# Spatial Variation Among Green Building Certification Categories: Does Place Matter?

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## 1. Introduction

Recently, the academic literature has seen numerous articles and much research attention concerning the meteoric growth of the green building sector. There are many definitions of green buildings, although they share a common emphasis on reducing the environmental impacts of the construction and maintenance of buildings. The United States Environmental Protection Agency (US EPA) offers the following comprehensive definition: "Green or sustainable building is the practice of creating healthier and more resource-efficient models of construction, renovation, operation, maintenance, and demolition" (US EPA, 2007). Larger issues of social justice, public health, and productivity can be linked to green buildings and sustainable development as well, although more in theory than in practice. Green buildings are a key aspect of the larger urban sustainability movement, complementing other strategies such as rooftop gardens (e.g. Mentens et al., 2006; Yuen and Hien, 2005), urban parks (e.g. Chiesura, 2004), and greenbelts/greenways (e.g. Amati and Yokohari, 2006; Frischenbrude and Pellegrino, 2006; Walmsley, 2006) in an effort to reduce urban ecological footprints. For the purposes of this study, green buildings are defined as buildings receiving accreditation from the United States

Green Building Council (USGBC) through the Leadership in Energy and Environmental Design (LEED) rating system.

The importance of building green as part of sustainable development has been demonstrated by numerous academic and governmental studies. The built environment is a significant consumer of natural resources and energy in the United States, accounting for 40% of energy consumption (US DOE, 2007), 65% of electricity consumption, 30% of greenhouse gas emissions, 30% of raw material use, and 136 million tons of waste output annually (USGBC, 2008a). Therefore, the adoption of more environmentally benign building techniques has the potential to greatly reduce energy consumption and greenhouse gas emissions (Brown and Southworth 2008).

The advantages of going green are not only to reduce environmental impact, but also to increase economic savings and health benefits over the long term. Numerous studies (e.g., Cassidy et al., 2003, Ries et al., 2006) quantify the profitability of green buildings for sale and for lease despite the potential for higher design and construction costs (an average of 5 percent over a standard building). Improved design and efficiency cut energy bills, operation expenses, and maintenance needs for building owners and operators in the long term.

As stated by Heerwagen (2001), “The real appeal of green buildings lies in their potential to create better building habitats, and to do so by incorporating design features that address health and well being in an integrated manner.” Improved indoor air quality and access to daylight and windows serve to promote physical and mental well-being (Heerwagen, 2001). Building-related illnesses are a real and often overlooked threat to workers’ health in developed nations; found in the modern office environment, they may impact 50% of industrialized workforces (Menzies and Bourbeau, 1997). Poor design and maintenance of buildings can lead to acute respiratory illnesses, allergies and asthma, and so-called “sick building syndrome” due to mold, moisture problems, and various indoor pollutants (Fisk, 2002).

Within green buildings, healthier workers are more productive workers, due to decreased levels of absenteeism and also to direct efficiency and productivity improvements. Fisk (2002) estimates savings and productivity gains from improved indoor environmental quality to be between $37B and $208B, admittedly a large range but impressive nevertheless in magnitude. However, measuring productivity, particularly for white-collar jobs, is a difficult task due to lack of a common metric and is also difficult to assess due to the lack of controlled experimental conditions (Ries et al., 2006).

Recent research has focused on the implications of the above findings outside of industry. The built environment has a profound impact not only on worker productivity and thus profits; healthier buildings can improve students’ performance in green schools. Kats (2006) demonstrates that school officials tend to shy away from green buildings, fearing increased design and construction costs. However, green schools cost on average less than 2% more than conventional schools to build, approximately $3/square foot, while yielding net financial benefits of $71/square foot, potentially enough savings to hire an additional full-time teacher (Kats, 2006).

Construction of green buildings has been particularly popular on university campuses. Cidell (2009) demonstrates that college towns fill many of the highest rankings in measurements of green buildings per capita in the United States. Increasingly, promoting green buildings is seen not only for its economic and environmental benefits; green credentials are a marketing and recruiting asset for America's universities (Egan, 2006). Universities are designing courses and class projects around on-campus green buildings, effectively incorporating the built environment into the classroom.

Numerous private, public, and non-profit organizations have adopted the mantle of green building from motivations spanning public interest to niche markets and profitability. Among the oldest, largest, and best-known players in the green building field is the United States Green Building Council (USGBC). The USGBC is a national non-profit organization dedicated to the promotion of sustainable building practices (USGBC, 2008a). It currently counts over 13 000 organizations and over 91 000 individuals among its members, representing a ten-fold increase in membership over the past eight years *(ibid.)*. Also, the USGBC has trained over 45 000 accredited professionals, who bring green building expertise to the architecture and engineering fields (*ibid.*).

The USGBC is perhaps best known for its Leadership in Energy and Environmental Design (LEED) sustainable building standards. Through the LEED program, the USGBC offers green building certification at four levels based on the number of points or credits earned through achievement of criteria in six broad categories: Sustainable Sites (SS), Materials/Resources (MR), Indoor Environmental Quality (IEQ), Water Efficiency (WE), Innovation/Design (I), and

Energy/Atmosphere (EA). Beyond a few prerequisites, building owners are free to choose from sixty-nine possible options to achieve the certified level (26-32 points), silver (33-38 points), gold (39-51 points), or platinum (52-69 points). First released in 2000, the LEED rating system has grown, and now embraces rating systems for specific uses and projects: New Construction, Existing Buildings, Commercial Interiors and Existing Buildings, Core and Shell, and Homes; Neighborhood Development, Retail, and Healthcare are currently in the pilot stages (USGBC, 2008a). The LEED program has grown tremendously over the past seven years, in late 2007 including 997 certified projects, totaling 114 million certified square feet, with 8 600 registered projects still under construction (Cidell, 2009). The adoption of the LEED rating system as the de facto green building metric may help to address concerns expressed in the literature regarding quantifiable standards to measure the “greenness” of sustainable buildings (Burnett, 2007).

