EA credits 1 and 2 | 0% | 56% | 0% | 100% | 0% | 78% | 0% | 78% |
| 3 | % electricity versus natural gas/fuel oil | 0% | 56% | 0% | 44% | 0% | 56% | 0% | 56% |
| 4 | Variation in building energy use | 0% | 56% | 0% | 22% | 0% | 44% | 0% | 67% |

**TABLE 3.** Suggested improvements to LEED's Energy & Atmosphere category

| Improving Accuracy and Precision Regarding a Building's Environmental Impacts | | |
|---|---|---|
| **Current or Proposed EA Credits** | **Alteration to LEED *** | **Additional Details** |
| 1. EA credit 1: **<br>Energy Optimization | Require:<br>– 2 points for Certified<br>– 4 points for Silver<br>– 6 points for Gold<br>– 8 points for Platinum | • Of all completed LEED projects:<br>– 64% of Certified earn ≥ 2 points<br>– 61% of Silver earn ≥ 4 points<br>– 55% of Gold earn ≥ 6 points<br>– 87% of Platinum earn ≥ 8 points<br>• Stresses the importance of direct reductions of building environmental impacts instead of offsetting impacts in other areas |
| 2. EA credit 6:<br>Green Power | Require:<br>– 20% for Certified<br>– 30% for Silver<br>– 40% for Gold<br>– 50% for Platinum | • Implies average of 2% increase in electricity costs, varies widely<br>• Allows for equalization and comparability of LEED buildings across regions<br>• Helps catalyze US renewable energy development<br>• Should be harmonized with carbon credit below to avoid awarding too many points to offsets<br>• Raises concerns of legitimacy, additionality, quality, etc. |
| 3. Proposed credit:<br>Carbon Offsets | Require:<br>– 14% for Certified<br>– 22% for Silver<br>– 29% for Gold<br>– 36% for Platinum | • Implies average 2% increase measured versus electricity costs, varies widely<br>• Allows for equalization and comparability of LEED buildings across regions<br>• Helps catalyze US low-carbon technologies<br>• Should be harmonized with EA credit 6 to avoid awarding too many points to offsets<br>• Raises concerns of legitimacy, additionality, quality, etc. |
| **New Ways of Awarding Certification Levels** | | |
| 4. Award LEED certification levels based on a building's environmental impacts compared to regionally relevant baselines | | • Score buildings based on a percentage reduction in impacts compared to a baselines<br>• Use EPA's eGRID, NREL and DOE data to create such regional baselines |
| 5. Award LEED certification levels based on normalized environmental impacts | | • Score buildings based on normalized environmental impacts, e.g., emissions per employee per year<br>• Use "employee per sq. ft." averages from LEED-Core and Shell v2.0 to create baselines |

*Another alteration is considered in Table 7, i.e., scoring and certifying LEED buildings within different building categories, e.g., LEED for offices, LEED for schools, etc. This change is not shown here because this is already occurring with LEED and the USGBC's development of programs for a wider variety of building types.

**The calculation of points for this credit also includes contributions from EA credit 2: On-site Renewable Energy.

marginal sustainability in buildings (e.g., movement towards the 60%–80% carbon reduction by 2050 rather than some more nominal measure of performance compared to existing buildings) and (3) the rising expertise in designing and building high performance buildings. On this last point, consider that in the latest set of certified buildings, more projects are earning the higher certification levels than in the past (RREFF 2007). In addition, note that the costs to meet these tiers for items #2 and #3 in Table 3 are, on average, quite minimal.

For item #1 in Table 3, consider that, as of December 2007, 16% of completed LEED buildings were no more efficient than the relevant ASHRAE 90.1 baseline, i.e., the projects earned no points for EA credit 1. As evident by the percentages in this table, minimum thresholds here would tend to only affect a minority of projects at each certification level. As a point of reference, consider that the USGBC's own policy move in 2007 to mandate 2 points for EA credit 1 meant that only 64% of completed Certified projects historically met that minimum level (USGBC 2007c). For model simulations, it was assumed that these minimum cut-offs for reductions in grid-supplied energy (i.e., via energy efficiency and renewable energy) did not affect the mean value for EA credit 1 as reflected in the USGBC point tally and as used in the model simulations.

For item #2 in Table 3, note that 60% of completed LEED projects purchased no renewable energy credits at all (USGBC 2007c). Even assuming that green energy purchases do confer actual emissions reductions, the quantification of this reduction is not always straightforward. If the source for green energy is located in the same US EPA eGRID sub-region (Figure 1) as the LEED building, it is essentially a 1:1 offset, assuming no time-of-day differences in energy use and production (which is untrue, but data on these differences is lacking). Note that the offset, even in this scenario, is not always 1:1 because not all renewable energy is without environmental impacts (Power Scorecard 2006; Wedding and Crawford-Brown 2007). If the green energy purchased is located in a different eGRID sub-region than the LEED building, then the air emission, waste generation and water consumption factors from that sub-region should be used (i.e., where the offset in conventional energy is supposed to occur), rather than the factors corresponding to the eGRID sub-region where the LEED building is located.

As for scoring, one point could be awarded for meeting the required green energy purchase at each certification level in Table 3, and an additional point could be available from the Innovation & Design category for purchasing more than double the required percentage—a reasoning which is common in current LEED programs. Table 4 illustrates the assumptions for calculating cost premiums for green energy purchases and carbon offsets; probabilistic modeling was also used for this assessment to generate the cost premiums shown in Table 3.

