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Relationship between Energy and Atmosphere (EA) Credits and Project Size in the LEED-NC Version 3 (v3) and 4 (v4) Projects

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Abstract: This study aims to explore the influence of project size on the Energy and Atmosphere (EA) credits in the Leadership in Energy and Environmental Design for New Construction and Major Renovations (LEED-NC) version 3 (v3) in California and version 4 (v4) in the United States (US) in office-type projects. If the relationship between the ordinal data of EA credits and project size changed monotonically, then Spearman's correlation coefficient was used. If the relationship between the EA credits ordinal data and project size did not change monotonically, then the EA credit data were divided into below and above the median project size groups, and, as a consequence, the Cliff's δ effect size and exact Wilcoxon–Mann–Whitney tests were used. If the EA credits were binary or dichotomous data, then the natural logarithm of the odds ratio and Fisher's exact 2×2 test with Lancaster's mid-*p*-value were used. The results showed that the performance of operational energy, enhanced the refrigerant management and that the renewable energy credits in LEED-NC v3/v4 Certified, Silver, and Gold projects depended on the project size. We concluded that the LEED project size is an important variable for developing LEED-NC strategies for office-type projects.

Keywords: LEED-NC v3; LEED-NC v4; energy and atmosphere credits; project size; office-type projects

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1. Introduction

During the last few decades, Leadership in Energy and Environmental Design (LEED) has gained high popularity as a system that rates building design on an environmental scale [1]. The system was designed for the United States (US) by the US Green Building Council (USGBC); however, this system has been adopted in many countries around the world [2]. LEED can evaluate different types of buildings, such as existing buildings (LEED-EB), commercial interiors (LEED-CI), core and shell development (LEED-C&S), and new construction buildings (LEED-NC), among others. According to the USGBC website, LEED-NC with its two latest versions, version 3 (v3) and 4 (v4), is the most popular system within LEED rating systems [2]. Therefore, the projects certified under LEED-NC v3 and v4 were the focus of this study.

Both LEED-NC v3 and v4 comprise several similar environmental categories, each of them with one/several relevant credits, and both versions include 110 points in total [2]. However, there are differences between these two versions. LEED-NC v3 contains the Sustainable Sites (SS), Water Efficiency (WE), Energy and Atmosphere (EA), Materials and Resources (MR), Indoor Environmental Quality (EQ), Innovation in Design (IN), and Regional Priority (RP) categories with the maximums of the available points at 26, 10, 35, 14, 15, 6, and 4, respectively.

LEED-NC v4 includes the Integrative Process (IP), Location and Transportation (LT), SS, WE, EA, MR, EQ, IN, and RP categories with the maximums of the available points at 1, 16, 10, 11, 33, 13, 16, 6, and 4, respectively. Thus, compared to LEED-NC v3, in LEED-NC v4: the SS category was divided into the LT and SS categories; the WE category included new cooling towers and water metering credits; the EA category mostly remained the same with only an increased number of points for enhanced commissioning credit (six points in LEED-NC v4 versus two points in LEED-NC v3); the MR category suggested new life-cycle-assessment-based credits; and the EQ category introduced a new acoustic performance credit [2]. According to the total awarded points, both LEED-NC v3 and v4 certify buildings as follows: Certified (40–49 points), Silver (50–59 points), Gold (60–79 points), and Platinum (80 points and above).

Due to these numerous LEED categories, the system has flexibility in using different certification strategies [3]. However, searching for the most appropriate certification strategy is a complicate issue for LEED managers due to lack of the necessary practice within the constraints of limited project-related budget and schedule [4]. Thus, the empirical study of LEED certified projects was started to provide help for LEED managers in applying the appropriate certification strategies in situ [5].

However, to draw the right conclusions about the prevailing LEED certification strategies, applying the correct design structure to LEED data appears to be a critical issue. This means that LEED empirical research should apply the LEED design data structure based on the principle of collecting independent and identically distributed (I.I.D.) data.

This I.I.D. data collection needs to exclude the effects of different LEED-related factors, such as the certification levels, local environmental policy and climatic conditions, building ownership, and type and size of buildings when performing statistical analyzes [4]. Thus, in one hand, the following logical design structure should be adopted: in comparing certified projects for one of the above factors, the other factors need to be fixed [6]. On the other hand, LEED data have several properties in terms of statistical analysis, namely (1) the assumption of normality is not met and (2) LEED data contain the same or "ties" data. Therefore, to perform Spearman's correlation nonparametric test, the acceptable sample size should be 20 and more [7], and, to perform the exact Wilcoxon–Mann–Whitney (WMW) but not approximate WMW nonparametric test, the acceptable sample size should be 11 and more [8].

Wu et al. and Wu et al. analyzed LEED-NC v2.2 and LEED-NC v3 certified projects, respectively, and revealed different certification strategies for the different certification levels, different climate conditions, and different building-related space types [9,10]. In both Wu et al. studies, if one factor was assessed (for example, transition through adjacent LEED levels such as Silver–Gold), then the influence of other factors (such as the building type, building size, and climate) was ignored [9,10].

Pushkar and Verbitsky analyzed LEED-NC v3 projects certified in the US and revealed the applied certification strategies [11]. However, when comparing between two adjacent certification levels (Silver–Gold), the authors ignored the factors of the space type and size of the studied projects. Pushkar studied LEED–NC v3 Gold projects certified in Sweden, Finland, Spain, and Turkey and determined the appropriate LEED strategies for these countries [12]. However, in this study, the factors of building-related space-type and project-size were also ignored.