Despite the somewhat intuitive importance of geographical constraints and local environmental conditions, little of the research surrounding green buildings has taken an explicitly spatial perspective. Considering the variability of environmental phenomena across space and their powerful influence on energy demands, cultural norms, physical constraints, and the construction and subsequent use of buildings, it is a shortcoming to overlook the role of geography in green buildings (Eliasson, 2000). This paper contributes a spatial perspective to the growing body of green building literature by determining if the distribution of points or credits earned in total and across categories varies among regions of the United States. The results will help determine to what extent green buildings are taking into account the demands and opportunities afforded by their local and regional environments, with an eye towards assisting the USGBC as they move forward in making their credit system regionally sensitive.

To answer these questions, this study employs classical and spatial statistics to measure and quantify the variation between regions of the country; i.e., do some regions outperform others in the construction of green buildings? We also examined variation among LEED certification categories; i.e., are some criteria adopted more consistently than others and is one criterion more likely to be adopted in one region than another? Anomalies among the certification criteria are identified and subject to further investigation. The following section describes the methodology of this study, followed by a presentation and discussion of results.

## 2. Methods

This paper considers all certified new construction LEED projects (LEED-NC) through December 2007 in the publicly available database from the USGBC, which lists the credits that each certified project achieved. LEED-NC includes commercial and institutional structures, including multifamily residential projects, as well as major renovations. These data were aggregated from the individual project level to the regional level using the US Environmental Protection Agency (EPA) regional classification system because it aggregates states according to common biophysical environments. The EPA system has ten regions, shown in Table 1.

Total points per LEED category were summed and ranked from highest to lowest. This process was conducted for absolute numbers of points and then standardized by population (based on the US Census Bureau, July 1, 2007 estimates). Basic descriptive statistics (standard deviations, means, and coefficients of variation) were also calculated for the absolute numbers of LEED points per category. Location quotients were calculated for each of the six LEED categories to assess the variability of concentration/dispersal for a given criterion across the United States. Location quotients (LQ) are a spatial analysis technique that measures concentration or dispersion of a given activity across space, with values greater than 1 demonstrating concentration and values less than one demonstrating dispersion. Again, the same sets of descriptive statistics were calculated for the location quotient values. The detailed results are provided in the appendix.

Eleven subcategories were then identified for further study because they represent the most place-specific LEED certification criteria, which were therefore expected to exhibit more spatial variability than the other, aspatial criteria. The eleven categories are listed in Table 2. The first subcategory, Site Selection, as well as the last two subcategories, Local/Regional Materials, are inherently spatial by definition in that they are based on the project site itself or a specified radius around it. The second and third subcategories, involving urban and brownfield redevelopment, are contingent on the existence of such sites, which tend to be constrained to certain places due to socioeconomic and geographic factors. The fourth subcategory, regarding public transportation, is also dependent on the previous existence of various facilities found unevenly across space. For the fifth and sixth subcategories, both related to water efficiency, water availability is uneven across the United States, and thus it is assumed that different regions of the country find water efficiency measures to be more or less of a priority due to local conditions. The green power subcategory is considered to be spatial because the viability of alternative energy sources, for example solar and wind power, is often highly dependent on local physical conditions and local utility policies and facilities. Construction waste management is considered spatially-specific due to the relatively local nature of waste disposal.

It is true that the selection of the above eleven subcategories is somewhat subjective; convincing arguments could be made for the inclusion of other subcategories, such as those related to stormwater management. However, the subcategories defined by this study are not meant to be exhaustive, but rather illustrative of the importance of geography in the implementation of green building standards.

As before, the points for these spatially-specific subcategories were summed and ranked from highest to lowest according to EPA region. The data were again standardized by population with the resultant per capita points summed and ranked from highest to lowest according to EPA region. Descriptive statistics were calculated for the absolute numbers of points. Location quotients were again tabulated for the eleven subcategories, in order to quantify the concentration/dispersion of a given criterion across the United States, and the same battery of descriptive statistics was calculated.

Thus far, only differences among LEED categories had been considered. In order to gain an idea of the differences among EPA regions, the same three descriptive statistics were calculated for each of the ten EPA regions. These calculations were performed for four distinct cases: general LEED categories in terms of points; general LEED categories in terms of location quotients; spatially-specific LEED categories in terms of points; and spatially-specific LEED categories in terms of location quotients.

To further investigate variance among general groups, several analysis of variance (ANOVA) tests were run using Statistical Package for the Social Sciences (SPSS) software. One-way ANOVA tests, including means plots and Scheffe post hoc tests, were run for several sets of data: among EPA regions using general categories, among EPA regions using spatially-specific categories, among the general LEED categories themselves, and finally among the spatially-specific LEED categories themselves.

Specific outlying cases were identified for further study from the results of the descriptive statistics and the Scheffe post hoc tests. Independent sample t-tests were run to compare a single group to the aggregate of other groups. This was done to compare the Sustainable Sites categories to the other five general LEED categories, and to compare the two outlying cases (Sustainable Sites 2 and 3) to the other ten spatially-specific categories. Additionally, several EPA regions (Regions 6, 7, 8) were isolated for further study based on the results of the Scheffe tests, and independent samples t-tests were run for both general and spatially-specific LEED categories for each of the three EPA regions.

Finally, one specific subcategory, Urban Redevelopment (SS 2), was identified for further investigation based on its unusual coefficient of variation scores and the independent samples t-test results. All buildings earning credit for Urban Redevelopment were mapped in ArcMap, a standard geographic information systems (GIS) program. From there, we compared the data to population distribution in order to see where green buildings meeting the Urban Redevelopment criterion are concentrated or missing.

