

A Closer Look at How LEED Buildings Achieved Sustainability

Prateek Jain, MS Candidate
Purdue University
West Lafayette, Indiana

Buildings are not manufactured products; their design, construction and operation are necessarily complicated and specialized endeavors. Heavy customization according to local conditions and functional requirements implies that ‘sustainability’ has different meanings for different buildings. Mindful of this diversity, US Green Building Council’s (USGBC) flagship building assessment program, LEED, provides a cross-cutting tool to define and evaluate best practices in sustainable design, construction and operation. This makes LEED inherently flexible – giving certification-seekers the opportunity to choose strategies they will pursue to score points on the LEED scorecard. Taking advantage of this flexibility, projects approach LEED in a variety of ways and no two LEED-certified buildings are exactly the same. The author, and other researchers in the past, have considered it a worthwhile endeavor to investigate trends in credit-achievement. In this paper, the author has analyzed relationships between LEEDv3 projects characterized by space use and credit-achievement patterns. Analysis has revealed frequently and rarely achieved credits, energy performance variation among buildings, and systemic deviations from the overall credit-achievement trends. This helps certification-seekers to better formulate their LEED strategies and the USGBC to make data-driven adjustments to the scorecard, as well as justify dedicated rating systems for different building types and alternate compliance paths.

Key Words: Sustainability, LEED, credit achievement trends

Introduction

One of the most prominent calls to action of our time – sustainable development – has profound impact on the way the building, transportation and industrial sectors develop. While it has a standard definition, the ways in which ideas of sustainable development find practical implementation vary widely (Palmer, Cooper & Van der Vorst, 1997). The author’s research deals with the variations in its application particular to the building sector, where sustainable development often boils down to ‘green building’.

A multi-family residential building project’s sustainable design choices might differ from an office building’s in the quest to be labelled ‘green’. Strategies for a data center or a warehouse might differ from these furthermore. So how does one decide if a building is ‘green’ enough? How do these design strategies vary with the building type? The author’s research attempts to explore the same, so that standards of green building may be made more suitable to accommodate these differences effectively. Having the same performance requirements for different building types might systemically hinder or favor one building type over another, so the author hopes that the knowledge gained from this exercise would help level the playing field.

Green building - unlike ‘sustainable development’- lacks a formal definition, but is rather defined by building assessment/rating tools (Zuo and Zhao, 2014). Building assessment tools perform the dual function of stating various sustainability objectives in actionable language, and providing a means for third-party verification of their achievement. Foremost among these tools in the United States is LEED (Leadership in Energy and Environmental Design) an acronym that lends itself to somewhat fitting wordplay as a buzzword, given its leadership in creating awareness about sustainable construction and design practices in the US construction industry.

The US Green Building Council’s (USGBC) LEED rating system, explained in detail in subsequent sections, gives certification-seekers the flexibility to choose their own strategies to fulfill the different sustainability criteria. This flexibility is well-warranted, because the construction and operation of buildings affect the triple-bottom-line in a variety of ways (energy consumption, potable water use, light pollution, etc), and thus a variety of strategies exist to minimize the undesirable effects (optimizing energy performance, water-efficient landscaping, etc). This leads to substantial diversity in the way projects achieve LEED certification, and examining these trends can provide valuable insight to both the curators of rating systems and seekers of certification.

The LEED Scorecard: Credit Accessibility and Effectiveness

The Rating System

Projects can achieve LEED certification using the appropriate rating system for their type of construction (New Construction, Existing Buildings, Commercial Interiors, Core and Shell, Neighborhood Development or Homes), by scoring at least 40 of the possible 100 points on the LEED Scorecard and meeting the mandatory pre-requisites. Points are attained by achieving credits, which are sustainability performance requirements stated in measurable metrics, for instance 'Outdoor Air Delivery Monitoring'. Credits are grouped under five primary categories – Sustainable Sites, Energy and Atmosphere, Water Efficiency, Indoor Environmental Quality and Materials and Resources. Innovation and Design and Regional Priority are additional categories that can account for bonus points. The complete checklist that forms the scorecard can be found on the USGBC website.