Gurgun and Arditi studied the influence of building-related ownership factor on the awarded credits of the EA category using a sample of LEED-NC v3 projects certified in the US and concluded that building-related space type factor influenced the selected certification strategy [13]. They revealed that educational institutions, government agencies, publicly traded corporations, privately held corporations, and investors employed different certification strategies toward certification [13].

Pham et al. studied LEED–NC v3 2009 projects certified in Vietnam and presented appropriate certification strategies for this country [14]. The authors analyzed three adjacent LEED levels (Certified–Silver, Silver–Gold, and Gold–Platinum) [14]. However, Pham et al. did not specify the building types and sizes of the studied projects [14]. Pham et al. studied LEED–NC v4 projects and compared Certified–Silver, Silver–Gold, and Gold–Platinum certifications of the projects certified in the world and described a world-applicable LEED v4 certification strategy [1]. However, building-related climate conditions, ownership, space type, and size were ignored by the authors [1].

Pushkar studied LEED-NC v4 Certified, Silver, Gold, and Platinum projects in the US and presented certification strategies for each certified level separately. However, this study also suffered from ignoring the following factors: building-related climate conditions, ownership, space type, and size [15].

More recently, Pushkar suggested design structure for analyzing LEED projects that included only one studied factor if possible, while the other factors were fixed. To compare between the LEED-CI projects certificated in China and the US, the projects were fixed to the factors, certification level, and climate conditions in these countries [16]. The similar design structure was recently used, when the rating system, version, certification level, space-type, and project size of the LEED project were fixed, while the country (culture and climate) variables were different [17].

However, in all of the above studies, the project size factor in the LEED-NC projects in a framework of I.I.D. data collection has not yet been studied. The aim of the present study is to evaluate the effects of the LEED project size on achieving EA credits in the LEED-NC v3/v4 office-type projects. The study will provide LEED managers a direction toward the correct project size-relevant certification strategies for the EA category, which, according to LEED certification, has the most significant influence on building sustainability. The significance of the EA category is due being the largest maximum of the available points (35 and 33 from the total 110 in LEED-NC v3 and v4, respectively).

2. Materials and Methods

2.1. LEED-NC v3 and v4: Energy and Atmosphere Credits

Table 1 shows LEED-NC v3 and v4 EA credits with reference to the common title assigned to them in this study. As can be noted, in v3 and v4, the EA credits are very similar. The only exception is a significantly different point allocation in the renewable energy and enhanced commissioning credits [2].

Table 1. Leadership in Energy and Environmental Design (LEED)- New Construction version 3 (v3) and version 4 (v4): Energy and Atmosphere (EA) credits. The numbers in brackets are the maximum points for each EA credit.

LEED-NC v3 and v4: EA Credits (Common Title)	LEED-NC v3: EA Credits (Points)	LEED-NC v3: EA Credits (Points)
Operational energy	Optimize energy performance (19)	Optimize energy performance (18)
Enhanced refrigerant management	Enhanced refrigerant management (2)	Enhanced refrigerant management (1)
Renewable energy	On-site renewable energy (7)	Renewable energy production (3)
Green power	Green power (2)	Green power and carbon offsets (2)
Enhanced commissioning	Enhanced commissioning (2)	Enhanced commissioning (6)
Operational energy metering	Measurement and verification (3)	Advanced energy metering (1) Demand response (2)
Total points	35	33

2.2. Methodology Flowchart of the Present Study

The two sequential steps for data collection and four types of data analysis were as follows:

Data collection

- We collected 18 space-types of the LEED-NC v3/v4 Certified, Silver, Gold, and Platinum projects in the US.
- We chose only LEED-NC v3/v4 Certified, Silver, and Gold office-type projects to have an acceptable number of projects in order to draw reliable statistical conclusions.

Data analysis

- If the EA credits were ordinal data and the relationship between EA credit achievement and LEED project size changed monotonically, we used Spearman's correlation coefficient.
- If the relationship between the EA credit achievement and project size did not change monotonically, we divided the EA credits into groups of below and above the median project size.

- If the EA credits were ordinal data, we used Cliff's effect size and exact Wilcoxon–Mann–Whitney tests.
- If the EA credits were binary or dichotomous data, we used the natural logarithm of the odds ratio and Fisher's exact 2 × 2 test with Lancaster's mid-p-value.

Data collection and analysis procedures are presented in Sections 2.2 and 2.3.

2.3. Data Collection

The USGBC website [2] and the Green Building Information Gateway (GBIG) website [18] were used to collect the LEED-NC v3/v4 Certified, Silver, Gold, and Platinum projects. For the LEED-NC v3 projects, California was selected as a representative US state [19]. For v4, LEED-NC projects were collected from the US.

The USGBC website contained 1214 LEED-NC v3/v4 projects (i.e., declared projects); after a comparison of LEED-NC projects from the GBIG database and the USGBC database, only 1170 LEED-NC v3/v4 projects were available (Table 2).

Table 2. The LEED-NC v3/v4 project distribution among space-types (accessed on 25 February 2021).