## 3. Results

The results of the above analyses confirmed some predictions regarding the importance of geography and place in the implementation of the LEED standards, but also identified other unusual patterns.

### 3.1 Rankings

The rankings of the data suggest the existence of patterns in the spatial distribution of LEED buildings (see Appendix for detailed results). For the six major categories in terms of absolute number of points, four EPA regions consistently perform the best (Regions 3, 5, 9, and 10, covering the Mid-Atlantic, Upper Midwest, and West Coast) and three EPA regions consistently perform the worst (Regions 6, 7, and 8, covering the Great Plains and Rocky Mountains). This stratification of the data mostly reflects the relative number of population and thus green buildings in each region, and thus the opportunity to score points in any given category.

Per capita rankings of the six major categories paints a different picture. Here the stratification is even more pronounced, with three distinct layers: top (Regions 1, 3, 8, and 10, covering New England, the Mid-Atlantic, and the Northwest), middle (Regions 5, 7, and 9, covering the Midwest and Southwest) and bottom (Regions 2, 4, and 6, covering New York and the South). Region 10 ranks first in all categories, reflecting the mainstream nature of sustainability in the Pacific Northwest coupled with a relatively small population. Typically poor performers in sustainability, i.e. the South and South Central states, fill the bottom ranks. The inclusion of Region 2 (NY/NJ) among the bottom ranks may seem surprising, but is explained by a relative lack of green buildings considering the large population.

The ranking results of the eleven spatially-specific subcategories are more of a mixed bag. As before, the results roughly break down in terms of population. Regions 3, 5, and 9 have large cities (Philadelphia, Baltimore-Washington, Chicago, and Los Angeles), making some of the Sustainable Sites criteria easier or more desirable to achieve (i.e., public transport). Perennially green Region 10 also scores well, despite its smaller population. Surprisingly, relatively urban Region 1 in New England performs at average-level rankings. Regions 7 and 8 in the Great Plains fare poorly in these categories, perhaps because of their small overall populations (and thus demand for buildings) and also because of their relative lack of large metropolitan areas. Despite large populations and large cities, Regions 2 and 6 in the South perform rather poorly.

The per capita rankings of the subcategories largely reflect the per capita breakdowns for absolute number of points. Regions 1, 3, 8, and 10 dominate. Regions 1 and 3 enjoy large, dense cities, which may provide an impetus to achieve some of the more urban-oriented LEED criteria. The Pacific Northwest is well known for its sustainable tendencies, so it should come as no surprise that its small population coupled with a large number of LEED projects launches it into the top of the rankings. Interestingly, Region 8 (Rocky Mountains) fares well considering its relative lack of large urban areas, suggesting that green builders in this region are more attuned to local conditions and possibilities as seen in their inclusion of spatially-specific criteria. Despite containing large cities, Regions 2, 4, and 6 perform rather poorly. Also, it is interesting to note how Regions 7 and 9 jump in ranking from category to category, suggesting that their green development is strong only in some aspects and not all-around as in other regions.

**3.2 Location quotients**

The results in the appendix show, first, that some LEED categories have little variance; the LQ scores are all close to 1 (i.e. equal representation). These categories include Materials and Resources, Indoor Environmental Quality, and Innovation and Design. In other words, these three categories are implemented roughly equally across all regions. The remaining three categories (Sustainable Sites, Water Efficiency, Energy and Atmosphere) exhibit a greater range in LQ values. This finding suggests that for these categories, regions either have a high or a low concentration of points for the criterion, with little middle ground. Therefore, regional differences may play a greater role in these three categories. Since seven of our nine spatially-specific subcategories fall into one of these three categories, this further supports our selection of those subcategories. Overall, there is modest variation among the ten EPA regions for the six LEED categories, considering the modest spread in LQ scores. It is worth noting that the two driest areas of the country, Regions 8 and 9, score the lowest in Water Efficiency.

Among the eleven spatially-specific subcategories, Site Selection, Construction Waste Management, and Local/Regional Materials have the least variation in LQ scores. Most subcategories show a variety in LQ scores, with the categories of Urban Redevelopment, Brownfield Redevelopment, and Green Power showing the greatest variation. Altogether, these findings suggest a larger regional role in the implementation of LEED subcategories, which should be assisted in 2009 by the new, bioregionally-sensitive ratings system (USGBC 2008b). A few observations stand out: Region 9 in the Southwest scores very low for Brownfield Redevelopment, as does Region 4 in the South. Since these regions are part of the Sunbelt where urban growth is relatively new, it is not surprising that redevelopment of contaminated land would be minimal in these areas.  Despite being a mostly semi-arid area, Region 8 in the Rockies scores low on Water Efficiency.  Regions 6 and 7 in the Great Plains and south-central U.S. fare very poorly in Urban Redevelopment, while Region 10 in the Pacific Northwest performs very well, illustrating the emphasis on denser urban development in the Northwest.

**3.3 Standard deviations, means, coefficients of variation**

Means and standard deviations have little value for comparing categories.  Categories with large values will have larger standard deviations; this does not necessarily imply a greater spread to such a data set compared to others per se.  An alternative calculation is more effective. Therefore, the coefficients of variation (CV), a standardized value, were calculated by dividing the standard deviations by respective means.

For the general LEED categories in absolute points, the CV values range from a low of about 0.47 to a high of about 0.54, suggesting that the general dispersion of observations for this variable is minimal.  Sustainable Sites has the smallest CV and Energy and Atmosphere has the highest.  For the spatially-specific categories, the CV values have a much larger range, from a low of 0.461 (MR 5.2) to a high of about 0.709 (SS 2), suggesting greater dispersion in the data and thus greater variability across space.  For general LEED category location quotients (LQ), the CV values range from a low of about 0.050 (Indoor Environmental Quality) to a high of about 0.141 (Energy and Atmosphere).  For spatially-specific LQ values, the CV range is greater, from about 0.050 (Site Selection) to about 0.439 (Urban Redevelopment).  Across the board, the CV values suggest that the Sustainable Sites category stands out, with either unusually high or low coefficient of variation values.

