LEED-NCV3 SILVER AND GOLD CERTIFIED PROJECTS IN THE US: AN OBSERVATIONAL STUDY

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ABSTRACT

The Leadership in Energy and Environmental Design (LEED) rating system has been widely used in the US. However, until now, there has been no clear understanding of the strategies that should be used to make the transition from Silver to Gold certified projects. The aim of this study was to determine the trends in certified projects for both Silver and Gold LEED for New Construction and Major Renovations (LEED-NCv3) in 2016. Three performances, including (i) certification, (ii) category/subcategory/sub-subcategory certification, and (iii) cross-certification, were evaluated for both Silver and Gold LEED-NCv3 certified projects. For an ordinal measurement scale, a two-tailed Mann-Whitney U test was used. For a ratio measurement scale, an unpaired two-tailed t-test was used. If eight or more Silver and Gold certified projects occurred in the same state, then the state was selected for statistical analysis. As a result, ten states were selected. The following was revealed: (i) low certification performances for both Silver and Gold; (ii) high category performance for Sustainable Sites and Innovation in Design and low category performance for Energy and Atmosphere for both Silver and Gold projects; and (iii) three different strategies of certified projects in transition from Silver to Gold that include (a) energy-emphasized (e.g., CA), (b) non-energy-emphasized (e.g., NY), and (c) integrated (e.g., GA) strategies. We speculate that the possible reasons for such deviations in the decision strategies were due to differences between the adopted ASHRAE 90.1 standards (ASHRAE Standard 90.1 2007 or ASHRAE Standard 90.1 2010) in each of the states.

KEYWORDS

LEED-NCv3, ASHRAE Standard 90.1, certification performance, Silver, Gold

INTRODUCTION

The Leadership in Energy and Environmental Design (LEED) rating system is the most popular certification system that has been widely applied in the US and throughout the world (Ma and Cheng 2016; Wu et al. 2017). Currently, among the many practiced LEED rating subsystems for different types of buildings (such as Existing Buildings: Operations & Maintenance

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[LEED-EB], Commercial Interiors [LEED-CI], Core and Shell Development [LEED-CS], Retail, Schools, Homes, Neighborhood Development, and Healthcare), LEED for New Construction and Major Renovations (LEED-NC) is one of the most requested rating subsystems (Cheng and Ma 2015). The LEED-NC rating subsystem was launched by the US Green Building Council (USGBC) in 1998 and has since been continuously improved through the realization of new versions, including LEED-NCv2.0 (2000), LEED-NCv2.1 (2002), LEED-NCv2.2 (2005), LEED-NCv3 (2009), and LEED-NCv4 (2013) (USGBC, LEED for New Construction Projects Directory).

To suggest improvements to green rating systems, researchers usually rely on the following: (i) rating system analyses (Yu and Kim 2011; Chen et al. 2015; Pushkar and Shaviv 2016; Illankoon et al. 2017) and (ii) certified project analyses (observational studies) (Fuerst 2009; Ma and Cheng 2016; Wu et al. 2016; Wu et al. 2017). An observational study is a survey of a certified project involving the point allocations to environmental categories of the green rating system. It reflects green system performances in practice and therefore presents important feedback that can lead to suggestions for improving future versions of the rating system (Wu et al. 2017).

To determine the trends in the LEED-NC certified projects, certification performance, category/subcategory/sub-subcategory performance, or cross-certification performance was performed (Fuerst 2009; Ma and Cheng 2016; Wu et al. 2016; Wu et al. 2017). The certification performance is an analysis of the total number of points that were received by a project in all seven LEED-NCv3 categories (Sustainable Sites [SS], Water Efficiency [WE], Energy and Atmosphere [EA], Materials and Resources [MR], Indoor Environmental Quality [EQ], Innovation in Design [ID], and Regional Priority [RP]) in any certification level (Certified, Silver, Gold, or Platinum) (Wu et al. 2017). The category/subcategory/sub-subcategory performance is an analysis of the number of points that are received by a project per the individual categories/subcategories/sub-subcategories (such as subcategories of WE category: WEc1 Water Efficient Landscaping, WEc2 Innovative Wastewater Technologies, and WEc3 Water Use Reduction) in any certification level (Ma and Cheng 2016; Wu et al. 2017). The cross-certification performance is an analysis of the differences in the number of points that are received by a project per category/subcategory/sub-subcategory for any two adjacent certification levels (Ma and Cheng 2016; Wu et al. 2017). The analysis aimed to disclose LEED categories that are responsible for moving projects from a lower to higher certification level, for example, from Certified to Silver, from Silver to Gold, or from Gold to Platinum (Wu et al. 2016).

Fuerst (2009) and Ma and Cheng (2016) analyzed LEED certified projects across different states of the US. Fuerst (2009) analyzed LEED-NC, LEED-CI, LEED-CS, and LEED-EB certified projects with a pooled sampling of over 2,000 LEED-registered projects as of March 2009. Ma and Cheng (2016) evaluated LEED-NCv3 certified projects with 1,000 pooled samples. Silver and Gold were found to be the most popular certification tiers (Ma and Cheng 2016). However, the total points obtained by the analyzed projects were only slightly above the lower thresholds of each certification level (50 pt and 60 pt for Silver and Gold respectively), thereby demonstrating low certification performance results (Fuerst 2009). In categories/subcategories/sub-subcategories performance, the lowest performance was revealed in the MR category, and the highest performance was revealed in the SS, EQ, and ID categories (Ma and Cheng 2016). In cross-certification performance, the EA category was noted as a driving force taking a project from lower to higher certification levels (Ma and Cheng 2016).