Development of the Credit Matrix

These credits are developed by volunteer experts in different Technical Advisory Groups, who come up with best practices and measurable levels of achievement using a consensus-based approach. A credit weighting tool is used to assess relative impact of each of these credits across 13 impact categories based on the EPA's TRACI Project (Bare et al., 2003) like 'Greenhouse Gas Emissions', 'Eutrophication', 'Ecotoxicity', etc. Points are allotted to credits based on these relative weights, with higher points associated for those credits that have high impact in 'heavier' impact categories. For LEED v4 however, the USGBC used seven new impact categories that were defined specifically to align with LEED goals.

While impact categories form the primary basis of the credit matrix, market considerations of achievement and issues related to adoption are taken into account by the Market Advisory Committee and Implementation Advisory Committee. Often these considerations might be at odds, but a balance is essential to maintain, as stated in the LEED v4 Points Allocation Process (USGBC, 2013, p. 11) –

> *"USGBC has always sought to balance the technical complexity necessary for LEED to be an effective environmental assessment methodology with a market focus enabling widespread adoption. By underpinning the market friendly "face" of LEED with a robust, scientifically grounded and academically respected prioritization process, USGBC hopes to further the market uptake LEED has experienced, but with a rating system that is increasingly more informed and effective at accomplishing the goals it was created to accomplish."*

Achievability Considerations

Technical feasibility of attempting a credit, documentation effort required and cost-effectiveness are not explicitly considered in the credit development. Instead, it is assumed that historic credit achievement trends would be a reflection of the industry's perception of these factors associated with each credit. In a document addressing Frequently Asked Questions about the LEED 2012 Weighting Process, the USGBC (2013, p. 5) stated this in response to a question about consideration of cost-effectiveness of credits –

> *"Cost effectiveness of a strategy is not considered within the weightings process. It is assumed that the market will find the most cost effective strategy to obtain a desired outcome or fulfill a requirement."*

These assumptions then make it extremely worthwhile to investigate historic credit achievement trends in ways that would offer actionable inferences. Specific questions that the author is trying to answer is listed in the 'Data Source and Basis of Analysis' section, immediately followed by the Analysis and Discussion section.

Previous Research

The difficulties faced by LEED project managers in selecting credits to pursue have been acknowledged (Cheng and Ma, 2013) and attempts to assist them in the credit-selection process by identifying indirect influences and local climate been made (Schiavon and Altomonte, 2014; Ravindu et al., 2015). The prevalence of LEED in certain geographic areas has been explained (Cidell, 2009; Cidell and Beata, 2009) as well as its relationship with public policy and political party (Choi and Miller, 2012).

Two groups of researchers have conducted investigations similar to the author's present study, analyzing general credit achievement trends. Ma and Cheng (2016) recently published their analyses in which they identified the top five and bottom five credits with respect to Percentage of Average Score – a way of equating binary credits with multi-level credits, tested strength of relationships between those credits the USGBC had listed as related credits, and examined correlation of credit-achievement with certification level. However, their results were based on sample of 1000 LEED v3 NC projects, and did not provide an analysis between different building characterizations.

Todd, Pyke and Tufts (2013) also presented analysis of credit-achievement trends for the entire population of New Construction buildings certified using the version of LEED preceding v3, which was LEED v2.2. The characterized buildings by owner/investor type, geography and gross area, observing trends in certification level over time and within specific credits.

Major findings from the above study revealed that

- Materials Reuse (1%), Rapidly Renewable Materials (2%), Building Reuse (10%), Innovative Wastewater Treatment (15%) and On-site Renewable Energy (15%) were the credits with lowest achievement rates
- Water Use Reduction (95%), Low-emitting Paints and Coatings (95%), Low-emitting Adhesives and Sealants (92%) and Recycled Content (92%) were credits with highest achievement rates
- Over the years, the trend was a shift towards higher levels of certifications
- There was little change in credit achievement rates for most credits over the years

The primary knowledge gap appears to be a breakdown of these credit trends with respect to functional characteristics of buildings or 'Space-use type' and level of urbanization of its location. This would be beneficial to customize rating systems or specific credits so as to tackle any systemic advantage or disadvantage a building might have. For instance, retail buildings, by virtue of their commercial activity, would have adequate glazing for display purposes – which might help them achieve the daylighting credit more easily.