For item #3 in Table 3, no ancillary benefits from carbon offsets—such as sulfur dioxide and nitrogen oxide emission reductions through the support of

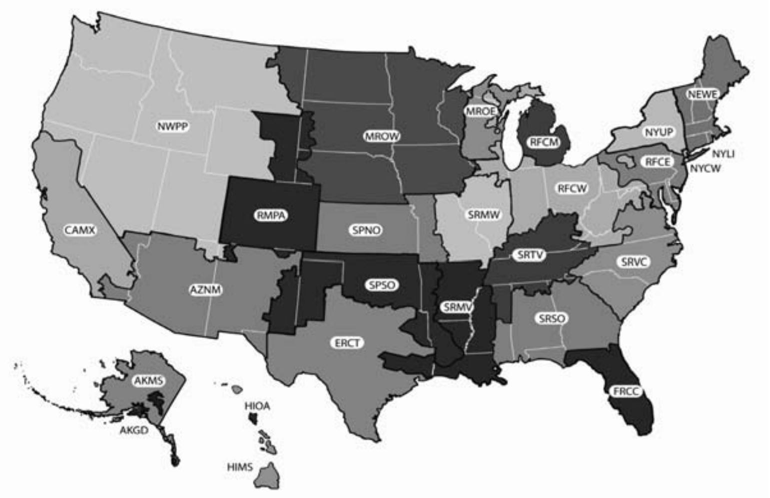



**FIGURE 1.** The 26 US EPA eGRID sub-regions used in the current study (US Environmental Protection Agency 2007c)

**TABLE 4.** Assumptions used to estimate cost premiums for green energy purchases and carbon offsets

| Parameter | Mean | Minimum | Maximum | Units | Source |
|---|---|---|---|---|---|
| Electricity costs | 10 | 5 | 21 | ¢/kWh | US EIA (2003b) |
| Electricity use | 12 | 9 | 16 | kWh/sf/year | 2003 US EIA CBECS |
| Electricity—emission factor | 1.4 | 0.5 | 2 | lbs/kWh | 2006 US EPA eGRID |
| Other energy use (e.g., natural gas) | 16 | 11 | 21 | kBTU/sf/year | 2003 US EIA CBECS |
| Other energy—emission factor | 1.4E-04 | 1.2E-04 | 1.7E-04 | lbs/BTU | 2006 US EPA eGRID |
| Green energy premiums | 1 | –0.7 | 2 | ¢/kWh | US EPA (2008) |
| Carbon offset cost | 10 | 4 | 16 | $/ton | Trexler (2006) |
| LEED certification level | Silver | | | | |
| Energy reduction vs. CBECS | 25% | | | | |
| Square footage | 46,000 | | | | |

renewable energy projects—were assumed in this analysis, because there are no data to support such calculations, though these co-benefits can be significant (Burtraw and Toman 1997). Tiers for carbon offsets were set in order to be equivalent to the carbon reductions created (potentially) by green energy purchases. Accordingly, percentages for green energy purchases requirements were multiplied by 72%, which is the average fraction of total office building energy coming from electricity (Jurovics 2007), to arrive at the tiers for this proposed credit.

The total contributions of emissions reductions from green energy purchases and carbon offsets should be capped so that projects are forced to prioritize direct (building design and operation) versus indirect (off-site energy production and offsets) reductions. For justification of the appropriate level for this cap, it is helpful to consider such limits which are already in place for carbon markets, legislation and other initiatives. The Northeast's RGGI program allows up to 50% of carbon reduction goals to be met with offsets while the European Trading Scheme, via the Marrakesh Accord to the Kyoto Protocol in 2001, permits unlimited use of offsets, such as those available through the Clean Development Mechanisms. Canada's Regulatory Framework for Air Emissions also allows unlimited use of offsets.

On the other hand, the Architecture 2030 Challenge suggests a cap of 20% on the use of green energy purchases or carbon credits to meet reduction goals for new buildings, and the current version of the Lieberman-Warner's proposed Climate Security Act proposes a limit of 15%. Recognizing that the current cost efficiency to reduce carbon emissions varies greatly by region, product type and technology, the authors propose an initial cap of 50%, which should be considered a temporary allowance or bridge until renewable energy technologies and the expertise of the design and construction community reach a point where buildings are able to more cost effectively reach significant carbon reduction goals.

For item #4 in Table 3, air emission, waste generation and water consumption factors were calculated and used to simulate impacts based on differences in fuel mix in the 26 US EPA eGRID sub-regions. See Table 5 for details. While emissions factors for carbon dioxide, sulfur dioxide, nitrogen oxide and mercury were drawn directly from the eGRID data, this is the first time that the other five impacts have been reported at this geographic level. Nuclear waste generation factors were created by multiplying average national "nuclear waste generation per MWh" data from the US DOE Office of Nuclear Energy by the percentage of nuclear energy in each eGRID fuel mix.

Values for water consumed in the generation of electricity were based on estimates derived from NREL research (Torcellini et al. 2003), though the water consumption factors used in this current research have been reduced compared to those from the NREL study. The NREL values assume that

**TABLE 5.** Emission, consumption and waste generation factors for building energy use by US EPA eGRID sub-region (eGRID sub-region locations can be seen in Figure 1)