Wu et al. (2016) and Wu et al. (2017) analyzed LEED certified projects across the entire world. Wu et al. (2016) evaluated LEED-NCv2.2 certified projects with pooled sampling of 5,340 projects for 2007–2015, and Wu et al. (2017) evaluated LEED-NCv3 certified projects with 3,416 pooled sampling as of July 2015. According to certification performance analyses, the LEED-NCv2.2 and LEED-NCv3 projects tended to obtain only certification levels (Wu et al. 2016; Wu et al. 2017), thereby confirming the results obtained early by Fuerst (2009). In both, LEED systems, Silver and Gold were the most popular tiers (Wu et al. 2016; Wu et al. 2017). In categories/subcategories/sub-subcategories performance analyses, the lowest performance was revealed in EA and MR categories, and the highest performance was in the ID category (Wu et al. 2016; Wu et al. 2017). In cross-certification performance, the EA category was revealed as a main driving force toward increasing certification level, pushing a project from a lower to higher certification level (Wu et al. 2016), and all seven categories (EA, SS, WE, EA, MR, EQ, and ID) constantly increased with an increase in the certification level (Wu et al. 2017).

As mentioned earlier, the design of the observational studies by Wu et al. (2016) and Wu et al. (2017) were based on the fact that LEED certified projects are pooled and evaluated within one event setting, e.g., the projects located throughout the world (Wu et al. 2016; Wu et al. 2017). However, determining significant differences through pooling observational data from different sampling frames (i.e., different countries) can lead to sacrificial pseudoreplication (Hurlbert 1984). Sacrificial pseudoreplication leads to artificially inflated degrees of freedom, giving the illusion of having a more powerful statistical conclusion (Hurlbert 1984, 2009; Picquelle and Mier 2011; Pushkar et al. 2014).

Moreover, pooling observational data from different sampling frames (i.e., different countries or different US states) can contain uncontrolled treatment factors which may influence the results. When different countries are considered together, different green building policies, market influences and technology preferences practiced in these countries are examples of uncontrolled treatment factors (Ma and Cheng 2016). When different US states are considered together, green building policies practiced in these states is an example of an uncontrolled treatment factor (Sun et al. 2016).

For example, two main energy regulations, such as ASHRAE 90.1 (Energy Standard for Buildings Except Low-Rise Residential Buildings) and the International Energy Conservation Code (IECC), are adopted in the US. Their implementations are not under national regulation; therefore, in general (without connection to the LEED certification), states can adopt any version of the IECC and/or ASHRAE 90.1 Standard to decrease their operational energy requirement (Sun et al. 2016). These regulations may have different influence on LEED results in different states. This requires the observational study analysis to be performed separately at the state level and the observational data from different countries and/or different states in the US to not be pooled.

In addition, pooling observational data needs to be restricted by a relatively narrow period of time, for example, for a one-year time period. This is because of different IECC/ASHRAE 90.1 Standard version adaptations (uncontrolled treatment factor[s]) have been dynamic through the years in the same state. For example, in California the following ASHRAE 90.1 versions were adopted through a seven year period: 2011—ASHRAE 90.1-2007, 2014—ASHRAE 90.1-2010, and 2017—ASHRAE 90.1-2013. An additional example is for Ohio in which the next ASHRAE 90.1 versions were adopted through a seven year period: 2011—ASHRAE 90.1-2004, 2014—ASHRAE 90.1-2007, and 2017—ASHRAE 90.1-2010.

Therefore, it was suggested that during a short time pooling period (i.e., one year) and one or two years (for project design and construction) that preceded this pooling year, uncontrolled treatment factors such as the ASHRAE 90.1 and IECC codes were unchangeable when the treatment effects were evaluated. Therefore, this paper was restricted to the analysis of US projects at the state level that were certified under the LEED-NCv3 rating subsystem for one year, from January 1 to December 31, 2016.

The aim of this study was to determine the trends in the LEED-NCv3 Silver and Gold certified projects for 2016 through evaluating three performances that include (i) certification, (ii) category/subcategory/sub-subcategory certification, and (iii) cross certification, separately in each of the states, where a suitable sample size of the observational data will be presented. This study will aid in understanding uniqueness and dissimilarity of current practitioner strategies in the performance of LEED certified projects within analyzed states. Such feedback can be helpful for rating system experts who are responsible for further LEED improvements.

METHODS

Data selection procedure

In this study, the projects certified in 2016 according to the LEED-NCv3 (2009) rating system are considered. These projects include commercial and multifamily residential projects that were newly built and greatly renowned. In total, according to the USGBC project directory (USGBC, LEED for New Construction Projects Directory), 920 such projects were revealed in 2016.

To increase confidence in the statistical conclusions, the following three procedures were consistently performed: (1) the 920 projects were divided into four certification groups (Certified, Silver, Gold, and Platinum certified projects), (2) the most representative certification groups were chosen, and (3) states that contained eight or more certified projects were selected in each of the certification groups. Two sets of data were collected as follows: (i) the ASHRAE 90.1 Standard versions adopted in the selected states through 2014–2015 (two years were suggested as a sufficient time period for the design and construction of the projects that received LEED-NCv3 certification in 2016) (ASHRAE 90.1., Commercial Code Status) and (ii) the USGBC scorecards of the projects in the selected states (USGBC, LEED for New Construction Projects Directory).

From the collected scorecards, information regarding the awarded points in the following LEED-NCv3 categories was accumulated: SS, WE, EA, MR, EQ, ID, and RP. Eventually, the RP points were redistributed among the relevant five basic categories: SS, WE, EA, MR, and EQ.

A hierarchical structure of the LEED-NC 2009 rating system

As a reminder, each of the five main categories (SS, WE, EA, MR, and EQ) contained two or more subcategories and a few subcategories contained additional sub-subcategories. Therefore, the LEED-NCv3 certification can be considered to have a hierarchical structure (Pushkar 2013). In such cases, a single-unit design was used (Hurlbert 2013; Pushkar et al. 2014). The single-unit design structure refers to observational studies in which the primary sampling unit was defined at only one scale (Hurlbert 2013).