Project Type	LEED-NC v3				LEED-NC v4			
	Certified	Silver	Gold	Platinum	Certified	Silver	Gold	Platinum
Datacenter	0	1	3	0	1	0	0	0
Educational	1	6	6	4	0	2	1	0
Healthcare	2	19	21	7	3	2	4	0
Higher Education	8	40	55	33	6	16	10	0
Industrial	7	4	5	0	4	2	0	0
K–12	3	3	5	2	0	2	0	0
Laboratory	1	2	14	6	1	1	1	0
Lodging	15	16	12	1	2	1	0	0
Residential	5	24	19	4	7	5	4	0
Office	32	64	79	38	25	21	28	8
Other	0	2	5	6	5	4	3	0
Public Assembly	5	40	56	40	6	14	3	0
Public Order and Safety	3	28	24	3	1	4	3	0
Religious Worship	0	2	1	1	1	0	0	0
Retail	11	32	11	3	7	0	1	0
Service	3	18	16	1	1	0	0	0
Undefined	0	1	3	3	2	1	0	0
Warehouse	8	29	26	1	3	5	0	0
Declared projects	109	347	374	156	77	83	60	8
Available projects	104	331	361	153	75	80	58	8

Table 2 shows that the LEED-NC v3/v4 projects included 18 space-types, of which the office type had the largest number of projects. Table 2 also shows that, in the LEED-NC v4 office-type Platinum group, there were only eight projects (i.e., sample size, $n = 8$). Applying statistical analysis to a small number of projects can lead to unreliable statistical conclusions [8].

Therefore, according to the literature analysis presented in Section 1 and the number of LEED-NC projects presented in Table 2, we focused on EA credits within LEED-NC v3/v4 Certified, Silver, and Gold certifications of office-relevant projects.

2.4. Data Analysis

2.4.1. Descriptive Statistics and Visual Analysis

The median of the project sizes was used to divide the analyzed projects into two groups, i.e., below and above the median project size LEED-NC v3/v4 office projects at each certification level. The LEED-NC projects below the median project size were called the "small" group, while the LEED-NC projects above the median project size were called the "large" group. Visual analysis was used to identify ordinal, binary, or dichotomous data.

The percentage of average score (PAS)—the ratio of achieved points to maximum points (expressed as a percentage)—was used to quantify changes in the LEED-NC v3/v4 data [1]. The maximal number of points for LEED-NC v3 and v4 was 110 points and the minimal number of points to achieve the Certified, Silver, and Gold certification was 40, 50, and 60, respectively. Therefore, we can conclude that, if PAS > 36, 46, and 55, these LEED credits were sufficient to achieve the Certified, Silver, and Gold certification levels, respectively. For Certified, for example, if PAS > 36, the PAS showed high performance and if PAS < 36, the PAS showed low performance.

2.4.2. Effect Size and Significance Test

The LEED project-size data were interval data. In this context, to choose between parametric and nonparametric statistical analysis, the normality assumption was tested. The Shapiro–Wilk test showed that the assumption of normality was not met for the LEED project-size data ($p < 0.00001$). Consequently, Cliff's δ effect size nonparametric test [20] and WMW nonparametric tests with corrections for both continuity and ties [8] were used to evaluate statistical differences between the two statistically independent groups.

LEED credit data were divided into three types: ordinal, binary, or dichotomous. If the relationship between the ordinal data and interval data had a pattern of monotonic increase or decrease, then the nonparametric Spearman's rank order correlation coefficient (r) was used. Recently, Pushkar and Verbitsky used Spearman's test to assess the strength of association between building and service layers in terms of LEED credit data [21]. If the relationship between the ordinal data and interval data did not have a monotonic increase or decrease pattern, then LEED credit data were divided into two groups, i.e., below and above the median project size. In this context, the Cliff's δ effect size [20] and exact WMW [8] nonparametric tests were used to assess statistical differences between the two groups (i.e., "small" and "large").

If the LEED credit data had a binary or dichotomous scale, i.e., 0 or 1, whereby values of 1 or more than 1 were grouped, the data were also divided into groups of below and above the median project size (i.e., "small" and "large"). In this case, we used the natural logarithm of the odds ratio $(\ln \theta)$, i.e., the effect size [22], and Fisher's exact 2×2 test with Lancaster's mid-p-value [23] to evaluate the statistical difference between two groups (i.e., "small" and "large").

2.4.3. Correlation Coefficient (r) and Effect Size Interpretation

The value of r ranged between -1 and +1. A positive value (+) indicates a monotonic increase two independent variables (i.e., LEED credit achievement and LEED project size). A negative value $(-)$ indicates a monotonic increase in one independent variable and a monotonic decrease in the other independent variable (i.e., monotonic increase in the LEED project size and monotonic decrease in the LEED credit achievement). A value of zero indicates no relationship between the two independent variables (i.e., LEED credit achievement and LEED project size). Table 3 illustrates the absolute strength of the association $(|r|)$ that was used to interpret the relationship between the LEED credit achievement and LEED project size.

Table 3. Interpretation of the correlation coefficient ($|r|$)

Coefficient	Very Weak	Weak	Moderate	Strong	Very Strong	Reference
$\|r\|$	0.00–0.19	0.20–0.39	0.40–0.59	0.60–0.79	0.80–1.00	[24]

Cliff's δ ranged between -1 and +1. A positive value $(+)$ indicate that Group 1 (i.e., below the median project size) was larger than Group 2 (i.e., above the median project size), a value of 0 indicates equality or overlap (i.e., equality between groups below and above the median project size), and a negative value $(-)$ indicates that Group 2 (i.e., above the median project size) was larger than Group 1 (i.e., below the median project size).