| EPA eGRID Sub-region Acronym | Impact | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Carbon Dioxide* (lbs/MWh) | High Level Nuclear Waste (lbs/MWh) | Low Level Nuclear Waste (cf/MWh) | Mercury* (lbs/MWh) | Nitrogen Oxides* (lbs/MWh) | Particulate Matter (lbs/MWh) | Solid Waste (lbs/MWh) | Sulfur Dioxide* (lbs/MWh) | Water (gallons/MWh) |
| AKGD | 1,257 | 0.0E+00 | 0.0E+00 | 1.7E-06 | 3.0 | 8.2E-02 | 3.1 | 1.3 | 1,156 |
| AKMS | 480 | 0.0E+00 | 0.0E+00 | 2.7E-05 | 6.5 | 1.1E-01 | 0.4 | 0.7 | 4,170 |
| AZNM | 1,254 | 1.3E-03 | 6.6E-04 | 2.5E-05 | 2.1 | 8.9E-02 | 32.3 | 1.4 | 608 |
| CAMX | 879 | 8.7E-04 | 4.4E-04 | 2.3E-06 | 0.8 | 8.1E-02 | 5.6 | 0.6 | 1,206 |
| ERCT | 1,421 | 8.1E-04 | 4.1E-04 | 2.9E-05 | 1.0 | 1.2E-01 | 38.4 | 3.2 | 420 |
| FRCC | 1,328 | 9.5E-04 | 4.9E-04 | 9.1E-06 | 2.3 | 9.3E-02 | 12.3 | 3.6 | 384 |
| HIMIS | 1,456 | 0.0E+00 | 0.0E+00 | 2.7E-05 | 7.0 | 1.1E-01 | 1.2 | 6.0 | 602 |
| HIOA | 1,728 | 0.0E+00 | 0.0E+00 | 1.6E-05 | 2.6 | 1.2E-01 | 6.1 | 3.5 | 470 |
| MROE | 1,859 | 8.1E-04 | 4.1E-04 | 3.1E-05 | 3.3 | 9.9E-02 | 82.4 | 7.5 | 623 |
| MROW | 1,814 | 9.8E-04 | 5.0E-04 | 4.3E-05 | 3.8 | 9.9E-02 | 91.5 | 5.9 | 648 |
| NEWE | 909 | 1.7E-03 | 8.6E-04 | 8.5E-06 | 1.0 | 8.9E-02 | 7.3 | 2.4 | 622 |
| NWPP | 921 | 2.2E-04 | 1.1E-04 | 9.7E-06 | 1.6 | 9.4E-02 | 57.3 | 1.3 | 3,159 |
| NYCW | 922 | 3.0E-03 | 1.5E-03 | 6.5E-06 | 0.9 | 9.2E-02 | 0.2 | 0.7 | 241 |
| NYLI | 1,412 | 0.0E+00 | 0.0E+00 | 5.7E-06 | 1.8 | 1.0E-01 | 0.3 | 5.4 | 470 |
| NYUP | 820 | 1.7E-03 | 8.5E-04 | 1.4E-05 | 1.0 | 9.6E-02 | 32.8 | 4.2 | 1,780 |
| RFCE | 1,096 | 2.3E-03 | 1.2E-03 | 4.1E-05 | 1.7 | 9.8E-02 | 57.3 | 8.0 | 378 |
| RFCM | 1,641 | 8.7E-04 | 4.5E-04 | 3.3E-05 | 2.5 | 9.5E-02 | 64.0 | 6.8 | 403 |
| RFCW | 1,556 | 1.4E-03 | 7.3E-04 | 4.4E-05 | 2.8 | 9.9E-02 | 91.3 | 10.2 | 398 |
| RMPA | 2,036 | 0.0E+00 | 0.0E+00 | 1.6E-05 | 3.1 | 9.7E-02 | 72.2 | 2.0 | 760 |
| SPNO | 1,971 | 9.3E-04 | 4.8E-04 | 2.7E-05 | 4.0 | 9.9E-02 | 85.6 | 6.1 | 401 |
| SPSO | 1,761 | 0.0E+00 | 0.0E+00 | 3.9E-05 | 2.6 | 9.0E-02 | 41.5 | 3.9 | 699 |
| SRMV | 1,135 | 1.6E-03 | 8.3E-04 | 1.1E-05 | 1.5 | 8.7E-02 | 13.2 | 2.3 | 431 |
| SRMW | 1,844 | 7.1E-04 | 3.7E-04 | 4.1E-05 | 2.5 | 9.9E-02 | 94.3 | 7.0 | 482 |
| SRSO | 1,490 | 1.1E-03 | 5.8E-04 | 3.5E-05 | 2.2 | 9.7E-02 | 72.8 | 8.5 | 554 |
| SRTV | 1,495 | 1.2E-03 | 6.4E-04 | 2.5E-05 | 2.6 | 1.0E-01 | 88.2 | 7.2 | 861 |
| SRVC | 1,146 | 2.4E-03 | 1.2E-03 | 2.2E-05 | 1.9 | 1.0E-01 | 85.6 | 5.9 | 378 |
| US | 1,363 | 1.2E-03 | 6.3E-04 | 2.7E-05 | 2.1 | 9.7E-02 | 58.5 | 5.4 | 737 |

*Emissions factors for these pollutant were taken directly from the US EPA's eGRID database, while the others were calculated based on data from NREL, the US Life-Cycle Inventory (LCI) Database, and the US DOE's Office of Nuclear Energy.

water lost through evaporation from reservoirs is due entirely to the need for electricity generation, and is, therefore, caused by hydroelectricity generation. However, our models assume that this water loss is also attributable to at least three other uses of dams, which may include recreation, flood control, irrigation or municipal water supply. As such, we use estimates of water consumption per kWh of hydroelectricity equal to one-third of the NREL estimates. These "gallons/kWh" data from NREL for thermoelectric and hydropower generation were then multiplied by the percentage of thermoelectric and hydropower generation in each eGRID sub-region (Torcellini *et al.* 2003). To assure that this two-thirds reduction of gallons consumed via hydroelectric energy use did not affect the conclusions drawn from this analysis, models were re-run with values for "gallons per kWh of hydroelectricity used" reduced by one-fourth, one-half and three-fourths as a form of sensitivity analysis to this assumption. These alterations produced values for variability in water-related impacts which only deviated from the base case (i.e., using the two-thirds reduction) by less than 4%.

Factors for particulate matter emissions and solid waste generation were obtained by multiplying the relevant emission or generation factors for each fuel type (from the US LCI database)—e.g., pounds of nitrogen oxides emitted per ton of coal—by the percentage of each fuel type on every eGRID sub-region.