Why hasn't such an analysis been performed by authors in the past? One reason could be that dedicated rating systems already exist for many of these 'Space-use' types - like LEED v3 BD+C Retail, Healthcare, Schools, Data Centers, Warehouses and Distribution Centers, and thus inter-class variability within New Construction might have been overlooked. Despite the existence of these specialized systems, however, a substantial number of buildings with these types of space use go for LEED v3 New Construction, which warrants such an analysis.

Data Source and Basis of Analysis

Detailed data with regard to any LEED certified project's characteristics (Space-use type and level of urbanization, among others) and credit-achievement details can be found on the GBIG website, which was also used by Todd, Pyke and Tufts (2013) in their analysis. The author had access to a dataset of 4597 LEED v3 NC projects that had acquired certification as of early June, 2015.

Assumptions

- *With the exception of EAc1 – Optimize Energy Performance – which is the single most important credit (worth 19 points) and has been analysed separately – credit achievement was considered a binary variable (Yes/No) for all other credits, even if they offered intermediate levels of achievement. The rationale behind this simplification for multi-level credits like WEc1 (0, 2 or 4) was to determine how many projects are achieving* *even the lower level of performance expected for LEED in these credits, which is not evident from a combined analysis tool such as the Percent Average Score (PAS) used by Ma and Cheng (2016).*

- *The Innovation in Design category was not accounted for separately, and Regional Priority points were added to the original credits they stemmed from.*

Table 1 lists the author's assessment of some questions that can be asked, how credit-trends information that would be useful in answering these questions, and how that information can be used by either certification-seekers (CS) or certification-developers (CD).

Table 1: Basis of Analysis

Questions	Information	Use of Information
Are some types of buildings more or less likely than building types to achieve a certain credit?	Noting significant deviations in specific building types from the general trend of credit achievement	CDs can identify if some building types are systemically advantaged or disadvantaged with respect a particular credit, and offer alternative compliance paths if required CSs can tailor their credit selection strategy in light of the past success/failure of their peers
Are some credits frequently achieved by a majority of LEED projects while others are rarely achieved?	Credits with lowest achievement rates across the building spectrum Credits with highest achievement rates across the building spectrum	CDs can make adjustment to compliance paths of the toughest credits, so as to increase adoption, or adjustments for easiest credits so as to increase environmental impact robustness CSs can evaluate the amount of effort that would be required for different credits at a glance
What characteristics of buildings are important factors in the likelihood of achieving a particular credit?	Variability of credit achievement trends within the categories of buildings according to particular method of characterization	CSs can know how to classify their peers and observe their trends

The statistical or graphical method used to answer each of these questions is explained in the subsequent section along with its results.

Analysis and Discussion

Low-Hanging Fruit and High-Hanging Fruit

To answer the second question from Table 1, Percentage Achievement Rates (PARs) for the 45 (EAc1/IDc/RPc not included) credits were calculated for the entire population of projects.

Percentage Achievement Rate (A, C) = (Number of Type A Projects Achieving Credit C) / Total Type A Projects

Figure 1 shows the achievement trends for all credits. As can be clearly seen, three credits in the Materials and Resources category – Rapidly Renewable Materials (MRc6), Building Reuse – Interior Non-Structural Elements (MRc1.2), and Materials Reuse (MRc3) – are very rarely achieved, having less than 5% frequency of achievement.

In contrast, Low-Emitting Materials – Paint and Coatings (EQc4.2), Construction IAQ Management Plan – During Construction (EQc3.1), and Construction Waste Management (MRc2) have achievement rates greater than or equal to 90% - which is not surprising, given these are standard industry practices and code requirements in many cases.