The value of $\ln \theta$ ranged between $(-)$ infinity and $(+)$ infinity. A positive value indicates that Group 1 (i.e., below the median project size) was larger than Group 2 (i.e., above the median project size), a value of 0 indicates no difference between Groups 1 and 2 (i.e., no difference between groups below and above the median project size), and a negative value indicates that Group 2 (i.e., above the median project size) was larger than Group 1 (i.e., below the median project size).

Table 4 shows the absolute effect size thresholds (small, medium, and large) for Cliff's δ and $|\ln \theta|$.

Table 4. The absolute effect size thresholds.

Effect Size Estimation Procedure	Small	Medium	Large	Reference
Absolute Cliff's δ $\|\delta\|$	0.147	0.33	0.474	[25]
Absolute natural log odds ratio $\|\ln \theta\|$	0.51	1.24	1.90	[26]

2.4.4. Two-Tailed *p*-Value Interpretation

In the current study, we used neo-Fisherian significance assessments (NFSAs) instead of the Paleo–Fisherian and Neyman–Pearson paradigms [27]. According to Hurlbert and Lombardi, the NFSA paradigm includes the following definitions: (1) the paradigm does not fix α (i.e., the level of significance); (2) the paradigm does not describe *p*-values as "significant" or "nonsignificant"; (3) the paradigm does not accept null hypotheses on the basis of high *p*-values but only suspends judgment; (4) the paradigm interprets significance tests according to "three-valued logic"; and (5) lastly, the paradigm presents effect size information in conjunction with significance tests [27].

According to Hurlbert and Lombardi, the *p*-values were evaluated according to three-valued logic, i.e., "it appears to be positive", "it appears to be negative", or "judgment is suspended" [27].

For the Spearman's correlation test results, the three-valued logic was interpreted as follows:

- There appears to be a correlation between LEED credit achievement and LEED project size.
- There does not appear to be a correlation between LEED credit achievement and LEED project size.
- "Judgment is suspended" regarding the correlation between LEED credit achievement and LEED project size.

For the WMW test and Fisher's exact 2 $\times$ 2 test with Lancaster's mid-*p*-value test results, the three-valued logic was interpreted as follows:

- There appears to be a difference between the LEED credits belonging to the group below the median project size and the LEED credits belonging to the group above the median project size.
- There does not appear to be a difference between the LEED credits belonging to the group below the median project size and the LEED credits belonging to the group above the median project size.

- "Judgment is suspended" regarding the difference between the LEED credits belonging to the group below the median project size and the LEED credits belonging to the group above the median project size.

The *p*-values in the figures and tables are presented according to three-valued logic: bold font—appears to be positive; ordinal font—appears to be negative; and italic font—judgment is suspended.

3. Results and Discussion

3.1. Project Sizes

Table 5 shows the medians of Certified, Silver, and Gold project sizes, *p*-values, and Cliff's δ in both versions of LEED-NC certification. The median of the project sizes gradually increased from Certified to Silver and from Silver to Gold in both versions of LEED-NC certification. However, only the difference between Certified project size and Gold project size in LEED-NC v3 appeared to be positive. In all other pairwise comparisons, the differences between project sizes of the compared certification levels appeared to be negative.

Table 5. LEED-NC v3/v4 office-type projects: LEED project sizes and results of the statistical analysis.

Version	Median (m^2)			*p*-Value (Cliff's δ)	
	Certified	Silver	Gold	Certified vs. Silver	Silver vs. Gold
LEED-NC v3	1711	2565	3391	0.1346 (−0.19)	**0.0253** (−0.27) [a]
LEED-NC v4	2286	3640	4169	0.1290 (−0.26)	0.1251 (−0.25) [a]

[a] The exact Wilcoxon–Mann–Whitney and Cliff's δ effect size tests were used.

3.2. Example of Raw EA Data of Real Projects of Different Sizes

Table 6 shows an example of EA awarded points in three small and three large projects certified with LEED-NC v3. The raw EA data were retrieved from the USGBC website [2]. The three small projects were: Certified small office project (317 m^2), "La Jolla Village Office Building Remodel" San Diego, California, US; Silver small office project: (200 m^2), "UCSD East Campus Parking Structure (4315)", San Diego, California, US; Gold small office project (130 m^2), "USCG Narwhal Building", Newport Beach, California, US. The three large offices were: Certified large office project (28,927 m^2), "FedEx Ground Package Systems" Rialto, CA, USA; Silver large office project (20,292 m^2), "County of Orange Building 16" Santa Ana, CA, USA; and Gold large office project: (44,326 m^2), "Hall of Justice", Los Angeles, CA, USA.

Table 7 demonstrates the example of EA awarded points in three small and three large projects certified with LEED-NC v4. The raw EA data were retrieved from the USGBC website [2]. The three small projects were: Certified small office project: (816 m^2), "Seasons of Hope Grief Support Center", Vancouver, Washington, US; Silver small office project (1231 m^2), "CA Lottery Rancho Cucamonga", Rancho Cucamonga, CA, USA; and Gold small office project (766 m^2), "Kaiser Pueblo MOB II", Pueblo, CO, USA.