These eGRID sub-region boundaries were used because the degree of electricity import-export between regions is small enough to create sufficient confidence in the values of these factors. At the same time, it allows greater granularity in estimating impacts versus regionally relevant baselines as compared to using national averages. Using analogous national values as a baseline for scoring a LEED building emissions reductions would address the importance of meeting absolute global reduction goals, but it would be unfair to projects in high-carbon sub-regions and too kind to those in low-carbon sub-regions. Baseload emissions estimates were used where available because of a lack of clarity on whether a given building contributes to baseload or non-baseload grid energy use. As Table 6 indicates, this is a conservative approach to impact estimation as non-baseload emissions factors for certain impacts tend to be higher (US Environmental Protection Agency 2007d).

For item #5 in Table 3, the importance of normalizing LEED building environmental impacts per employee or other user becomes apparent when considering examples such as the Indian billionaire aiming for LEED certification for his 24-story family home with a 168-car garage (Brook 2007); the *per capita* environmental impacts of such a project remain large despite the attainment of LEED certification. In addition, normalization adds an element of broader economic consideration to LEED, where job creation (i.e., number of employees) is a positive feature of a project and air pollution, for example, is a negative feature. A higher ratio of the former over the latter would then suggest a better building, especially on the scale of city, state or nation as related to policy matters. To the influence of normalizing environmental impacts in this manner, average "employee per square foot" values were obtained from the LEED-Core and Shell Reference Guide (USGBC 2006); for office buildings, this value is 250 square feet per employee. As an illustration, variations in sulfur dioxide emissions reductions, with and without normalization, are shown in Table 10.

### Assessment of simulation results

Two types of variation in impacts were analyzed: (1) "between-group" variability (e.g., discrete means for the impact distributions from buildings with different LEED certification levels would be ideal) and

**TABLE 6.** Comparing non-baseload vs. baseload emissions factors by EPA eGRID sub-region*

| Impact | % of Sub-regions with Lower Non-baseload Emissions Factors** | Average % Increase in Non-baseload Emission Factors*** |
|---|---|---|
| Carbon dioxide | 12% | 25% |
| Mercury | 50% | –3% |
| Nitrogen oxides | 27% | 47% |
| Sulfur dioxide | 23% | 28% |

*Non-baseload data is only availablevia the EPA eGRID database for these four impacts, rather than for all nine impacts.
**There are 26 EPA eGRID subregions in total.
***This average is not weighted by the magnitude of energy generation in each subregion.

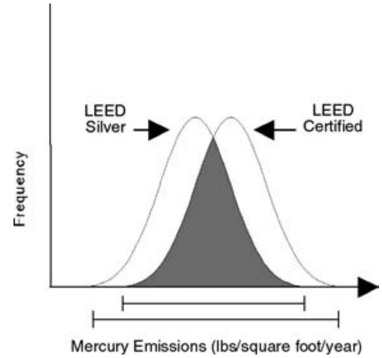
(2) "within group" variability (e.g., smaller standard deviations within the impact distributions from buildings at each LEED certification level would indicate a well-designed rating system). Within-group variability was measured with two statistics: (1) standard deviation and (2) coefficient of variability, or the standard deviation divided by the mean. Between-group variability was also measured with two types of impact ratios: (1) "rank order phase shift" and (2) "percent distribution overlap." Both of these impact ratios will now be described in more detail.

The first impact ratio used to measure between-group variability, referred to as "rank order phase shift," was calculated by first rank ordering the results of the 1,000 calculated impacts from a simulated LEED building's energy use from lowest to highest (one set of 1000 for each specific category of environmental impact). Then a set of impacts from a building with a given LEED certification level was divided by another set of impacts from a building with a higher LEED certification level (e.g., Silver divided by Gold). These ratios for sets of 1,000 simulated building impacts were then averaged and converted into a percentage. The resulting number is an expression of the difference in impacts which occurs as different categories of LEED building certification are considered, from base case, non-LEED buildings through LEED Platinum buildings. A rank order phase shift of 15% when comparing LEED Certified to Silver building impacts suggests that the impacts of the former are on average 15% greater than those of the latter. An example calculation is shown below for one set of particulate matter emissions:

$$\left(\frac{\text{PM Emissions}_{\text{LEED Certified}}}{\text{PM Emissions}_{\text{LEED Silver}}}\right) - 1 \times 100 = \text{Rank order phase shift}$$

The second impact ratio used to measure between-group variability, referred to as "percent distribution overlap," quantifies the degree of overlap in comparisons of probability distribution functions of these sets of 1,000 simulated buildings and their impacts. This ratio ignores the issue of the frequency of simulated impacts and represents the possibility that individual buildings certified at different levels of LEED could have the same level of environmental impact. Figure 2 depicts how this measure of variation is calculated using simplified probability distribution functions for the simulated mercury (Hg) emissions for 1,000 LEED Silver buildings and 1,000 LEED Certified buildings as an example. The range represented by the upper, shorter line was divided by the range represented by the lower, longer line to arrive at the percent distribution overlap. Note that the red area is the overlap of buildings in the two LEED categories considered. The relative level of kurtosis and degree of separation among each distribution can be seen in these graphs. Because the derivation of base case, non-LEED building energy use in these models was not derived from actual or modeled energy use and is, therefore, less than perfect, it is worth stressing that actual energy use and impact predictions in this research are less important than the degree of variation in said impacts between buildings. Consider the formula below for an example calculation of this overlap for carbon dioxide emissions:

**FIGURE 2.** Visual representation of the calculation of the "percent distribution overlap" using two probability distribution functions for hypothetical mercury emissions resulting from building energy use




$$\left(\frac{\text{Maximum HG Emissions}_{\text{LEED Silver}} - \text{Minimum HG Emissions}_{\text{LEED Certified}}}{\text{Maximum HG Emissions}_{\text{LEED Certified}} - \text{Minimum HG Emissions}_{\text{LEED Silver}}}\right)$$

$$= \text{Percent Distribution Overlap}$$

## RESULTS

In Table 7, the contributions to overall reduction of within-group impact variability and magnitude from each of the suggested alterations to the LEED rating system can be observed. LEED Silver buildings were used as the representative example category in this table because of the frequency with which this level of certification is used as a basis for municipal, federal, institutional or corporate policy. Note that a building scored with all these changes showed an average of 62% reduction in variability and a 30% reduction in magnitude across all nine impacts (i.e., the variability in impacts for a given LEED category go down, and the entire distribution shifts to lower impacts).