Therefore, each of the certificated projects were defined as a primary sampling unit for the category/subcategory/sub-subcategory. In this way, a pairwise comparison between the states (the factor of interest) or the differences between Silver and Gold certified projects (the factor of interest) in the states was carried out considering the hierarchical structure of the LEED-NCv3 rating system.

Design of the study

The observation study. In the present study, a retrospective cross-sectional design was used. In a cross-sectional study, each primary sampling unit is observed at just one time point. In this study, "… the investigator may have substantial control not only over which [primary sampling units] are included but also over the measuring processes used" (Cox and Reid, 200, p. 13). In the LEED project context, an individual LEED project is equal to a primary sampling unit within one state. Collection and measurement points of LEED and CADs are equal to the measuring processes.

The sample sizes. de Winter (2013) defined an extremely small sample size with the assumption that the normality distribution was met as $n_1 = n_2 = 5$, where n_1 and n_2 are the sample sizes of two independent groups. It was found that if there is an extremely small sample size, the independent two-tailed *t*-test can be applied, as long as the effect size is expected to be large (de Winter, 2013). Janušonis (2009) defined the small sample size for equal independent groups as $n_1 = n_2 = 3–7$ cases per group. It was detected that if the sample size for equal groups was to be set as $n_1 = n_2 = 5$ or 6, then the independent, two-tailed *t*-test would have comparably high power (Janušonis, 2009). Dwivedi et al. (2017) found that if the sample size was to be set as $n_1 = n_2 = 8$ and a normal distribution was met, then the type I error probabilities for the *t*-test were found to be 5%. However, if a normal distribution was not met, the type I error probabilities for the exact Wilcoxon rank sum test (equivalent to the Mann-Whitney test) were found to be 5%. Therefore, in the present study, a minimal sample size was to be set equal to n = 8 in order to have the possibility to use either the *t*-test or the Mann-Whitney test.

Multiplicity problem. In the current study, a hybrid of the paleo–Fisherian and Neyman–Pearsonian paradigms is replaced by a neoFisherian significant assessment (NFSA) (Hurlbert and Lombardi, 2009, 2012). In NFSA, in a two-group case, one examines the P value yielded by a significance test for a difference between groups and comes to one of three conclusions: the difference between the true population means seems to be negative; the difference seems to be positive; or the difference cannot confidently be described as either positive or negative, so judgment is reserved or suspended. Interpretation of "three-valued logic" should be made without reference to a specified α, without use of terms such as 'significant' and 'non-significant' and without any post hoc corrections of Type I errors. In addition, for the multiple testing problem, using the "universal null hypothesis" in terms of Rothman (1990) or the "global null hypothesis" in terms of Goodman (1998) for theoretical justification of the application of correction of Type I errors may lead to the undermining of the basic premises for empirical research (Rothman 1990). Finally, Hurlbert and Lombardi (2012) clearly demonstrated that "in all basic and applied research, significance tests function mainly to assist assessment of the existence, sign and magnitude of effects, and worry over the maximum probability that one or more Type I errors might have been made in some arbitrarily defined set of tests is unwarranted."

Statistical analysis

A two-tailed Mann-Whitney nonparametric test or an unpaired two-tailed t-test was used to evaluate the following: (i) the difference between delta for Silver projects and delta for Gold projects, (ii) the difference between each category of LEED in both Silver projects and Gold projects, and (iii) the differences between Silver and Gold certified projects in the states. If an ordinal measurement scale was used, then the two-tailed Mann-Whitney U nonparametric test was used. The descriptive statistics are presented as medians of the rating ± the interquartile range (IQR). If a ratio measurement scale was used, then the unpaired two-tailed *t*-test was used. Before using the *t*-test, the Fisher-Snedecor F-test was used to confirm equal variability. Satterthwaite's approximate *t*-test was performed if the variances were not confirmed to be equal. The descriptive statistics are presented as the means ± standard deviations (SD). The credit achievement degree (CAD) was calculated using the ratio (Wu et al. 2017, p. 372)

$$CAD = \frac{\text{points of layer obtained}}{\text{total points of the layer}} \cdot 100\% .$$

The CAD scale was also converted to the decile range to evaluate the quality of the data. NFSAs were used to interpret the signs and magnitudes of the statistical effects. The precise P-values are shown and evaluated according to three-valued logic as follows: "it seems to be positive" (i.e., there seems to be a difference between the two states), "it seems to be negative" (i.e., there does not seem to be a difference between the two states) and "judgment is suspended."

RESULTS AND DISCUSSION

Preliminary events: setting the projects from the most representative certifications and from the most representative states

The percent distributions among the Certified, Silver, Gold, and Platinum LEED-NCv3 certified projects (in total, 920 projects) that received their certifications in the US in 2016 were evaluated. Silver and Gold were the most preferred certification levels. Both the Certified and Platinum projects represented approximately 30% (202 projects) of the total LEED-NCv3 certified projects, while both Silver and Gold projects represented approximately 70% (698 projects). The share of the Silver certified projects was 44% (405 projects), and the share of the Gold certified projects was 32% (293 projects) of the total LEED-NCv3 certified projects. These results are associated with the results presented by Wu et al. (2017) (38% and 35% of Silver and Gold projects, respectively), who studied the same LEED version from 2010 to 2015. Several reasons for the preference for both Silver and Gold certification by building practitioners were revealed by Sandoval and Prakash (2016), who concluded that the Silver and Gold certifications have better benefit–cost ratios, building practitioners have the most experience with these levels and the levels can be attained within reasonable time frames, etc.