The three large projects were: Certified large office project (23,226 m^2), "Adventist Health Shared Services Campus", Roseville, CA, USA; Silver large office project (65,497 m^2), "Triad 1828 Center", Camden, NJ, USA; and Gold large office project (40,818 m^2) "Spruce Goose", Los Angeles, CA, USA.

Table 6. The Energy and Atmosphere (EA) credits in three small and three large project sizes in LEED-NC v3 projects.

EA Credit (Maximum Points)	Certified		Silver		Gold	
	Small	Large	Small	Large	Small	Large
Optimize energy performance (19)	10	10	15	9	19	10
Enhanced refrigerant management (2)	0	2	0	2	0	2
On-site renewable energy (7)	0	0	0	0	7	0
Green power (2)	2	0	2	0	2	0
Enhanced commissioning (2)	0	0	0	2	2	2
Measurement and verification (3)	0	0	0	0	0	1
EA total (35)	12	12	17	13	30	15

Table 7. The Energy and Atmosphere (EA) credits in three small and three large project sizes in LEED-NC v4 projects.

EA Credit (Maximum Points)	Certified		Silver		Gold	
	Small	Large	Small	Large	Small	Large
Optimize energy performance (18)	12	6	18	8	18	5
Enhanced refrigerant management (1)	0	1	0	1	1	0
Renewable energy production (3)	0	0	3	0	3	0
Green power and carbon offsets (2)	0	0	0	2	2	2
Enhanced commissioning (6)	3	3	3	4	4	4
Advanced energy metering (1)	0	1	0	0	1	1
Demand response (2)	0	0	0	0	0	0
EA total (33)	15	11	24	15	29	12

3.3. Operational Energy Credit

The operational energy credit is aimed at decreasing the space-related heating, cooling, and lighting energy needs. This decrease is measured relative to the prescribed minimum energy performance in the EA Prerequisite: minimum energy performance. According to LEED-NC v3, for the operational energy decreasing from 12% to 48% in an incremental step of 2%, a project can be awarded 1–19 points with an incremental step of one point [28]. LEED-NC v4 has a similar point (1–18) awarding scheme that ranges from 6% to 50% of the energy decreasing below the prescribed minimum energy performance in the EA Prerequisite [29].

Table 8 shows the results of the operational energy credit. Considering the PAS values of LEED-NC v3 projects, small and large Certified and Silver offices demonstrated low performance, whereas small and large Gold offices demonstrated high performance. Considering the PAS values of LEED-NC v4 projects, small and large Certified, Silver, and Gold projects had high performances. According to the effect size analysis, the small offices outperformed the large offices in both versions and at the three certification levels. However, according to the p-values, the difference between small and large offices appeared to be positive for the LEED-NC v3 Gold and LEED-NC v4 Silver and Gold certifications only, whereas, in other cases, this difference appeared to be negative or suspected.

Table 8. LEED-NC v3/v4 office-type projects: operational energy credit.

Version	Level	Percentage of Average Score (PAS)		*p*-Value (Effect Size)
		Small	Large	
LEED-NC v3	Certified	35	28	0.6593 (0.09) [a]
	Silver	49	40	0.2417 (0.17) [a]
	Gold	81	64	**0.0017** (0.40) [a]
LEED-NC v4	Certified	66	49	*0.0699 (0.44)* [a]
	Silver	80	57	**0.0082** (0.68) [a]
	Gold	95	71	**0.0004** (0.73) [a]

[a] The exact Wilcoxon–Mann–Whitney and Cliff's δ effect size tests were used.

This small office-relevant higher performance of operational energy credit was also confirmed in the correlation analysis, which demonstrated a negative correlation between the LEED-NC v3 and v4 achievements of the operational energy credit and the project size (Figures 1 and 2, respectively). In both LEED-NC v3 and v4 certifications, the negative correlation between the achievements of the operational energy credit and the project size monotonically increased from level to level of the certification. For both LEED-NC v3 and v4 Silver and Gold projects, the correlation between the LEED-NC v3 and v4 achievements of the operational energy credit and the project size appeared to be positive.

Thus, in this study, the operational energy credit for LEED-NC v3/v4 Silver and Gold showed better achievements with decreasing project size. The higher operational energy credit achievements for smaller projects compared to larger projects can be explained by analyzing two factors that differ with office-type project size. The first factor was the type of envelope construction, and the second factor was HVAC equipment installed.

According to a commercial building energy consumption survey (CBECS) by the US Department of Energy, mass walls are recommended for small offices, whereas steel frame walls or mass walls are recommended for large offices; furthermore, the recommended average window-to-wall ratios are 19% and 54% for small and large offices, respectively [30]. Thus, smaller projects can be better insulated through a less costly option compared with larger projects. Accordingly, smaller projects have more opportunity to achieve a highly decreased operational energy compared to larger projects.

According to a CBECS by the US Department of Energy, small and large offices typically install different typical HVAC equipment. Small offices prefer Packaged Air Conditioning Units (PACUs) for air cooling and heating, whereas large offices prefer chillers for air cooling and boilers for air heating [31]. PACU equipment is related to decentralized systems (DXs), whereas chillers and boilers are related to centralized systems. These two different HVAC configurations have completely different media for their air heating/cooling needs: DX systems use refrigerants, and centralized systems use water [32] (p. 561).