The following changes, in order of decreasing priority, contributed to this reduction in variation: (1) using regionally relevant environmental impact benchmarks (based on eGRID sub-regions), (2) scoring LEED buildings by building type rather than scoring all with the same LEED program, (3) the degree of building energy efficiency and on-site renewable energy and (4) the amount of off-site green energy purchases. These latter two changes, #3 and #4, also produced reductions in impact magnitude which were of a smaller degree than expected. For #3, this was likely due to the influence of more dominant sources of variability in the models. For #4, this probably occurred because green energy purchases only offset electricity use (i.e., not natural gas use on site) and corresponding impacts, and because not all renewable energy is without impacts (e.g., biomass versus solar).

Table 8 highlights the changes in the between-group variability of these impacts in the new LEED scheme compared to the existing LEED rating system. These results indicate less overlap in impacts and a greater distinction among impacts of buildings at different certification levels. However, the percent distribution overlap impact ratio still showed a high degree of overlap (i.e., an average 64% overlap) in impacts from buildings with different levels of LEED certification. This is caused by a combination of some of the following conditions: (1) the relative percentage of electricity (e.g., versus on-site source such as natural gas) as a source of energy varies considerably by building, which affects the level of a building's environmental impacts, (2) a building's on-site use of conventional energy can result in varying environmental impacts depending on the fuel source (e.g., natural gas versus fuel oil), and (3) the alterations to LEED proposed in this research only set minimum thresholds of performance, which implies no cap on upper levels of performance for each level of certified building (e.g., LEED Certified buildings can exceed the energy performance of LEED Gold buildings). In addition, Table 8 shows that differentiation between non-LEED and Certified buildings is much more significant using the new LEED program—that is, an overlap of simulated impacts between the two of 91% before alterations to LEED becomes only 29% after with the alterations to LEED.

Figures 3a and 3b depict these results graphically with the example of carbon dioxide emissions

**TABLE 7.** Changes in variability and median impact values across all nine impacts for LEED Silver Buildings—after versus before the suggested alterations to LEED

| | Sugggested Change to LEED | Change in Variability* | Change in Median |
|---|---|---|---|
| 1 | Use US EPA eGRID data as benchmarks** | –48% | *** |
| 2 | 4 points required for EA credit 1** | –28% | –16% |
| 3 | Score by building type**** | –30% | –39% |
| 4 | RECs required at 30%** | –10% | –4% |
| 5 | Carbon offsets required at 22%** | See note below. | |
| 6 | All changes combined** | –62% | –30% |

*"Change in Variability" is measured as an average across all nine environmental impacts of the changes in (1) standard deviation and (2) coefficient of variability, or the standard deviation divided by the mean impact level.

**These are based only on variation in impacts from office buildings.

***Values are not shown here because impacts, such as sulfur dioxide emissions per kWh, vary by eGRID region and affect changes to impact magnitude in ways that do not reflect additional improvements to LEED.

****This is based on a comparsion of variation in impacts from only office buildings versus all buidling types.

No percentages are listed for #5 because the co-benefits from carbon reduction strategies are not well documented, which prohibits an estimation of the range of variability reduction across all nine impacts.

**TABLE 8.** Decreases in between-group impact variation for 1,000 simulated LEED buildings before and after the suggested changes to the rating program

| Impact Ratios | LEED: Before | LEED: After | % Change |
|---|---|---|---|
| Percent distribution overlap impact ratio *(Negative "% Change" values are desired)* | | | |
| Non-LEED vs. Certified buildings | 91% | 29% | –68% |
| Comparing Certified through Platinum buildings | 86% | 64% | –26% |
| Rank order phase shift impact ratio *(Positive "% Change" values are desired)* | | | |
| Non-LEED vs. Certified buildings | 47% | 201% | 328% |
| Certified vs. Silver buildings* | 23% | 18% | –22% |
| Silver vs. Gold buildings | 12% | 15% | 25% |
| Gold vs. Platinum buildings* | 30% | 27% | –10% |

*Despite the negative "% Change" values here, graphical overlays showing probability distributions of impacts as in Figures 3 and 4 do show a greater degree of separation between these paired impact comparisons at different LEED certification levels.