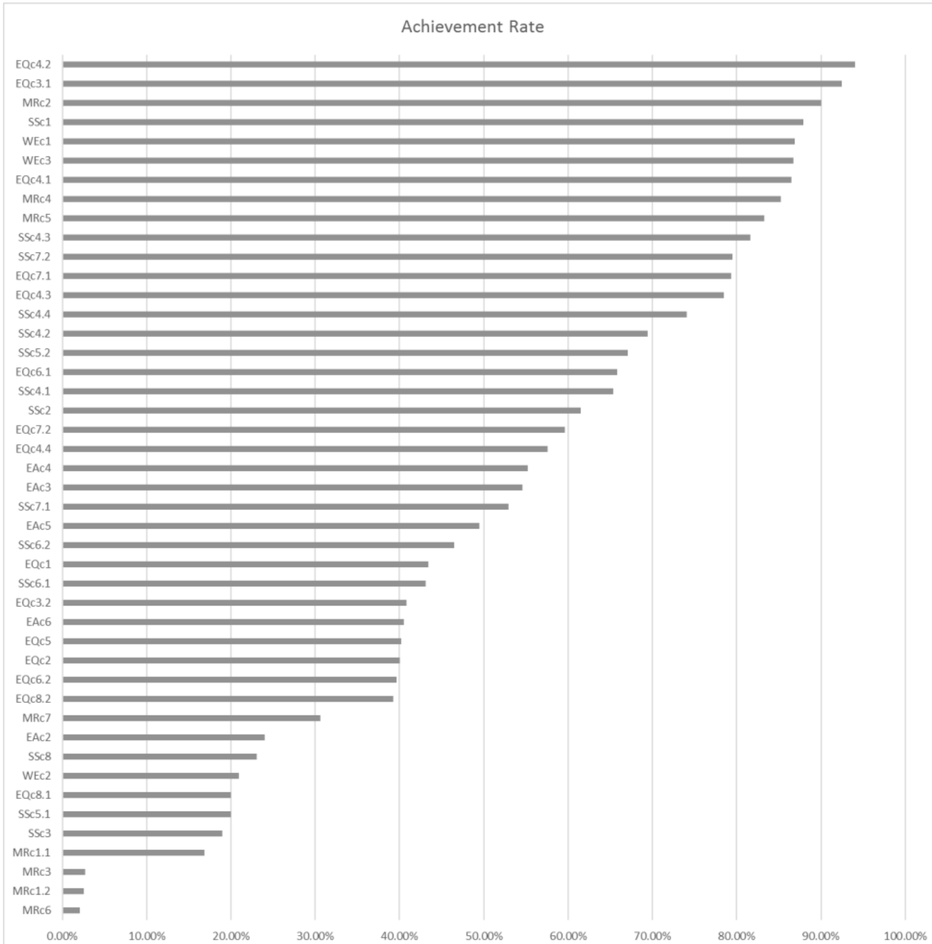

Figure 1: Percentage achievement rates across all credits

Energy Performance

From patterns evident in Figure 2, the lowest-performing building types with respect to Energy Performance are Multi-Family Residential, Health Care, Lodging and Industrial Manufacturing. For hospitality and residence buildings, occupants would have a high degree of autonomous control over energy consumption, which could be a contributing factor. For healthcare and industrial manufacturing, process loads would constitute a substantial portion of the total energy load, making savings more difficult.

Warehouse and Distribution Centers showed the highest average score in energy performance, probably enhanced by factors like limited full-time equivalents and occupants and greater autonomy over building systems for building operators.

It would be worthwhile to note that specialized rating systems exist for specialized building types in LEED v3 and even more have been included in LEED v4 to account for these systemic differences. The author's analysis then serves to reinforce the basis for creating separate systems for these building types, or offering alternate compliance paths.