Thus, DX systems are more appropriate for separate installations in smaller projects due their flexibility, whereas centralized systems are more appropriate for installations in larger projects due to their ability to provide a dense energy supply. Accordingly, smaller projects have more opportunities to appropriately adjust the thermal conditions for each office space, thereby achieving better economic operational energy consumption compared to larger projects.

3.4. Enhanced Refrigerant Management Credit

The enhanced refrigerant management credit requires using HVAC equipment with refrigerants that have minimum or zero emissions related to ozone depletion and climate change [28,29].

Table 9 demonstrates a similar tendency in the results of enhanced refrigerant management credit of the projects certified with both LEED-NC versions, v3 and v4. Considering the PASs, the small offices had low performance and large offices had high performance. This better performance of large offices was also confirmed by effect size analysis. However, according to the *p*-value analysis, the difference between small and large offices appeared to be positive for the LEED-NC v3 Gold and LEED-NC v4 Certified and Gold certifications only, whereas, in other cases, this difference appeared to be negative or suspected.

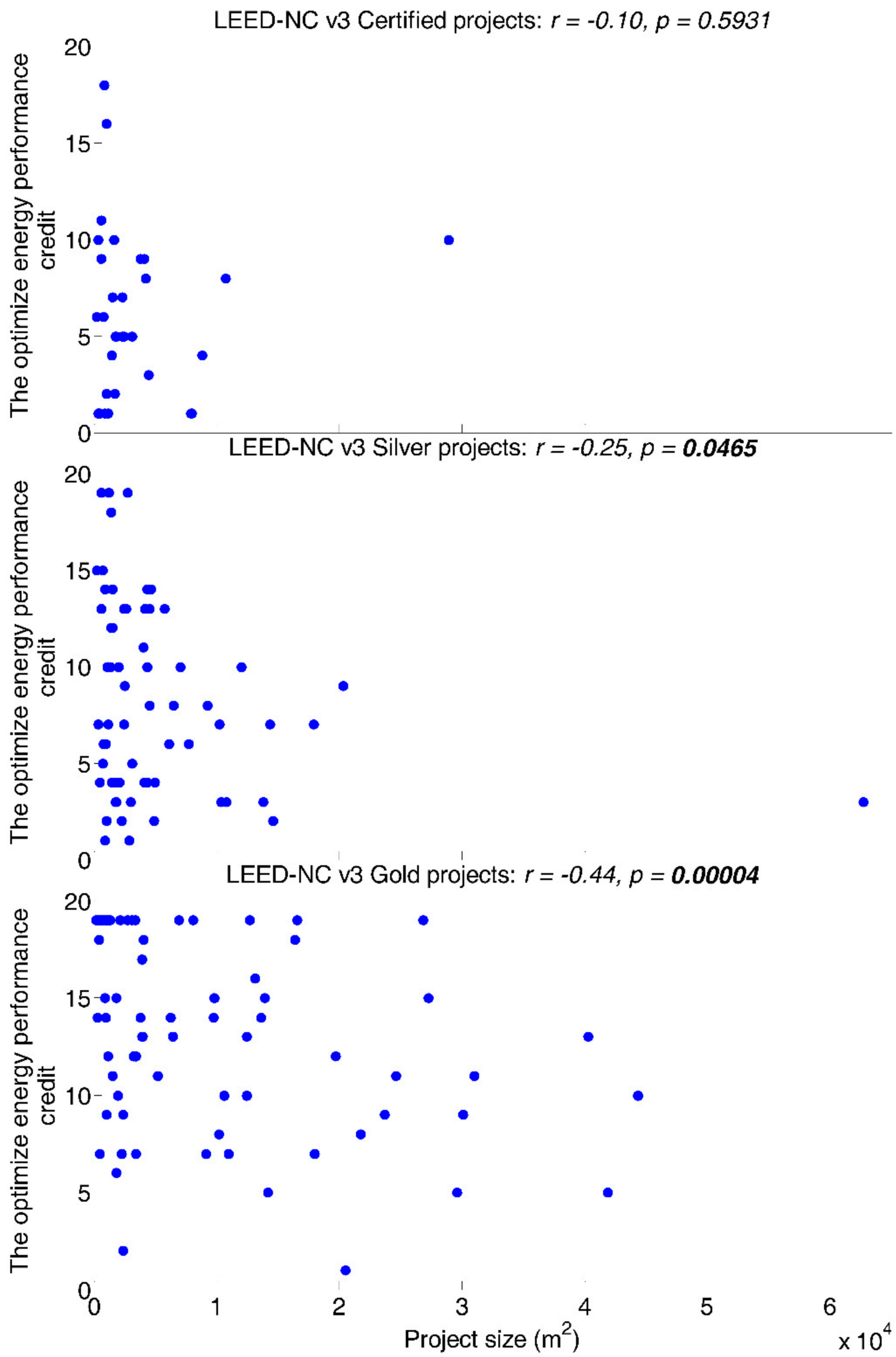

Figure 1. LEED-NC v3 office-type projects: optimized energy performance credit versus project size.