**FIGURE 3A.** Overlay of probability distributions for carbon dioxide impacts before changes were made to LEED

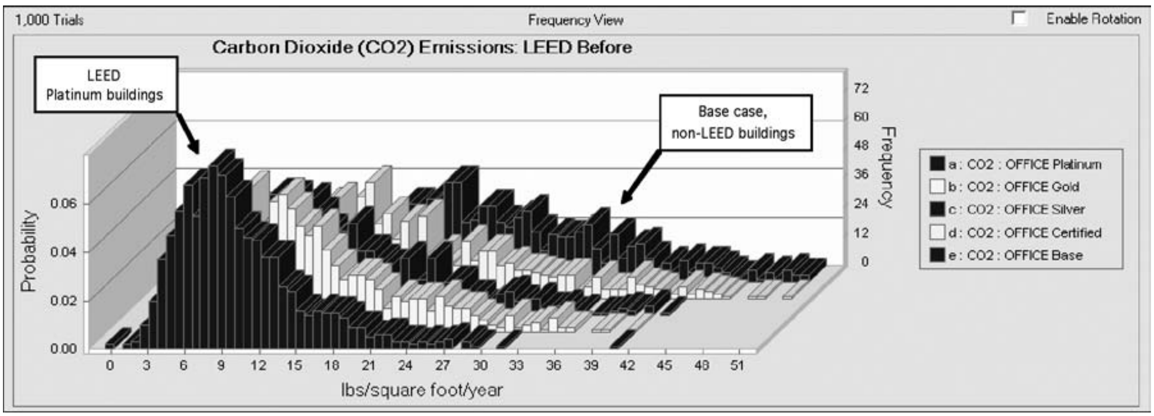
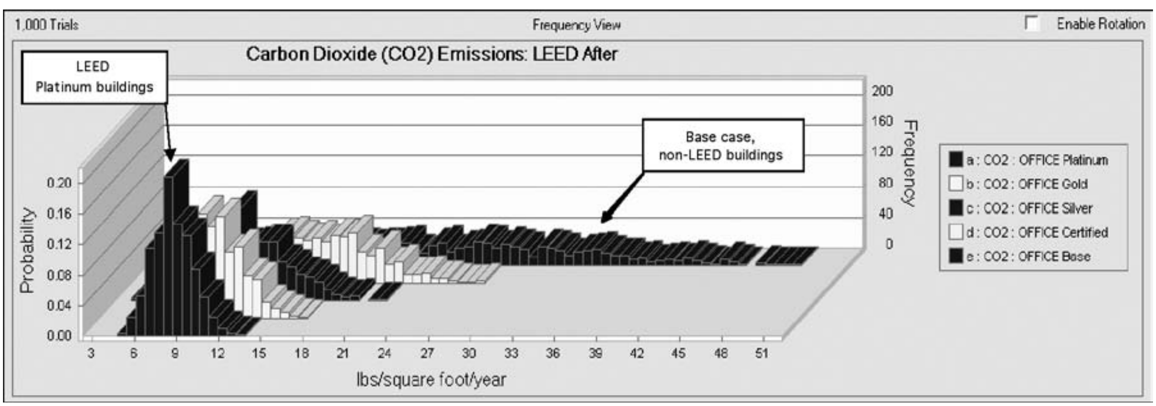



**FIGURE 3B.** Overlay of probability distributions for carbon dioxide impacts after changes were made to LEED



for the range of buildings from non-LEED buildings to LEED Platinum projects. Figures 4a and 4b illustrate the same patterns for particulate matter emissions. Overlays for the other environmental impacts analyzed in this project display similar trends. Notice that the alterations in LEED produce smaller ranges of impacts for each certified building level and the increase in separation between the impact distributions for each of the four LEED building levels as well as the base case, non-LEED building impacts.

The downside to using this form of scoring has to do with (1) the frequency with which the number of employees may change and (2) the variation in office programmatic needs which affect employee density. For item #1, consider that as businesses grow and shrink, which sometimes happens within short periods of time, the effective score of a LEED building would change. For item #2, offices which tend to have more large meetings or which have data processing centers (perhaps even for other offices' data) would tend to be at a disadvantage in this scoring scheme, unless rules were creating by first normalizing square foot values to account for this variation.

While the improvements in the overlap of distributions noted above are not insignificant in and of themselves, setting targets at levels which are cognizant of the larger global problems is critical. As such, Table 9 shows how the simulated carbon dioxide emissions of versions of LEED buildings before and after the suggested changes compare with the 50% carbon reduction goal of the Architecture