Now we shift our focus to differences among EPA regions, not among LEED categories. The CV values for general LEED points are tightly clustered between 0.35 and 0.42 (Region 1 and Region 8, respectively), showing very little variation between implementation levels of LEED categories across regions. Spatially-specific LEED categories show greater variation, ranging from a low of 0.459 in Region 10 to a high of 0.601 in Region 6, again demonstrating that the choices made in meeting the LEED standard vary from place to place. The CV values for the LQs of general LEED categories range from 0.037 (Region 4) to 0.1522 (Region 9). Finally, the CV values for LQs of spatially-specific LEED categories again have a greater range, from a low of 0.055 (Region 3) to a high of 0.274 (Region 7). In other words, categories that are dependent to some extent on local conditions do in fact vary across space; building designers and owners are taking into account local conditions in choosing which LEED points to pursue.

**3.4 ANOVA**

The ANOVA results comparing EPA regions in terms of general categories were statistically significant ($p=0.000$). The Scheffe test suggests significant difference ($p<0.10$) between EPA Regions 6, 7, and 8 (roughly from the Mississippi River to the Rocky Mountains) and other regions. These three regions by far have the lowest means, contributing to their statistical difference. The ANOVA results comparing EPA regions in terms of spatially-specific categories were also statistically significant ($p=0.000$). Again, Regions 6, 7, and 8 generically prove to be statistically different from other regions with the lowest means.

The ANOVA results comparing the six general LEED categories were statistically significant (p=0.001). On the other hand, the only statistically significant pairings were between WE and IEQ and between IEQ and I. The difference shown by WE and I may be attributable to their low means, which is due to the low number of possible points in these categories. IEQ has the largest mean. The ANOVA results comparing the eleven spatially-specific categories were statistically significant (p=0.000). The statistically significant pairings involved SS 2 and SS 3, perhaps because of their very small means and the much larger means of the other categories. The ANOVA tests therefore confirm the above results that there are differences across space in the implementation of the LEED standards.

**3.5 T-tests**

The ANOVA tests proved a statistical difference exists among groups, but could not prove which groups were causing the difference. Due to irregular coefficients of variation, means, and standard deviations, a few categories were isolated for further investigation. A simple independent samples t-test was calculated to determine statistical difference between specific categories and all other categories. When the Sustainable Sites group was compared to the other five general LEED categories, it was not found to be significant. When the SS 2 (Urban Redevelopment) and SS 3 (Brownfield Redevelopment) groups were compared to the other ten general LEED categories, they were found to be significant.

EPA Regions 6, 7, and 8 were considered for further study based on the results of the ANOVA testing (Scheffe tests) described above. Independent samples t-tests were run twice for each region, once for general LEED categories and once for spatially-specific LEED categories. All six t-tests gave statistically significant results, all less than p=0.05, indicating significant differences. Considering the consistent ranking of these regions towards the bottom of the list, the results are not surprising, but they confirm that the South and South Central states lag behind the rest of the country in green buildings.

### 3.6 Urban Redevelopment

One subcategory, SS 2 (Urban Redevelopment), was identified for further study based on its consistently unusual coefficient of variation values in terms of both points and location quotients. Independent samples t-testing also confirmed that SS 2 is statistically different from the ten other subcategories. We mapped the distribution of these buildings across the country (see methods) to compare them to overall population distribution.

Not surprisingly, these buildings are overwhelmingly located in large urban areas. From Figure 2, the locations of green buildings that achieved the Urban Redevelopment credit seem to be concentrated in four areas: the Pacific Northwest, the Southwest, the Midwest, and the East Coast. As compared to population, the results further highlight the Pacific Northwest and Upper Midwest. The results also show a lack of buildings meeting this criterion across the South, which is perhaps not surprising given the relative youth of many of these cities. On the other hand, despite a wealth of older cities and higher population, the East Coast has not many more buildings than the Pacific Northwest. Scattered sites in the Rocky Mountains and Midwest are reminders that a major metropolis is not needed for *urban* redevelopment to occur, as in Springfield, MO, or Bozeman, MT.

## 4. Discussion

Common sense would suggest that green buildings and the criteria fulfilled to achieve certification would vary across the country due to differences in physical and human environments. One would expect site and situation characteristics to play a key role in many USGBC criteria, constraining what points are simplest to earn or most pressing to incorporate into a project. Our results show that significant variation does exist, both among EPA regions and LEED categories.

### 4.1 Variation by category

Generically, the statistics showed less variation by region among the six general categories than among the eleven spatially-specific categories, as one would expect. The standardized CV values for the general categories show little variation, suggesting the flexibility and case-specific nature of LEED certification (i.e., no one category dominates, and all are used uniquely by each project). Nevertheless, when the concentration of activity is calculated by LQs, one sees a breakdown among the six categories: SS, WE, and EA are often clustered together and MR, IEQ, and I are clustered together. One could argue that the first three categories are more sensitive to local sites and environments while the other three are somewhat more aspatial.

The eleven spatially-specific criteria show great variation in CV values for both general and LQ points. This is logical, considering the unique constraints site and situation play in each LEED project. Of the eleven categories, Urban and Brownfield Redevelopment are among the most variable. Regions have either high or low concentrations, probably reflecting the availability of urban and/or brownfield areas to redevelop in each region. Green Power also demonstrates some variability, reflecting the uneven availability of green power (although compliance can be achieved by purchasing tradable renewable certificates from an outside source (USGBC 2007)).