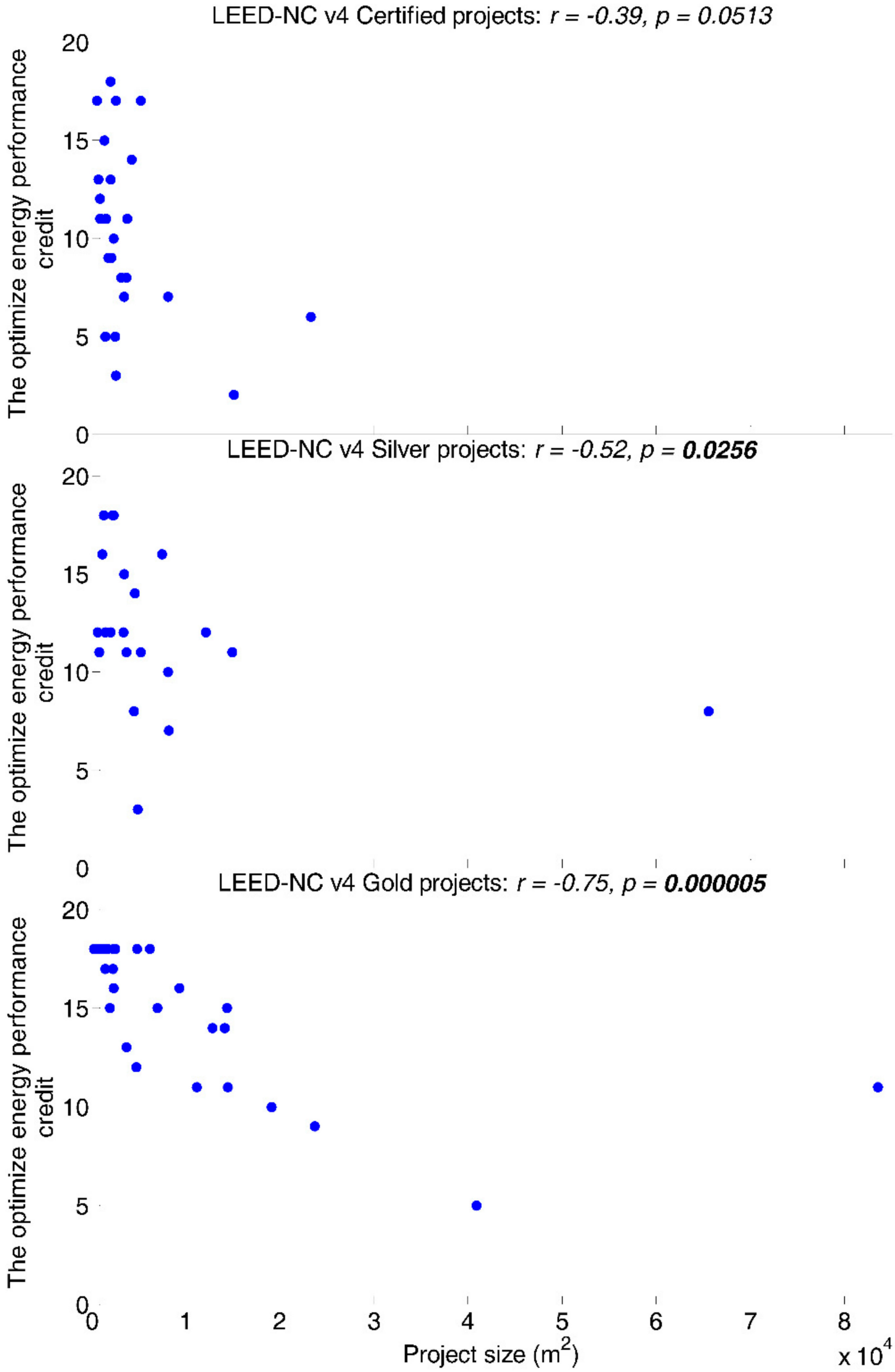

Figure 2. LEED-NC v4 office-type projects: optimized energy performance credit versus project size.

This study revealed that more than half of the studied large offices achieved enhanced refrigerant management credit in a strong way in both certification versions. Such success in achieving the enhanced refrigerant management credit appears justified, because new projects typically use the required HVAC equipment [33]. The low achievements of this credit demonstrated in this study by the small offices were similar to the results of the study of Gurgun and Arditi for LEED-NC v3 projects certified in the US [13].

Table 9. LEED-NC v3/v4 office-type projects, enhanced refrigerant management credit.

Version	Level	Percentage of Average Score (PAS)		*p*-Value (Effect Size)
		Small	Large	
LEED-NC v3	Certified	19	50	*0.0513 (−1.47)* [b]
	Silver	41	53	0.2708 (−0.50) [b]
	Gold	33	62	**0.0103** (−1.16) [b]
LEED-NC v4	Certified	17	75	**0.0036** (−2.71) [b]
	Silver	40	70	0.1448 (−1.25) [b]
	Gold	21	71	**0.0164** (−2.22) [b]

[b] The Fisher's exact 2 × 2 with Lancaster's mid-*p*-value and natural logarithm of the odds ratio ($\ln\theta$) tests were used.

However, the present study also revealed a difference between the achievements of smaller and larger projects in the enhanced refrigerant management credit. In particular, for the LEED-NC v3 Gold and LEED-NC v4 Certified and Gold projects, the credit showed better achievements for larger projects compared with smaller projects. For the remaining certification levels in both versions of the certification, a tendency toward an increase in the awarded points with an increasing in project size still persisted.