**FIGURE 4A.** Overlay of probability distributions for particulate matter emissions before changes were made to LEED

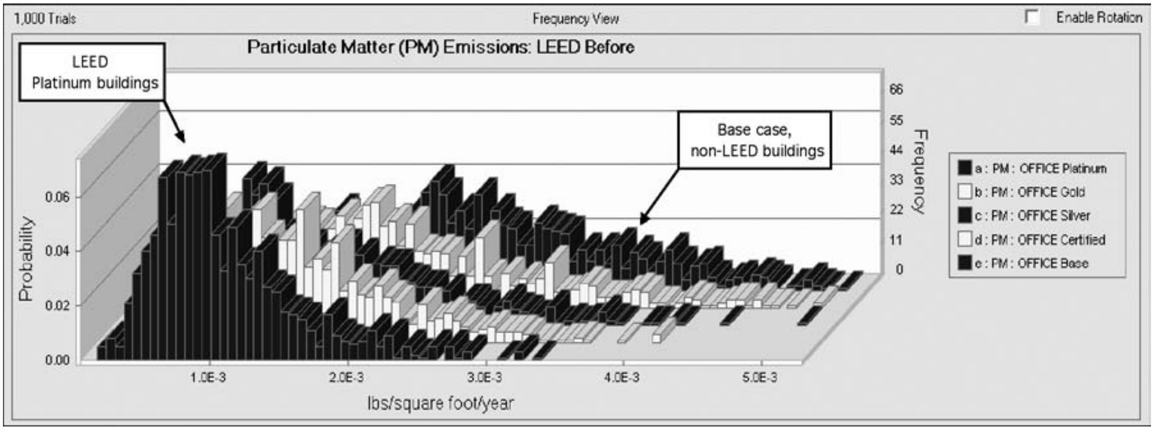



**FIGURE 4B.** Overlay of probability distributions for particulate matter emissions after changes were made to LEED

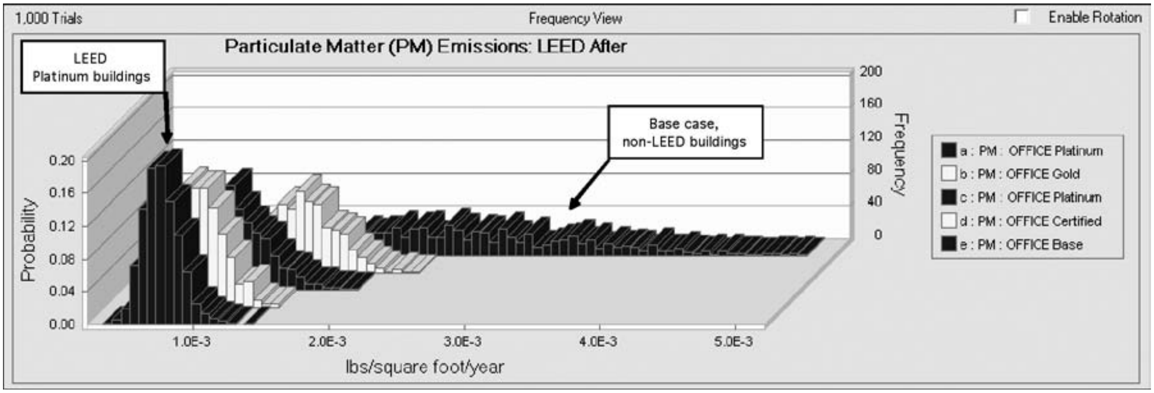


**TABLE 9.** The effect of different LEED schemes on whether a LEED building's carbon dioxide emissions meet or exceed Architecture 2030 Challenge goals*

| LEED Certification Level | LEED: Before | LEED: After |
|---|---|---|
| Certified | –31% | –46% |
| Silver | –46% | –58% |
| Gold | –54% | –64% |
| Platinum | –64% | –70% |

*The 2030 Challenge urges the design community to design buildings today with a 50% smaller carbon footprints compared to the existing building stock, with incremental moves towards zero carbon new buildings by 2030.

2030 Challenge. The simulated impacts from the new LEED rating scheme (i.e., "After") as suggested in this research shows that all levels meet this challenge except for the Certified level. "Before" and "After" scenarios include contributions from green energy purchases as obtained historically in LEED buildings or as shown in Table 3, respectively. Some of these are higher than the 2030 Challenge's suggested 20% cap on these purchases; however, per previous discussions related to item #3 in Table 3, the use of 50% caps for the "After" scenario" seems to be a reasonable bridge for the time being.

As for normalization, currently LEED for Homes is the only LEED rating program that addresses the issue of size versus the function of a building, i.e., the resource use or impact level per building user or use. In that program, as the home size increases, even while accounting for number of rooms, the points required to earn each certification level also increases. In the commercial arena, it seems appropriate to normalize impacts or benefits on a "per employee" basis; this is, in part, a recognition of the three goals of the "triple bottom line" of sustainability in the business sector (environmental quality, social equity and economic vitality).

Table 10 shows the substantially different measures of reductions in emissions in the standard versus normalized measures of performance. Note that regardless of building square footage and impact, this analysis indicates that, based on a very high performing LEED Silver building, for every 1% deviation from the average number of employees per square foot, the difference between normalized and non-normalized (as is currently measured) impact reduction for a LEED building changes by approximately 0.6%–0.8%. For example, if a building has 10% fewer employees than average and shows a non-normalized 35% reduction in carbon dioxide emissions compared to a non-LEED building, the normalized emission reduction may only be 28%. If the USGBC chose to score buildings in this way, it would be relatively easy to convert the air emission, waste generation and water consumption factors from Table 5 into factors normalized per employee per eGRID sub-region.

Operationalizing these suggested changes to LEED is logical next step. The authors propose that the changes to LEED suggested here could be made quite user friendly even while improving the environmental footprinting capacity of LEED. For example, by providing kWh and kBTU usage infor-

**TABLE 10.** Variation in sulfur dioxide impacts when normalized by number of office employees

| | # of employees* | lbs of SOx/ year/employee | Normalized per employee? No | Normalized per employee? Yes | Change in % emissions reduction |
|---|---|---|---|---|---|
| | | | % emissions reduction** | | |
| 25% fewer employees | 138 | 25 | –30% | –7% | –23% |
| 10% fewer employees | 166 | 21 | –30% | –22% | –8% |
| Average # of employees*** | 184 | 19 | –30% | — | |
| 10% more employees | 202 | 17 | –30% | –36% | 6% |
| 25% more employees | 230 | 15 | –30% | –44% | 14% |

*Based on a 46,000-square foot, LEED Silver building — the median size of a certified LEED building as of 12/2007
** Compared to an ASHRAE 90.1-compliant, non-LEED building
*** Assumes 250 square feet per employee as the average used in the LEED for Core and Shell Reference Guide

mation along with a project zip code, minimal effort would be required to allow outputs to be fed into a nutrition label program for LEED buildings, which is also currently being created by the authors. Note that a comprehensive, quantitative, scientific nutrition label for buildings, versus products, is currently non-existent in the US green building market. This would allow for greater transparency regarding the various types of benefits and impacts that investors, tenants, owners, customers and brokers could use in making building, leasing and purchasing decisions. For example, data used by EPA's PowerProfiler and made publicly available by OpenEco—a free on-line resource providing tools to aid in greenhouse gas tracking and reduction—links all US zip codes to an EPA eGRID sub-region, which would then facilitate impact estimation using the factors generated in this research by eGRID sub-region (as in Table 5).