The distribution of the Silver and Gold certified projects within the states is presented in Table 1. As a result, in the present study, interestingly, the first 10 states in the US that had the highest numbers of LEED-NCv3 Silver and Gold projects in 2016 were CA, FL, GA, IL, MA, NY, OH, TX, VA, and WA.

Certification performance

First, for each of the 10 states, summing the medians of the awarded points evaluated in all of the six LEED-NCv3 categories was performed and denoted as a "total median of the LEED-NCv3 awarded point." Then, the 10 states were ranked in descending order of the total medians of the LEED-NCv3 awarded points in Silver and Gold certifications separately (Figure 1). To visualize the total median achievements over certification lower boundaries (delta measurements) in the 10 states, the lower boundaries of the Silver certification (50 pt) and Gold certification (60 pt)

TABLE 1. The distribution of LEED-NCv3 Silver and Gold certified projects in states in 2016.

State		Silver	Gold	State		Silver	Gold
Alabama	AL	4	0	Mississippi	MS	1	0
Alaska	AK	2	1	Missouri	MO	3	3
Arizona	AZ	13	7	Montana	MT	1	3
Arkansas	AR	4	4	Nevada	NV	4	2
California	***CA***	***42***	***58***	New Jersey	NJ	6	1
Colorado	CO	4	10	New Mexico	NM	8	5
Connecticut	CT	2	0	***New York***	***NY***	***14***	***11***
District of Columbia	DC	10	5	North Carolina	NC	12	7
Florida	***FL***	***31***	***11***	***Ohio***	***OH***	***23***	***8***
Georgia	***GA***	***11***	***9***	Oklahoma	OK	2	1
Hawaii	HI	5	1	Oregon	OR	6	10
Idaho	ID	2	0	Pennsylvania	PA	18	7
Illinois	***IL***	***13***	***19***	Rhode Island	RI	1	1
Indiana	IN	2	4	South Carolina	SC	5	2
Iowa	IA	2	3	South Dakota	SD	1	0
Kansas	KS	2	1	Tennessee	TN	7	6
Kentucky	KY	6	3	***Texas***	***TX***	***27***	***9***
Louisiana	LA	2	9	Utah	UT	3	2
Maine	ME	4	0	Vermont	VT	0	2
Maryland	MD	17	6	***Virginia***	***VA***	***38***	***11***
Massachusetts	***MA***	***19***	***14***	***Washington***	***WA***	***10***	***11***
Michigan	MI	5	12	Wisconsin	WI	7	7
Minnesota	MN	4	1	Wyoming	WY	1	4

Note: Bold italic font–the 10 analyzed States

(dashed line) are also presented in Figure 1. As a result, the ranges of the total median of the LEED-NCv3 certifications were as follows: 55–51 pt and 61–68.5 pt for the Silver and Gold certified projects, respectively (Figure 1). The delta measurements for both Silver and Gold certifications were calculated and presented in Table 2. The difference in the delta measurements between the Silver and Gold certifications were evaluated and appeared to be negligible (P = 0.820). Thus, in both Silver and Gold certifications, the similar low certification performances were revealed in LEED-NCv3 certified projects in 10 states in 2016.

This result confirms the results presented by Fuerst (2009), Wu et al. (2016), and Wu et al. (2017). However, the conclusion that this difference decreases with an increase in the certification level (suggested by Wu et al. 2016) was not confirmed in this study. Thus, the trend toward a willingness to pay only for a certification level and not for sustainability, which has

FIGURE 1. The total median of the awarded points in the LEED-NCv3 categories for Silver and Gold certified projects in 10 US states in 2016.