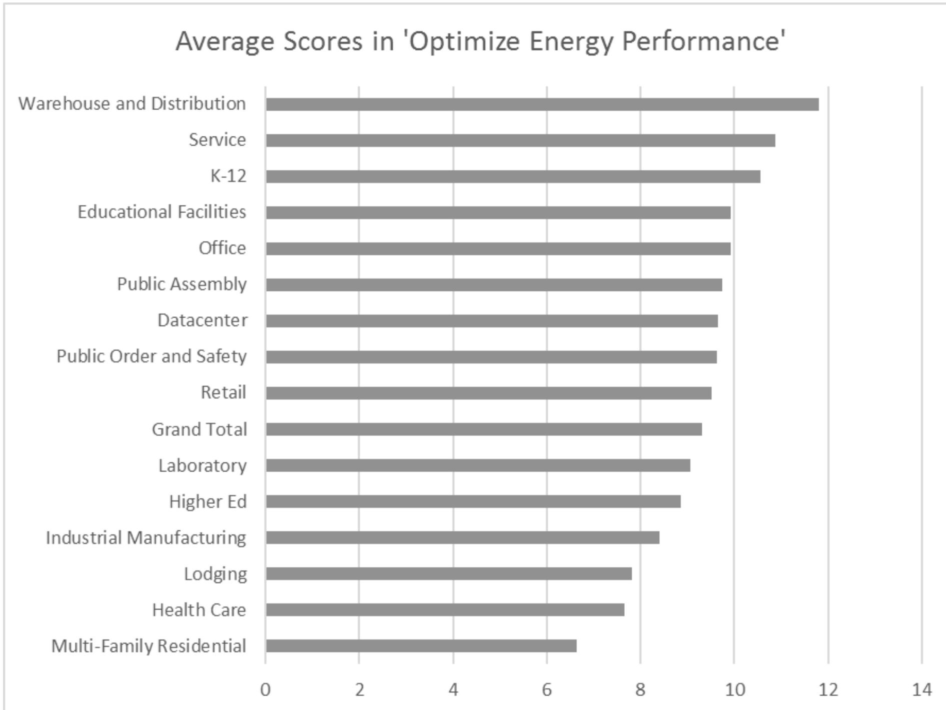

Figure 2: Average points scored in EAc1 across space use categories

Systemic Preferences of Building Types in Achieving or Avoiding Credits

Before examining deviant categories with respect to credit-achievement trends for a characterization, it's worthwhile to examine if the categories have meaningful differences among them in first place. To examine whether a 'Space Use' characterization reflects more inter-class differences than a 'Level of Urbanization' characterization, the Coefficient of Variance (Std dev/Mean) was calculated for PARs for each of the 45 credits for both ways of characterization. For an overwhelming majority of credits, the 'Space Use' characterization showed higher Coefficients of Variance, and subsequent analysis deals with the same.

Table 2 lists credits in decreasing order of the aforementioned Coefficient of Variation, along with categories that show 'Positive Deviation' or 'Negative Deviation' from the overall trend. For identifying these deviant categories, lower and upper fences for PAR scores was set using the Inter-Quartile Range method. The lower fence is Q1 – 1.5*IQR and the upper fence is Q3 + 1.5*IQR where:

Q1: First Quartile of PAR Scores; Q3: Third Quartile of PAR Scores: IQR = Q3 – Q1.

If the PAR for category is above the upper fence for a credit (e.g. for SSc3, the PAR for Multi-family Residential buildings is 42.77%, well above the upper fence of 28.44% and the overall average 17.9%) it is a 'Positive Deviation'. Similarly if category's PAR is below the lower fence for a credit, it's a 'Negative Deviation'.

Selected Observations

- Multi-family Residential buildings fare poorly in a host of credits like Increased Ventilation, Construction IAQ before occupancy, Heat Island Effect, etc. The creation of the Multi-Family Midrise variant in LEED v4 is then well-warranted, so that systemic disadvantages to this type of building stock can be addressed.
- Retail buildings fare well in 'Daylight and Views' as would be expected from their nature of commerce, which involves showcasing. These buildings also fare poorly in maximizing open space and reducing parking capacity, which is a reasonable outcome given the high volume of transients for the building (daily shoppers) and their positioning in commercial zones.

- Warehouses fare poorly in 'Site Selection' which would be expected, as they are often located in areas disconnected from heavy civilization.
- Health care facilities fare poorly in Water Use Reduction, which can also be understood in light of their stringent sanitary requirements and nature of establishment.

Table 2: Category Deviations from Overall PAR Trends

Credit	Credit Name	Negative Deviation	Positive Deviation
MRc6	Rapidly renewable materials		Educational Facilities
MRc3	Materials reuse		Educational Facilities
WEc2	Innovative wastewater technologies		Data Center, Industrial Manufacturing
SSc3	Brownfield Redevelopment		Multi-family
MRc1.1	Building reuse - maintain existing walls, floors and roof		Educational Facilities
EQc2	Increased ventilation	Multi-family Residential	Data Center
EQc3.2	Construction IAQ management plan - before occupancy	Multi-family Residential	
EQc8.1	Daylight and views - daylight		Retail
MRc7	Certified wood	Lodging, Multi-family Residential	Data Centers
EQc7.2	Thermal comfort - verification	Multi-family Residential	
EQc4.4	Low-emitting materials - composite wood and agrifiber products	Multi-family Residential	
SSc7.1	Heat island effect - nonroof	Multi-family Residential	
EAc5	Measurement and verification		Data Center
WEc3	Water use reduction	K-12, Health Care	
SSc5.2	Site development - maximize open space	Retail	
SSc4.4	Alternative transportation - parking capacity	Retail	
SSc4.3	Alternative transportation - low-emitting and fuel-efficient vehicles	Higher Ed	
SSc1	Site selection	Warehouse	
MRc5	Regional materials	Educational Facilities, Health Care	Data Centers