## DISCUSSION

### *Fixing LEED—ensuring that we get what we think we're getting*

The "perfect" should not interfere with the progress facilitated by the "good." As such, while this research suggests needed changes to improve LEED, certifications and labels like LEED serve much of their purpose and address a great deal of opportunities for reducing negative impacts and increasing positive impacts from buildings by simply raising the level of awareness around these issues and suggesting areas for improvement. Clearly, LEED has stimulated a growing movement in green building, but the use of LEED as a policy and environmental management tool warrants closer scrutiny. As an illustration, consider that of ~94 cities and towns that have policies to encourage or mandate the use of LEED for public and/or private projects in their jurisdiction, 71% of these municipalities have also signed the US Mayors Climate Protection Agreement. It is likely that the mayors and council members in these cities see a direct correlation between the two initiatives, and while they are related, the implications of one on the other are unclear, as highlighted in the results of Phase I.

Accordingly, while the focus of the analyses and suggestions in this paper appear to emphasize the need for a scientific, quantitative basis for LEED—which is true—an equally important additional goal focuses on improving policy effectiveness, transparency and accurate communication to a broader group of interested parties—such as neighbors, environmental non-profits, city council members, owners, developers, real estate agents, banks, designers, customers, investors and concerned voters—who can help drive greater market share for green buildings. However, the adoption of changes like these and the effective acceptance, understanding and use of an enhanced LEED rating program depends on the successful completion of a number of important steps, which are described below.

### *Future work*

Next steps for implementing these changes include a number of considerations. One set of tasks would likely occur specifically within the USGBC and its community of direct stakeholders, such as (1) a consensus-based decision making process to assess which portions of this research as well as ideas from related investigations and efforts should be included in the next iteration of LEED, (2) comparable assessments using similar methodologies—such as probabilistic modeling based on empirical data—of the other sections of LEED (e.g., Water Efficiency) to understand ways to limit the variation in other environmental or health impacts from LEED projects, (3) a strategic analysis of whether LEED should remain a "green" building program versus a "sustainable" building program, as described earlier, and if the latter, how more economic and social issues can be better included, (4) an analysis of the proper weighting of impacts in each LEED category (e.g., Sustainable Sites) and across categories, which will differ depending on the pool of stakeholders being surveyed, (5) the act of transforming the models and data analysis in this research and related projects into a user-friendly tool that allows LEED users to enter basis data, such as zip code, and create nutrition labels such as those proposed here and (6) training on the use of and reasons to use a revised LEED program, such as that proposed here.

The other set of additional research required would likely be covered by the wider scientific, energy and sustainability community. These might include (1) the resolution of the legitimacy of the use of carbon credits and green energy purchases in accounting for a building's environmental impacts, (2) attempts to better quantify the co-benefits of carbon reduction strategies and their impacts on the accounting for other pollutants and (3) the creation of a wide-ranging and quantitative nutrition label program for LEED buildings. The authors have already begun work on such a nutrition label, which lays out a comprehensive framework for the display of impacts in great detail and states said impacts in terms that more stakeholders can identify with (e.g., equivalent truckloads of nuclear waste avoided, equivalent bus miles not driven because of particulate matter reductions). This research will be part of a future paper.

### *Conclusions*

By making the suggested changes to LEED, this research has shown that variability in impacts from LEED buildings could be reduced by 62% and the median magnitude could be reduced by 30%. Moreover, air emission, waste generation and water consumption factors have been created or compiled for nine environmental impacts for each of the 26 US EPA eGRID sub-regions, which allows for benchmarking and scoring LEED buildings according to regionally relevant baselines. In addition, impacts from LEED buildings under the proposed scheme show a 26% reduction in overlap between different LEED certification levels and a 68% reduction in impact overlap between non-LEED and LEED Certified buildings. Moreover, methods and motivation have been demonstrated for assessing the variability of impacts from other LEED categories, other green building programs and other eco-labels as well. The opportunities for evaluation abound—ecolabelling.org counts over 300 eco-labels worldwide (Ecolabelling.org 2008). The importance of normalizing impacts for commercial LEED buildings per employee or other user has also been demonstrated quantitatively. Essentially for every 1% change from the average "employee per square foot" values for a mid-level LEED-certified space, the percentage impact reduction changes by 0.6%–0.8%.

Finally, just as the bar for environmental performance should and does continue to rise for green buildings, so should the methods and tools for scoring, facilitating and promoting those buildings, as well their benefits and impacts. With 22,000 in attendance in Chicago for the USGBC's 2007 Greenbuild conference and "green" on the cover of every magazine at the grocery store, enthusiasm coupled with a steady but dangerous satisfaction with incremental improvement is a risk of which to be wary. Instead, the scale and urgency of many global problems—such as the need for 80% reductions in carbon dioxide emissions by 2050 or the projection that 36 states will face water shortages within five years—demand a re-doubling of efforts to change the way we meet our needs with buildings (US General Accounting Office 2003). A few thousand LEED-certified buildings will be exciting, but with 4.8 million commercial buildings and over 115 million households in the US, it will take more than this to move the needle in terms of US buildings' impacts and benefits. Perhaps a more robust building rating and communication system, such as those proposed in this research, can help with the mainstreaming of low-impact, high-performance building.

## ACKNOWLEDGEMENTS

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## NOTES

1. While all three terms, among others, are often used interchangeably, "high performance building" tends to focus on building features which reduce energy and water use while enhancing worker health and productivity. "Green building" may be used to describe buildings designs focused on reducing a building's environmental footprint. On the other hand, "sustainable building" might address a building's contribution to triple bottom line goals of economic, social and environmental concerns; it may also deal with more absolute or rigorous sustainability goals instead of what some would call a type of marginal or incremental sustainability addressed by other labels or programs.
2. This calculation relies on the US Energy Information Administration (EIA) 2003 CBECS database and assumes 1.7% annual growth in commercial buildings per year, for a total of ~82,000 new buildings per year. In 2007, USGBC data shows that ~14 Platinum and ~44 Gold buildings were certified.

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