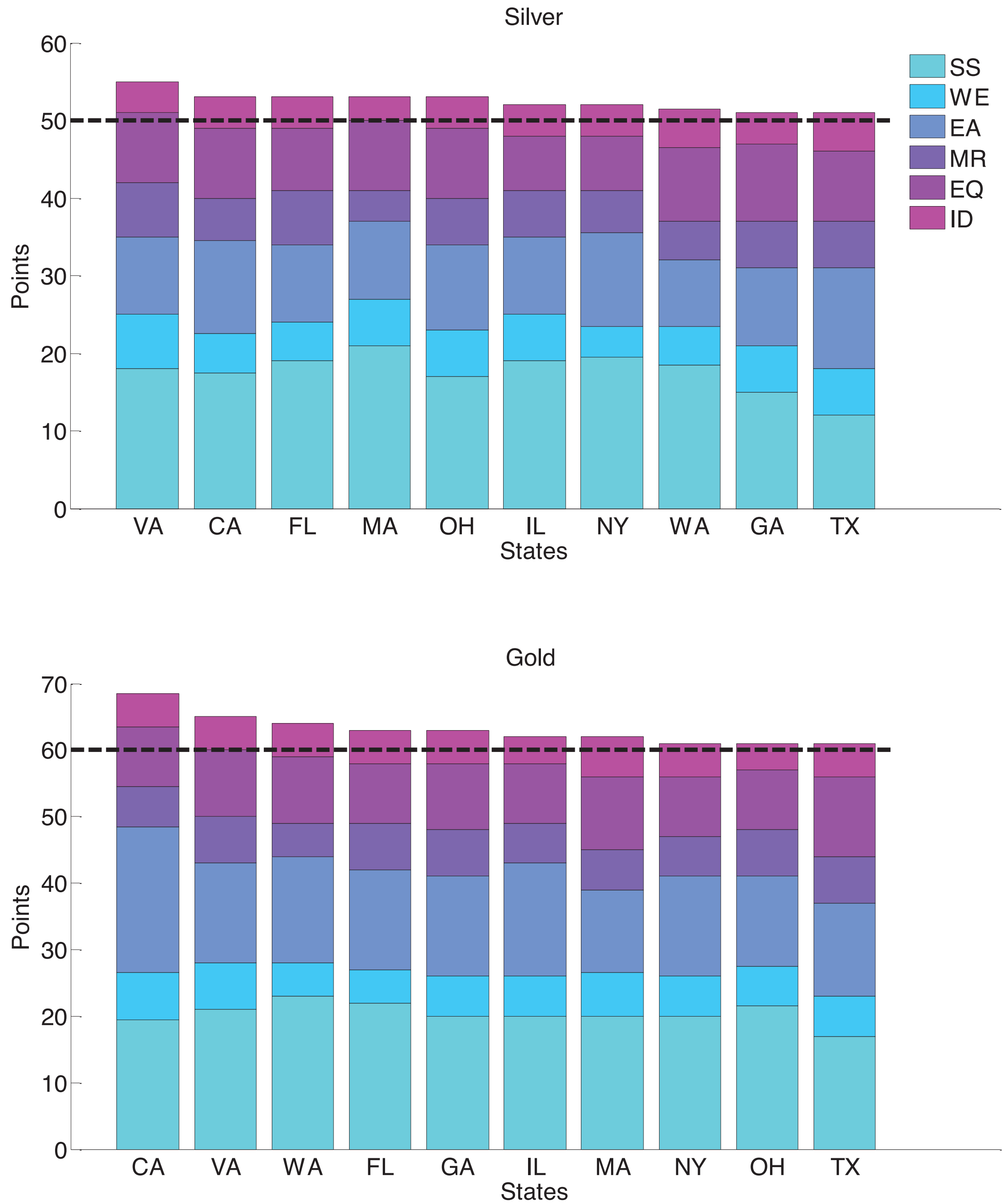

TABLE 2. Delta measurements of the Silver and Gold certifications (the total median points over the lower boundary of the certification: above 50 pt for Silver and above 60 pt for Gold) in 10 US states in 2016.

Certification/ States	States										Median±IQR	P-value
States	VA	CA	FL	MA	OH	IL	NY	WA	GA	TX		0.820
Silver	5.0	3.0	3.0	3.0	3.0	2.0	2.0	1.5	1.0	1.0	2.5±1.5	
States	CA	VA	WA	FL	GA	IL	MA	NY	OH	TX		
Gold	8.5	5.0	4.0	3.0	3.0	2.0	2.0	1.0	1.0	1.0	2.5±3.0	

been recognized previously by Fuerst (2009), Wu et al. (2016), and Wu et al. (2017), was still relevant for LEED-NCv3 Silver and Gold projects certified in 2016.

Category performance

The median values of the credits obtained for the Silver certificate projects (cyan-colored bar) in descending order and the total points of the assessment area (red dashed line) are shown in Figure 2. The CADs of the categories and the decile ranges were calculated and are shown in Table 3. The following four decile ranges were revealed: decile = 7, ID (68.33%) and SS (67.89%); decile = 6, WE (56.00%) and EQ (57.67%); decile = 5, MR (41.43%); and decile = 4, EA (30.43%). As shown in Table 3, the differences between the following CAD categories seemed to be negative: CAD_{SS} vs CAD_{ID} (P = 0.918) and CAD_{WE} vs CAD_{EQ} (P = 0.630), which means that the CAD performances were the same in these two pairs. All other comparison pairs, such as CADss vs CAD_{WE}, CAD_{SS} vs CAD_{EA}, and CAD_{WE} vs CAD_{EA} appeared to be

FIGURE 2. Medians of the awarded points in the LEED-NCv3 categories for the Silver certified projects in 10 US states in 2016.

TABLE 3. CAD of Silver LEED-NCv3 certified projects in 10 US states in 2016.

Category	SS	WE	EA	MR	EQ	ID
Mean	67.89	56.00	30.43	41.43	57.67	68.33
SD	9.81	8.43	3.81	6.34	6.68	9.46
Decile range	7	6	4	5	6	7
SS	X	**0.0094**	**0.0000001**	**0.000001**	**0.0139**	0.9182
WE		X	**0.000001**	**0.0004**	0.63003	**0.00649**
EA			X	**0.0002**	**0.00000001**	**0.0000001**
MR				X	**0.00003**	**0.000001**
EQ					X	**0.0093**
ID						X

Note: The 10 states are as follows: CA, FL, GA, IL, MA, NY, OH, TX, VA, and WA. These states were defined as 10 primary sampling units for each LEED category. Mean and SD are the mean and SD of the 10 states. The P values were evaluated according to the following three-valued logic: bold font—seems to be positive, ordinal font size—seems to be negative, and italic font—judgment is suspended.

positive ($0.00000001 \leq P \leq 0.0139$), which means that the CAD performances in these pairs were different.

The median values of credits obtained for the Gold certificate projects (magenta-colored bar) in descending order and the total credits of the assessment area (red dashed line) are shown in Figure 3. The CAD and decile range were calculated and are shown in Table 4. The following four decile ranges were obtained: decile = 9, ID (81.67%); decile = 8, SS (78.46%) and EQ (65.33%); and decile = 5, MR (45.71%) and EA (44.29%). As shown in Table 4, the differences between the following categories appeared to be negative: CAD_{SS} vs CAD_{ID} ($P = 0.384$), CAD_{WE} vs CAD_{EQ} ($P = 0.133$), and CAD_{EA} vs CAD_{MR} ($P = 0.620$), which means that the CAD performances were the same in these three pairs. All other paired comparisons, such as CAD_{SS} vs CAD_{WE}, CAD_{SS} vs CAD_{EA}, and CAD_{WE} vs CAD_{EA} appeared to be positive ($0.000000001 \leq P \leq 0.00033$), which means that the CAD performances in these pairs were different.