Summary and Future Research

The primary objective of the study was to examine how LEED credit-achievement trends vary for different types of buildings, as categorized by their primary use. For each of the 45 LEED BD+C v3 NC credits analyzed for the study, inter-category variation was determined. In those credits with significant inter-category variation, the building categories were identified that either far outperformed the trend or underperformed compared to other categories. The existence of these deviations can quantitatively justify the creation of dedicated rating systems for building types like Multi-family Midrise, Data Centers, Retail and Healthcare. Lowest-achieved and highest-achieved credits across the building spectrum were identified as well, and energy performance trends were broken down to differentiate between the levels achieved by different building categories.

However, ground-reasons for these deviations need to be identified by understanding the motivations/limitations of the stakeholders involved in the process. The author is performing an industry survey of LEED professionals to unearth these, which would form the second part of this study. Such a survey would reveal what reasons give rise to these trends – financial constraints, documentation difficulty, nature of commerce, occupant demand, etc. An understanding of these reasons would help modify credit language and requirements accordingly.

Another key area for future research would be establishing a connection between credit-achievement trends and their assumed impact in different 'Impact Categories' defined by USGBC. For example, are LEED-certified buildings mostly minimizing contribution to climate change? Or do credit-trends indicate that the major focus is on enhancing human health? This knowledge would be able to inform whether weights given to each credit need to be adjusted.

Acknowledgements

The author is grateful to the US Green Building Council and administrators of the Green Building Information Gateway's (GBIG) website for providing the dataset.

References

Bare, J. (2011). TRACI 2.0: the tool for the reduction and assessment of chemical and other environmental impacts 2.0. *Clean Technologies and Environmental Policy*, *13*(5), 687-696.

Cheng, J.C. and Ma, L.J. (2013). A study of the relationship between credits in the LEED- EB&OM green building rating system. *IACSIT International Journal of Engineering Technology, 5*, 438-442.

Choi, E., & Miller, N. G. (2012). Explaining LEED concentration: effects of public policy and political party. *Journal of Sustainable Real Estate, 3*(1), 91–108.

Cidell, J. (2009). Building green: the emerging geography of LEED-certified buildings and professionals. *Professional Geographer, 61*(2), 200–215.

Cidell, J., & Beata, A. (2009). Spatial variation among green building certification categories: does place matter? *Landscape and Urban Planning, 91*(3), 142–151.

Ding, G. K. C. (2008). Sustainable construction—The role of environmental assessment tools. *Journal of Environmental Management*, *86*(3), 451–464.

Ma, J., & Cheng, J. C. P. (2016). Data-driven study on the achievement of LEED credits using percentage of average score and association rule analysis. *Building and Environment*, *98*, 121–132.

Palmer, J., Cooper, I., & Van der Vorst, R. (1997). Mapping out fuzzy buzzwords-who sits where on sustainability and sustainable development. *Sustainable development*, *5*(2), 87-93.

Ravindu, S., Rameezdeen, R., Zuo, J., Zhou, Z., & Chandratilake, R. (2015). Indoor environment quality of green buildings: Case study of an LEED platinum certified factory in a warm humid tropical climate. *Building and Environment*, *84*, 105–113.

Schiavon, S., & Altomonte, S. (2014). Influence of factors unrelated to environmental quality on occupant satisfaction in LEED and non-LEED certified buildings. *Building and Environment, 77*, 148–159.

Todd, J. A., Pyke, C., & Tufts, R. (2013). Implications of trends in LEED usage: rating system design and market transformation. *Building Research & Information*, *41*(4), 384-400.

U.S. Green Building Council. (2013). LEED v4. Impact Category and Point Allocation Development Process, 1–16. Available on *http://www.usgbc.org/sites/default/files/LEED%20v4%20Impact%20Category%20and%20Point%20Allocation%20Process_Overview_0.pdf* last accessed on 01/26/2017

Zuo, J., & Zhao, Z. Y. (2014). Green building research–current status and future agenda: A review. *Renewable and Sustainable Energy Reviews, 30,* 271-281.