**4.2 Variation by region**

The geography of LEED-certified buildings in the United States exhibits regional variation at the broadest of levels as exhibited by the consistent stratification of category rankings both before and after standardization by population (i.e. per capita calculations), with the usual green suspects such as the Pacific Northwest dominating the top ranks and the same regions filling out the bottom rungs. This variation is not as visible in the CV values as measured for general and spatially-specific LEED categories, attesting to the flexibility of the LEED certification program; many different combinations of credits can lead to the same certification. However, the variation becomes apparent when location quotients are calculated, especially for spatially-specific criteria. Additionally, ANOVA testing identified EPA Regions 6, 7, and 8 as statistically different from all EPA regions, a finding later confirmed by independent samples t-tests. These results are likely due to the relative paucity of LEED-certified buildings in these regions. Mapping the data demonstrated the overwhelmingly urban orientation of at least one subcategory, Urban Redevelopment, showing particular prominence in the older cities of the Midwest and the newer cities of the Northwest.

In sum, spatial variation exists in the certification of green buildings across the country. This variation is less pronounced among regions, with a consistent pattern of high and low achievers. Variation is more pronounced when looking at differences among categories, especially among spatially-specific categories. In general, one observes expected greater variation among the eleven spatially-specific categories than among the broad, aggregate six categories, indicating that local environmental and social conditions *do* matter in the decisions made about by designers and contractors as to how to build green.

**5. Conclusion**

Two of the chief constraints facing every building project are its site and situation; geography plays a central role in determining what is possible and what is not in terms of incorporating a building into its surroundings. Cidell (2009) has noted the lack of a spatial perspective in the growing body of green buildings literature, despite the obvious importance of variations in local climate, terrain, and the existing built environment to the success of green building projects. This paper has demonstrated that spatial variation in the implementation of LEED standards does exist across the United States and that green building construction is uneven across the United States. This variability across criteria and across space underscores the intuitive fact that designers, architects, and builders take advantage of the flexibility allowed in the LEED certification process, and that they apply the criteria that best fit the budget, resource constraints, and human and physical environments of specific projects.

The research in this project only considered certified new construction projects in the publicly available database through December 31, 2007. Therefore the results found in this paper must be considered as a snapshot in time, especially in light of the thousands of projects currently under construction (including LEED for Homes) and the overall rapid growth in this field. As more complete data is made publicly available, further attention can be applied to this area of research, leading to more robust findings and a more comprehensive discussion of the role of space in green buildings and sustainability.

The relevance of these results to public policy is significant. The 2009 version of the LEED standards will incorporate regional differences in the form of priorities given to certain credits based on the regional physical environment (USGBC, 2008b). We have shown that different credits are taken up in different parts of the country, therefore justifying the regional approach. Similarly, as jurisdictions across the country implement policies to encourage or mandate green buildings in the public and/or private sector, our results suggest where such policies are most needed. While over three hundred such policies currently exist according to the USGBC's database, the majority were implemented in the last couple of years and therefore can not be expected to have an impact on the current distribution of green buildings; revisiting this topic in a few years' time will give us a better idea of how public policy is influencing the location of green buildings. In the meantime, as green building standards are improved to further incorporate the environmental and social constraints and imperatives of places, newly-constructed buildings will have a reduced impact on the natural environment, no matter where they are located.

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List of tables

Table 1: EPA Regions

| | |
|---|---|
| Region 1 | ME, MA, CT, VT, RI |
| Region 2 | NY, NJ |
| Region 3 | VA, DC, MD, WV, DE, PA |
| Region 4 | FL, GA, SC, NC, TN, KY, MS, AL |
| Region 5 | IL, IN, OH, MI, WI, MN |
| Region 6 | TX, OK, AR, LA, NM |
| Region 7 | MO, KS, NB, IA |
| Region 8 | CO, UT, WY, MT, ND, SD |
| Region 9 | CA, HI, AZ, NV |
| Region 10 | ID, AK, OR, WA |

Table 2: Spatially-Specific Subcategories

| | |
|---|---|
| SS 1 | Site selection |
| SS 2 | Urban redevelopment |
| SS 3 | Brownfield redevelopment |
| SS 4.1 | Public transportation |
| WE 3.1, 3.2 | Reduction in water usage |
| EA6 | Green power |
| MR 2.1, 2.2 | Construction waster management |
| MR 5.1, 5.2 | Local/regional materials |

Table 3: ANOVA Summary

| Comparing | To | Significant | F | P-Value |
|---|---|---|---|---|
| EPA Regions | EPA, General | Yes | 8.317 | 0.000 |
| EPA Regions | EPA, Spatially-specific | Yes | 11.496 | 0.000 |
| LEED Categories | General | Yes | 4.879 | 0.001 |
| LEED Categories | Spatially-specific | Yes | 6.019 | 0.000 |

Table 4: T-Test Summary

| Comparing | To | Significant | P-value |
|---|---|---|---|
| SS | General LEED | No | 0.353 |
| SS2 | Spatially-specific LEED | Yes | 0.001 |
| SS3 | Spatially-specific LEED | Yes | 0 |
| EPA 6 | Other Regions, General | Yes | 0.031 |
| EPA 7 | Other Regions, General | Yes | 0.004 |
| EPA 8 | Other Regions, General | Yes | 0.021 |
| EPA 6 | Other Regions, Spatially-specific | Yes | 0.01 |
| EPA 7 | Other Regions, Spatially-specific | Yes | 0 |
| EPA 8 | Other Regions, Spatially-specific | Yes | 0.003 |