According to Wu et al. (2017), SS, WE, EQ, and ID are the most easily accessible categories that have a high possibility of implementation without requiring large investments, while EA and MR are the difficult access points and require large investments (EA category) or have a much lower possibility of reducing construction material consumption (MR category).

In the present study, CAD_{SS} and CAD_{ID} were the best performance categories, while CAD_{EA} and CAD_{MR} were the worst performance categories, confirming the results revealed by the observational study by Wu et al. (2017). This similarity in the results was expected due to the same LEED-NCv3 version that was applied for the following certified projects: (i) through 2010–2015 (Wu et al. 2017) and (ii) in 2016 (this study).

However, minimal differences were revealed between the performances of WE and EQ. In the present study, the CADs of these categories were evaluated at a somewhat intermediate position (located between the best and the worst performance categories), while Wu et al. (2017) evaluated their performance as the best category position.

FIGURE 3. Medians of the awarded points in the LEED-NCv3 categories for the Gold certified projects in 10 US states in 2016.

TABLE 4. CAD of Gold LEED-NCv3 certified projects in 10 US states in 2016.

Gold	SS	WE	EA	MR	EQ	ID
Mean	78.46	60.50	44.29	45.71	65.33	81.67
SD	6.27	6.85	7.44	4.99	6.89	9.46
Decile range	8	7	5	5	7	9
SS	X	**0.00001**	**0.00000001**	**0.000000001**	**0.0003**	0.3836
WE		X	**0.0001**	**0.00003**	0.13301	**0.00002**
EA			X	0.6202	**0.000004**	**0.00000001**
MR				X	**0.000001**	**0.00000001**
EQ					X	**0.00033**
ID						X

Note: The 10 states are as follows: CA, FL, GA, IL, MA, NY, OH, TX, VA, and WA. These states were defined as 10 primary sampling units for each LEED category. Mean and SD are the mean and SD of the 10 states. The P values were evaluated according to the following three-valued logic: bold font—seems to be positive, ordinal font size—seems to be negative, and italic font—judgment is suspended.

Cross-certification performance

Category analysis. A statistical analysis of the cross certification between the LEED-NCv3 Silver and Gold categories was performed for each of the 10 states. According to this analysis, the following three main strategies for transitioning projects from Silver to Gold were revealed: "energy-emphasized," "non-energy emphasized," and "integrated" (Table 5).

TABLE 5. Silver and Gold certified projects in 10 US states in 2016. Median ± interquartile range (IQR) of the awarded points in the six categories of LEED-NC 2009.

State	Category	Silver	Gold	P-value	State	Category	Silver	Gold	P-value
CA[1]	SS	17.5±8.0	19.5±9.0	0.337	WA[1]	SS	18.5±2.0	23.0±2.8	**0.001**
	WE	5.0± 4.0	7.0±2.0	**0.013**		WE	5.0±2.0	5.0±1.0	0.916
	EA	12.0±7.0	22.0±13.0	**0.001**		EA	8.0±5.0	16.0±4.3	**0.001**
	MR	5.5± 2.0	6.0±1.0	0.591		MR	5.0±1.0	5.0±2.0	0.341
	EQ	9.0±3.0	9.0±3.0	0.523		EQ	9.5±2.0	10.0±2.0	0.180
	ID	4.0±4.0	5.0±1.0	*0.054*		ID	5.0±2.0	5.0±2.0	0.573
FL[1]	SS	19.0±11.8	22.0± 5.5	*0.057*	NY[2]	SS	19.5±3.0	20.0±2.0	0.311
	WE	5.0±2.0	5.0±2.0	0.808		WE	4.0±3.0	6.0±3.8	0.132
	EA	10.0± 6.8	15.0±11.0	**0.016**		EA	12.0±6.0	15.0±7.3	0.250
	MR	7.0±1.0	7.0±1.8	0.841		MR	5.5±4.0	6.0±1.0	0.228
	EQ	8.0±4.0	9.0±1.8	0.558		EQ	7.0±2.0	9.0±1.0	**0.003**
	ID	4.0±2.0	5.0±1.8	0.129		ID	4.0±3.0	5.0±3.3	0.273
IL[1]	SS	19.0±6.8	20.0±6.5	0.478	OH[2]	SS	17.0±6.5	21.5±1.0	**0.001**
	WE	6.0±4.0	6.0±2.0	0.645		WE	6.0±2.5	6.0±2.0	0.619
	EA	10.0±5.3	17.0±14.5	**0.004**		EA	11±5.8	13.5±4.0	0.269
	MR	6.0±2.5	6.0±1.8	0.173		MR	6.0±1.8	7.0±2.5	0.125
	EQ	7.0±3.0	9.0±3.5	*0.053*		EQ	9.0±3.8	9.0±3.0	0.804
	ID	4.0±2.0	4.0±1.0	0.398		ID	4.0±3.0	4.0±2.0	0.684
MA[1]	SS	21.0±5.5	20.0±9.0	0.884	TX[2]	*SS*	12.0±7.5	17.0±7.3	*0.083*
	WE	6.0±2.8	6.5±3.0	0.362		WE	6.0±3.8	6.0±3.5	0.342
	EA	10.0±3.8	12.5±7.0	**0.001**		EA	13.0±7.5	14.0±5.0	0.609
	MR	4.0±2.8	6.0±2.0	*0.051*		MR	6.0±2.0	7.0±1.5	0.596
	EQ	9.0±3.0	11.0±2.0	*0.090*		EQ	9.0±1.0	12.0±1.8	**0.012**
	ID	3.0±3.5	6.0±1.0	**0.031**		ID	5.0±2.0	5.0±1.3	0.221
VA[1]	*SS*	18.0±6.0	21.0±6.8	*0.043*	GA[3]	*SS*	15.0±4.3	20.0±4.8	*0.048*
	WE	7.0±4.0	7.0±3.5	0.719		WE	6.0±2.5	6.0±1.0	1.000
	EA	10.0±5.0	15.0±6.5	**0.001**		EA	10.0±5.5	15.0±5.8	*0.080*
	MR	7.0±1.0	7.0±2.0	0.533		MR	6.0±1.0	7.0±3.3	*0.048*
	EQ	9.0±3.0	10.0±3.0	0.557		EQ	10.0±2.5	10.0±3.5	0.704
	ID	4.0±3.0	5.0±1.8	0.119		ID	4.0±1.75	5.0±1.5	0.447

Note: The P values were evaluated according to the following three-valued logic: bold font—seems to be positive, ordinal font size—seems to be negative, and italic font—judgment is suspended.