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# Appendix: Data Tables

1: Total points by EPA region in general LEED categories

| EPA Region | SS | WE | EA | MR | IEQ | I | Total |
|---|---|---|---|---|---|---|---|
| 1 | 463 | 220 | 430 | 373 | 538 | 222 | 2247 |
| 2 | 268 | 157 | 320 | 272 | 468 | 189 | 1674 |
| 3 | 680 | 405 | 728 | 666 | 1060 | 468 | 4007 |
| 4 | 645 | 307 | 582 | 508 | 859 | 376 | 3277 |
| 5 | 741 | 345 | 651 | 632 | 1003 | 436 | 3808 |
| 6 | 289 | 127 | 195 | 208 | 345 | 164 | 1336 |
| 7 | 194 | 93 | 165 | 138 | 245 | 106 | 941 |
| 8 | 246 | 84 | 265 | 181 | 322 | 145 | 1244 |
| 9 | 767 | 316 | 988 | 602 | 959 | 452 | 4084 |
| 10 | 757 | 295 | 595 | 584 | 878 | 398 | 3507 |

2: Total points by EPA region for spatially-specific criteria

| EPA Region | SS 1 | SS 2 | SS 3 | SS 4.1 | WE 3.1 | WE 3.2 | EA 6 | MR 2.1 | MR 2.2 | MR 5.1 | MR 5.2 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 55 | 18 | 17 | 46 | 55 | 41 | 27 | 62 | 50 | 60 | 41 | 472 |
| **2** | 34 | 12 | 8 | 29 | 32 | 28 | 14 | 40 | 29 | 45 | 32 | 303 |
| **3** | 88 | 25 | 18 | 64 | 96 | 79 | 44 | 97 | 71 | 115 | 84 | 781 |
| **4** | 80 | 12 | 8 | 51 | 83 | 64 | 32 | 76 | 50 | 93 | 72 | 621 |
| **5** | 87 | 19 | 20 | 53 | 83 | 64 | 39 | 99 | 62 | 115 | 72 | 713 |
| **6** | 34 | 3 | 8 | 20 | 30 | 27 | 19 | 34 | 22 | 36 | 32 | 265 |
| **7** | 21 | 2 | 5 | 10 | 24 | 18 | 10 | 19 | 13 | 26 | 21 | 169 |
| **8** | 28 | 7 | 6 | 25 | 23 | 14 | 21 | 32 | 13 | 33 | 28 | 230 |
| **9** | 100 | 20 | 11 | 82 | 93 | 81 | 52 | 99 | 80 | 98 | 75 | 791 |
| **10** | 89 | 39 | 19 | 73 | 77 | 61 | 46 | 97 | 88 | 95 | 78 | 762 |

3: Ranking of EPA regions by absolute points

| Ranking | SS | WE | EA | MR | IEQ | I | Total |
|---|---|---|---|---|---|---|---|
| **1** | 9 | 3 | 9 | 3 | 3 | 3 | 9 |
| **2** | 10 | 5 | 3 | 5 | 5 | 9 | 3 |
| **3** | 5 | 9 | 5 | 9 | 9 | 5 | 5 |
| **4** | 3 | 4 | 10 | 10 | 10 | 10 | 10 |
| **5** | 4 | 10 | 4 | 4 | 4 | 4 | 4 |
| **6** | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **7** | 6 | 2 | 2 | 2 | 2 | 2 | 2 |
| **8** | 2 | 6 | 8 | 6 | 6 | 6 | 6 |
| **9** | 8 | 7 | 6 | 8 | 8 | 8 | 8 |
| **10** | 7 | 8 | 7 | 7 | 7 | 7 | 7 |

4: Ranking of EPA regions by per capita points

| Ranking | SS per cap. | WE per cap. | EA per cap. | MR per cap. | IEQ per cap. | I per cap. | Total per cap. |
|---|---|---|---|---|---|---|---|
| **1** | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| **2** | 1 | 1 | 1 | 1 | 1 | 3 | 1 |
| **3** | 8 | 3 | 8 | 3 | 3 | 1 | 3 |
| **4** | 3 | 8 | 3 | 8 | 8 | 8 | 8 |
| **5** | 9 | 7 | 9 | 9 | 9 | 9 | 9 |
| **6** | 7 | 9 | 5 | 5 | 5 | 5 | 5 |
| **7** | 5 | 5 | 7 | 7 | 7 | 7 | 7 |
| **8** | 4 | 4 | 2 | 4 | 2 | 4 | 4 |
| **9** | 2 | 2 | 4 | 2 | 4 | 2 | 2 |
| **10** | 6 | 6 | 6 | 6 | 6 | 6 | 6 |

5: Ranking of EPA Regions by spatially-specific LEED criteria in absolute points

| Ranking | SS 1 | SS 2 | SS 3 | SS 4.1 | WE 3.1 | WE 3.2 | EA 6 | MR 2.1 | MR 2.2 | MR 5.1 | MR 5.2 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 9 | 10 | 5 | 9 | 3 | 9 | 9 | 5 | 10 | 3 | 3 | 9 |
| **2** | 10 | 3 | 10 | 10 | 9 | 3 | 10 | 9 | 9 | 5 | 10 | 3 |
| **3** | 3 | 9 | 3 | 3 | 4 | 4 | 3 | 3 | 3 | 9 | 9 | 10 |
| **4** | 5 | 5 | 1 | 5 | 5 | 5 | 5 | 10 | 5 | 10 | 4 | 5 |
| **5** | 4 | 1 | 9 | 4 | 10 | 10 | 4 | 4 | 1 | 4 | 5 | 4 |
| **6** | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 |
| **7** | 2 | 4 | 4 | 2 | 2 | 2 | 8 | 2 | 2 | 2 | 2 | 2 |
| **8** | 6 | 8 | 6 | 8 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| **9** | 8 | 6 | 8 | 6 | 7 | 7 | 2 | 8 | 7 | 8 | 8 | 8 |
| **10** | 7 | 7 | 7 | 7 | 8 | 8 | 7 | 7 | 8 | 7 | 7 | 7 |