[1]Energy-emphasizing strategy; [2]non-energy-emphasizing strategy, [3]integrated strategy.

SS (sustainable sites), WE (water efficiency), EA (energy and atmosphere), MR (material and resources), EQ (indoor environmental quality), and ID (innovation in design).

CA, FL, IL, MA, VA, and WA used the energy-emphasized strategy, while NY, OH, and TX used the non-energy emphasized strategy and GA used the integrated strategy. These strategies differed in their treatment of the EA category. Moving from Silver to Gold, the states with energy-emphasized strategies relied mostly on increasing the award points in the EA category, for which the difference between the Silver and Gold certified projects seemed to be positive. The states with non-energy emphasized strategies relied on significantly increasing the award points in the SS or EQ categories, in which the difference between the Silver and Gold certified projects seemed to be positive. The states that used integrated strategies relied on increasing the award points in three categories, SS, EA, and MR, in which judgment was suspended regarding the difference between the Silver and Gold certified projects.

ASHRAE Standard 90.1 version application. The implementation of the ASHRAE 90.1 code is not under national regulation; therefore, in general (without connection to the LEED certification), states can adopt any version of the ASHRAE code to decrease their operational energy requirement (Sun et al. 2016). Thus, in Table 6, the ASHRAE 90.1 Standard versions that were adopted in the 10 states from 2014–2015 are presented. The following state-by-state commercial building code statuses as of 2014–2015 were as follows: CA, FL, IL, MA, VA, and WA worked under ASHRAE Standard 90.1-2010, while NY, OH, TX, and GA worked under ASHRAE Standard 90.1-2007. In particular, by July of 2014, five of the six states that preferred adopting an energy-emphasized strategy for LEED-NCv3 certification, CA, IL, MA, VA, and WA, worked under ASHRAE Standard 90.1-2010 (only FL worked under ASHRAE Standard 90.1-2007). However, by July of 2015, all of the six states (including FL) that the preferred an energy-emphasized strategy for LEED-NCv3 certification worked under ASHRAE Standard 90.1-2010. The states that preferred non-energy-emphasized (NY, OH, and TX) and

TABLE 6. ASHRAE 90.1 Standard versions in the 10 states from 2014 to 2015.

State	2014 July		2015 January		2015 July	
	Commercial	Residential	Commercial	Residential	Commercial	Residential
CA	***2010***	***2010***	***2010***	***2010***	***2010***	***2010***
WA	***2010***	***2010***	***2010***	***2010***	***2010***	***2010***
OH	2007	2004	2007	2004	2007	2007
IL	***2010***	***2010***	***2010***	***2010***	***2010***	***2010***
NY	2007	2007	***2010***	2007	***2010***	2007
VA	***2010***	2007	***2010***	2007	***2010***	2007
MA	***2010***	***2010***	***2010***	***2010***	***2010***	***2010***
FL	2007	2007	2007	2007	***2010***	***2010***
GA	2007	2007	2007	2007	2007	2007
TX	2007	2007	2007	2007	2007	2007

Note: 2004—ASHRAE 90.1 Standard-2004; 2007—ASHRAE 90.1 Standard-2007; ASHRAE 90.1-2010.
Bold italic font—ASHRAE 90.1-2010.

combined (GA) strategies for LEED-NCv3 certification worked under ASHRAE 2007 from 2014 to 2015.

Subcategory/sub-subcategory analysis. For the categories in which the differences between the Silver and Gold certified projects appeared to be positive, statistical analyses of their subcategory and sub-subcategory were performed (Table 7). In the states that applied energy-emphasized strategies, for the EA category, EAc1 Optimize Energy Performance was the subcategory with the greatest influence for which the difference between the Silver and Gold certified projects appeared to be positive in five of the six states in the following subcategories: EAc2 On-Site Renewable Energy, EAc3 Enhanced Commissioning, EAc4 Enhanced Refrigerant Management, EAc5 Measurement & Verification, and EAc6 Green Power (each of these is employed in one or two of the six states).

TABLE 7. Details of the categories in which the differences between Silver and Gold certified projects appeared to be positive. Median ± interquartile range (IQR) of the awarded points for subcategory and sub-subcategory levels.