6: Ranking of EPA regions by spatially-specific LEED criteria in per capita points

| Ranking | Per cap. SS 1 | Per cap. SS 2 | Per cap. SS 3 | Per cap. SS 4.1 | Per cap. WE 3.1 | Per cap. WE 3.2 | Per cap. EA 6 | Per cap. MR 2.1 | Per cap. MR 2.2 | Per cap. MR 5.1 | Per cap. MR 5.2 | Per cap. Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| **2** | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 1 | 1 | 1 | 1 | 8 |
| **3** | 3 | 3 | 3 | 8 | 3 | 3 | 1 | 3 | 8 | 3 | 3 | 1 |
| **4** | 8 | 8 | 8 | 3 | 8 | 9 | 3 | 8 | 3 | 8 | 9 | 3 |
| **5** | 9 | 9 | 5 | 9 | 9 | 8 | 9 | 9 | 9 | 9 | 8 | 9 |
| **6** | 5 | 2 | 7 | 5 | 7 | 7 | 5 | 5 | 5 | 7 | 7 | 5 |
| **7** | 7 | 5 | 2 | 2 | 5 | 5 | 7 | 7 | 2 | 5 | 5 | 7 |
| **8** | 4 | 4 | 9 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| **9** | 2 | 7 | 6 | 7 | 2 | 2 | 6 | 2 | 7 | 2 | 2 | 6 |
| **10** | 6 | 6 | 4 | 6 | 6 | 6 | 2 | 6 | 6 | 6 | 6 | 2 |

7: Location quotient scores by EPA region for general categories

| EPA Region | LQ SS | LQ WE | LQ EA | LQ MR | LQ IEQ | LQ I |
|---|---|---|---|---|---|---|
| 1 | 1.065965 | 1.088912 | 1.016354 | 1.041481 | 0.936816 | 0.873176 |
| 2 | 0.828217 | 1.04308 | 1.015252 | 1.019434 | 1.093869 | 0.997834 |
| 3 | 0.877919 | 1.12411 | 0.96492 | 1.042799 | 1.03505 | 1.032235 |
| 4 | 1.018235 | 1.041922 | 0.943248 | 0.972597 | 1.025632 | 1.014059 |
| 5 | 1.006668 | 1.007617 | 0.907953 | 1.041276 | 1.030573 | 1.011909 |
| 6 | 1.119068 | 1.057233 | 0.775189 | 0.976793 | 1.010387 | 1.084899 |
| 7 | 1.06654 | 1.099174 | 0.931266 | 0.9201 | 1.018712 | 0.995562 |
| 8 | 1.023009 | 0.750987 | 1.131371 | 0.912859 | 1.012769 | 1.030148 |
| 9 | 0.971571 | 0.860547 | 1.284845 | 0.924818 | 0.918772 | 0.978148 |
| 10 | 1.11667 | 0.935534 | 0.901074 | 1.044775 | 0.979566 | 1.002996 |

8: Location quotient scores by EPA region for spatially-specific categories

| EPA Region | SS 1 | SS 2 | SS 3 | SS 4.1 | WE 3.1 | WE 3.2 | EA 6 | MR 2.1 | MR 2.2 | MR 5.1 | MR 5.2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.97 | 1.24 | 1.53 | 1.0987 | 0.9985 | 0.93 | 0.961 | 1.0242 | 1.1318 | 0.9067 | 0.82919 |
| 2 | 0.93 | 1.29 | 1.12 | 1.079 | 0.905 | 0.9894 | 0.776 | 1.0293 | 1.0226 | 1.0593 | 1.00814 |
| 3 | 0.93 | 1.04 | 0.98 | 0.9238 | 1.0533 | 1.083 | 0.946 | 0.9684 | 0.9713 | 1.0503 | 1.02669 |
| 4 | 1.07 | 0.63 | 0.55 | 0.9259 | 1.1453 | 1.1034 | 0.866 | 0.9542 | 0.8602 | 1.0682 | 1.10676 |
| 5 | 1.01 | 0.87 | 1.19 | 0.838 | 0.9975 | 0.961 | 0.919 | 1.0826 | 0.9291 | 1.1504 | 0.96395 |
| 6 | 1.06 | 0.37 | 1.28 | 0.8508 | 0.9701 | 1.0909 | 1.204 | 1.0004 | 0.887 | 0.969 | 1.1527 |
| 7 | 1.03 | 0.38 | 1.26 | 0.6671 | 1.2169 | 1.1403 | 0.994 | 0.8766 | 0.8219 | 1.0973 | 1.18616 |
| 8 | 1.01 | 0.99 | 1.11 | 1.2254 | 0.8569 | 0.6517 | 1.534 | 1.0848 | 0.6039 | 1.0234 | 1.1621 |
| 9 | 1.05 | 0.82 | 0.59 | 1.1687 | 1.0075 | 1.0964 | 1.104 | 0.9759 | 1.0806 | 0.8837 | 0.9051 |
| 10 | 0.97 | 1.66 | 1.06 | 1.08 | 0.8659 | 0.8571 | 1.014 | 0.9925 | 1.2339 | 0.8892 | 0.97713 |

9: Descriptive statistics for EPA regions, general LEED categories, total points

| EPA Region | Mean | Std Dev | CV |
|---|---|---|---|
| 1 | 374 | 130.2101 | 0.35 |
| 2 | 279 | 110.0509 | 0.39 |
| 3 | 668 | 230.9029 | 0.35 |
| 4 | 546 | 198.2578 | 0.36 |
| 5 | 635 | 232.6479 | 0.37 |
| 6 | 221 | 81.15335 | 0.37 |
| 7 | 157 | 56.98216 | 0.36 |
| 8 | 207 | 86.9009 | 0.42 |
| 9 | 681 | 272.3363 | 0.4 |
| 10 | 585 | 216.6109 | 0.37 |