State	Subcate-gory	Silver	Gold	P-value	State	Subcate-gory	Silver	Gold	P-value
CA[1]	WEc3	3.0±3.0	4.5±2.0	**0.011**	VA[1]	EAc1	6.0±7.0	12.0±8.5	**0.002**
	EAc1	8.0±7.0	13.0±10.0	**0.001**		SSc6.2	0.0±1.0	1.0±0.8	*0.063*
	EAc2	0.0±0.0	5.0±8.0	**0.001**		SSc6	1.0±2.0	3.0±2.0	*0.048*
FL[1]	EAc1	8.0±6.8	10.0±6.8	*0.067*	WA[1]	SSc4	9.5±3.0	11.0±4.0	*0.049*
	EAc6	0.0±2.0	2.0±1.5	*0.049*		SSc6.2	0.0±1.0	1.0±0.0	**0.028**
	SSc2	5.0±5.0	6.0±0.0	**0.004**		EAc1	6.5±2.0	11.0±8.8	*0.057*
	SSc4.1	6.0±7.0	7.0±0.8	*0.055*		EAc3	0.0±0.0	2.0±0.0	**0.006**
IL[1]	EAc1	6.0±4.5	10.0±12.0	**0.038**	NY[2]	EQc1	0.0±0.0	1.0±0.8	**0.014**
	EAc6	0.0±2.0	2.0±1.5	*0.043*		EQc2	0.0±1.0	1.0±0.8	*0.065*
	EQc8.1	0.0±0.0	1.0±1.0	**0.024**	OH[2]	SSc4	8.0±3.0	11.0±2.5	**0.009**
MA[1]	EAc3	0.0±2.0	2.0±0.0	*0.079*		SSc5.2	1.0±1.0	1.0±0.5	*0.081*
	EAc4	0.0±0.0	2.0±2.0	**0.015**	TX[2]	EQc8.1	0.0±0.0	1.0±1.0	**0.014**
	EAc5	0.0±1.0	1.0±3.0	*0.074*		SSc7.1	1.0±1.0	1.0±0.0	*0.072*
	MRc5	1.0±1.8	2.0±1.0	**0.036**	GA[3]	SSc8	0.0±0.0	1.0±1.0	*0.072*
	EQc4.4	1.0±1.0	1.0±0.0	*0.075*		MRc7	0.0±0.0	1.0±1.0	**0.038**
	EQc6	1.0±1.8	2.0±1.0	*0.063*		EAc1	6.0±6.8	8.0±8.3	0. 210

Note: The P values were evaluated according to the following three-valued logic: bold font—seems to be positive, ordinal font size—seems to be negative and italic font—judgment is suspended.

[1]Energy-emphasizing strategy; [2]non-energy-emphasizing strategy, [3]integrated strategy.

SSc4 (alternative transportation), SSc5 (site development), and SSc6.2 (stormwater design, quality control); WEc3 (water use reduction); EAc1 (optimize energy performance), EAc2 (on-site renewable energy), EAc3 (enhanced commissioning), EAc4 (enhanced refrigerant management), EAc5 (measurement and verification), and EAc6 (green power); and EQc1 (outdoor air delivery monitoring), EQc2 (increased ventilation), and EQc8.1 (daylight and views, daylight 75% of spaces).

As discussed earlier (Tables 5 and 6), a strong correlation between the EA category and ASHRAE 90.1 code was revealed during the cross-certification category analysis. EAc1 can be noted as the subcategory responsible for this correlation. LEED-NCv3 requires evaluating the EAc1 according to its ability to improve the operational energy performance relative to the baseline building performance, which can be modeled according to Appendix G of ANSI/ASHRAE/IESNA Standard 90.1-2007 (LEED-NC 2009). However, different ASHRAE Standard 90.1 versions were adopted by the different states (Table 6). In this respect, it should be noted that ASHRAE Standard 90.1-2010 is more stringent in its operational energy requirements than ASHRAE Standard 90.1-2007. As was reported by the US Department of Energy (DOE), the operational energy saving of buildings constructed according to Standard 90.1-2010 is approximately 18.2% when compared to buildings constructed according to Standard 90.1-2007 (DOE 2011).

Thus, as revealed in this study, the states that adopted the more stringent ASHRAE Standard 90.1-2010 (CA, FL, IL, MA, VA, and WA) could increase their number of allocated EAc1 points more easily. As a result, these states preferred to use an energy-emphasized strategy when transitioning their projects from a Silver to Gold certification. The states that adopted the less stringent ASHRAE Standard 90.1-2007 (NY, OH, and TX) preferred a non-energy-emphasized strategy, while increasing points in the SS or EQ categories when transitioning their projects from a Silver to Gold certification.

CONCLUSIONS

Three performance levels including (i) certification, (ii) category/subcategory/sub-subcategory certification, and (iii) cross certification were evaluated to analyze Silver and Gold LEED-NCv3 projects that received their certifications in 2016. The following conclusions were drawn from this study.

1. The certification performance. Low performance levels for both Silver (51–55 pt) and Gold (61–68.5) certified projects were revealed.
2. The category/subcategory/sub-subcategory performance. In both Silver and Gold certified projects, Sustainable Sites and Innovation in Design were the high-performance categories, while Energy and Atmosphere was the low-performance category. In Gold certified projects, the Materials and Resources category was also a low-performance category.
3. The cross-certification performance. Three different strategies for transitioning LEED-NCv3 certified projects from a Silver to Gold certification were revealed as follows: (a) energy-emphasized, (b) non-energy-emphasized, and (c) integrated. It was speculated that the variance in the three strategies was due to the differences between the ASHRAE 90.1 version (ASHRAE 90.1 2007 or ASHRAE 90.1 2010) adopted in each of the 10 states. The states that utilized ASHRAE 90.1 2010 (CA, FL, IL, MA, VA, and WA) were recognized as those that preferred the energy-emphasized strategy, while the states that utilized ASHRAE 90.1 2007 (NY, OH, TX, and GA) were recognized as those that preferred the non-energy-emphasized strategy.

In comparison to other previously mentioned observational LEED studies, the contribution of this paper is the finding of the relationship between states that adopted ASHRAE 90.1 versions and the strategies for achieving LEED certification. Thus, in future versions of the

LEED rating system, the credit EAc1 Optimize Energy Performance (Energy and Atmosphere category) should reference compliance with the newest version of the ASHRAE 90.1 Standard. In this way, the current low performance of the EA category can be raised in future LEED certified projects.

The limitations of this study were the relatively small number of states of the US in which projects certified under the LEED-NCv3 rating system were analyzed and the absence of comparison evaluations between LEED-NCv3 and LEED-NCv4.

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