10: Descriptive statistics for EPA regions, spatially-specific LEED categories, total points

| EPA Region | Mean | Std Dev | CV |
|---|---|---|---|
| 1 | 39.41667 | 19.4724 | 0.494014 |
| 2 | 25.41667 | 13.31751 | 0.523968 |
| 3 | 65.33333 | 35.29186 | 0.540181 |
| 4 | 52.08333 | 31.3208 | 0.601359 |
| 5 | 59.83333 | 34.06367 | 0.569309 |
| 6 | 22.58333 | 11.65768 | 0.516207 |
| 7 | 14.66667 | 7.889387 | 0.537913 |
| 8 | 19.83333 | 9.861157 | 0.497201 |
| 9 | 66.66667 | 34.81988 | 0.522298 |
| 10 | 64.33333 | 29.53375 | 0.459074 |

11: Descriptive statistics for EPA regions, general LEED categories, location quotients

| EPA Region | Mean | Std Dev | CV |
|---|---|---|---|
| **1** | 1.0037839 | 0.082747262 | 0.08243534 |
| **2** | 0.9996143 | 0.090322397 | 0.09035725 |
| **3** | 1.0128389 | 0.08324422 | 0.082189 |
| **4** | 1.0026156 | 0.037081792 | 0.03698505 |
| **5** | 1.0009993 | 0.047643064 | 0.0475955 |
| **6** | 1.0039279 | 0.123088845 | 0.12260726 |
| **7** | 1.0052256 | 0.071522644 | 0.07115084 |
| **8** | 0.9768571 | 0.130573581 | 0.13366702 |
| **9** | 0.9897835 | 0.150660845 | 0.15221596 |
| **10** | 0.9967692 | 0.077359961 | 0.0776107 |

12: Descriptive statistics for EPA regions, spatially-specific LEED categories, location quotients

| EPA Region | Mean | Std Dev | CV |
|---|---|---|---|
| 1 | 1.0563112 | 0.19493885 | 0.1845468 |
| 2 | 1.01918861 | 0.13023716 | 0.12778514 |
| 3 | 0.99812889 | 0.05461054 | 0.05471291 |
| 4 | 0.93404067 | 0.19794338 | 0.21192159 |
| 5 | 0.99215445 | 0.11174628 | 0.11262992 |
| 6 | 0.98563369 | 0.24336374 | 0.24691094 |
| 7 | 0.97041241 | 0.26559405 | 0.27369193 |
| 8 | 1.02286402 | 0.25982816 | 0.25402024 |
| 9 | 0.97132195 | 0.1642224 | 0.16907103 |
| 10 | 1.05492902 | 0.22937743 | 0.217434 |

13: Descriptive statistics for general categories, total points

| | SS | WE | EA | MR | IEQ | I | Total |
|---|---|---|---|---|---|---|---|
| **Standard Deviation** | 237.2 | 114.16 | 263.69 | 205.15 | 314.6 | 143 | 1251.28 |
| **Mean** | 505 | 234.9 | 491.9 | 416.4 | 667.7 | 296 | 2612.5 |
| **CV** | 0.47 | 0.486 | 0.5361 | 0.4927 | 0.471 | 0.48 | 0.47896 |

14: Descriptive statistics for spatially-specific subcategories, total points

| | SS 1 | SS 2 | SS 3 | SS 4.1 | WE 3.1 | WE 3.2 | EA 6 | MR 2.1 | MR 2.2 | MR 5.1 | MR 5.2 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Std Dev** | 30.277 | 11.136 | 5.85 | 23.8516 | 30.0081 | 25.1133 | 14.48 | 32.108 | 27.5754 | 35.1953 | 24.6408 | 251.31 |
| **Mean** | 61.6 | 15.7 | 12 | 45.3 | 59.6 | 47.7 | 30.4 | 65.5 | 47.8 | 71.6 | 53.5 | 510.7 |
| **CV** | 0.4915 | 0.7093 | 0.4875 | 0.52653 | 0.50349 | 0.52648 | 0.476 | 0.4902 | 0.57689 | 0.49155 | 0.46057 | 0.4921 |

15: Descriptive statistics for general categories, location quotients

| | SS | WE | EA | MR | IEQ | I | Total |
|---|---|---|---|---|---|---|---|
| **Standard Deviation** | 0.095344 | 0.118178 | 0.13953 | 0.055273 | 0.050414 | 0.053796 | 0.095344 |
| **Mean** | 1.009386 | 1.000912 | 0.987147 | 0.989693 | 1.006215 | 1.002096 | 1.009386 |
| **CV** | 0.094458 | 0.11807 | 0.141347 | 0.055848 | 0.050103 | 0.053684 | 0.094458 |

16: Descriptive statistics for spatially-specific subcategories, location quotients

| | SS 1 | SS 2 | SS 3 | SS 4.1 | WE 3.1 | WE 3.2 | EA 6 | MR 2.1 | MR 2.2 | MR 5.1 | MR 5.2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Std Dev** | 0.05 | 0.41 | 0.3 | 0.1733 | 0.1152 | 0.1499 | 0.213 | 0.0618 | 0.1779 | 0.093 | 0.11847 |
| **Mean** | 1 | 0.93 | 1.07 | 0.9858 | 1.0017 | 0.9903 | 1.032 | 0.9989 | 0.9542 | 1.0098 | 1.03179 |
| **CV** | 0.05 | 0.44 | 0.28 | 0.1758 | 0.115 | 0.1513 | 0.206 | 0.0619 | 0.1865 | 0.0921 | 0.11482 |