To produce air heating/cooling needs, small offices install PACUs (decentralized systems) that use a refrigerant media, whereas large offices install chillers and boilers (centralized systems) that use a water media [32] (p. 561). As a result, centralized HVAC systems have a greater chance of being free from emissions related to ozone depletion and climate change.

3.5. Renewable Energy Credit

The renewable energy credit requires replacing some of the operational energy based on fossil fuels such as coal, gas, and oil with renewable energy based on solar, wind, and hydro power [28,29].

Table 10 shows the mostly low PAS performance of renewable energy credits in the analyzed small and large offices for both certification versions. The only exception was small Gold offices, which, according to PAS, had a high performance for the Gold certification in both versions. At the same time, according to the effect size analysis, the small office outperformed the large offices in both versions and at all certification levels. However, the difference in the performance of the renewable energy credit between small and large offices appeared to be positive at the Gold certification only in both v3 and v4, while in other comparison of the pairs of small and large offices, the difference in the performance of this credit appeared to be negative or suspended.

Table 10. LEED-NC v3/v4 office-type projects, renewable energy credit.

Version	Level	Percentage of Average Score (PAS)		*p*-Value (Effect Size)
		Small	Large	
LEED-NC v3	Certified	17	0	*0.0565* (2.15) [b]
	Silver	24	8	**0.0376** (0.22) [a]
	Gold	74	44	**0.0066** (0.33) [a]
LEED-NC v4	Certified	17	8	0.4130 (0.79) [b]
	Silver	37	10	0.1002 (1.79) [b]
	Gold	79	40	*0.0542* (0.40) [a]

[a] The exact Wilcoxon–Mann–Whitney and Cliff's δ effect size tests were used. [b] The Fisher's exact 2 × 2 with Lancaster's mid-*p*-value and natural logarithm of the odds ratio ($\ln\theta$) tests were used.

Thus, the renewable energy credit mostly had low popularity in the analyzed offices. Such low popularity of this credit may be explained by the economic and technical risks related to installing and operating these relatively new renewable technologies [34]. Gurgun and Arditi revealed a similarly low popularity of the renewable energy credit for LEED-NC v3 Silver and Gold projects certified in the US [13].

However, this study also revealed a tendency toward an increase in the awarded points with a decrease in the project size. This evidence of better achievements by smaller projects relative to larger offices appears reasonable. Combining renewable energy systems, for example, building-integrated photovoltaic and active wind power systems, is an easier task for smaller projects than larger projects [32] (p. 214). This is because the main HVAC systems in smaller projects are autonomous separate DX systems that can be partly replaced with building-integrated renewable systems with less economical and technical risks compared to central HVAC systems that provide a dense energy supply to the whole building in a centralized way in larger projects.

3.6. Green Power Credit

The green power credit requires applying grid-source renewable energy technologies. In particular, it necessitates signing a contract with green power-supply qualified resources [28,29].

Table 11 shows the results regarding the green power credit. Different PAS performance was revealed: high PAS values for small and large Certified offices (v3) and small Certified and large Silver and Gold offices (v4) and low PAS values for the rest of the cases. In addition, according to the effect size analysis, no particular tendency for any type of office to dominate in PAS performance over another was revealed.

Table 11. LEED-NC v3/v4 office-type projects, green power credit.

Version	Level	Percentage of Average Score (PAS)		*p*-Value (Effect Size)
		Small	Large	
LEED-NC v3	Certified	38	50	0.3944 (−0.51) [b]
	Silver	41	34	0.7072 (0.27) [b]
	Gold	37	49	0.3135 (−0.42) [b]
LEED-NC v4	Certified	42	17	*0.0687* (1.61) [b]
	Silver	5	60	**0.0437** (−2.60) [b]
	Gold	39	57	0.3692 (−0.58) [b]

[b] The Fisher's exact 2 × 2 with Lancaster's mid-*p*-value and natural logarithm of the odds ratio ($\ln\theta$) tests were used.

In the cases of the Silver (v3) and Certified (v4) levels, small offices performed better than large offices; whereas, in other cases of certification levels in both versions, the results were the opposite with the advantage of large offices over small offices. However, the positive difference in the performance of the green power credit between small and large offices appears to be only at the Silver certification in v4; whereas, in all other cases of the comparison, the performance of this credit between two offices sizes appears to be negative or suspended.

As revealed by previous researchers, this credit was poorly implemented by design teams due to the grid-source renewable energy cost constraints and contract availability [13,15]. The present research also revealed low popularity of the green power credit.

3.7. Enhanced Commissioning Credit

The enhanced commissioning credit deals with mechanical and electrical equipment, such as HVAC, plumbing, and renewable energy systems [28,29]. This credit requires using an independent commissioning authority (CxA) to verify the appropriateness of the equipment-related design to the owner's requirements. The credit has numerous benefits as it can reveal equipment installation faults, which may influence tenant-related indoor air quality, thermal comfort, and operational energy-savings [35]. The employment of an independent CxA is considered to be a successful approach to guarantee the quality of the installed mechanical and electrical equipment [13,36].

Table 12 demonstrates high PAS values of the enhanced commissioning credit for both small and large offices at all certification levels in both LEED-NC versions, v3 and v4. However, also in this credit, according to the effect size analysis, no particular tendency for any type of office to dominate in PAS performance over one another was revealed. In the cases of Certified (v3 and v4) levels, small and large offices had similar performances; in the case of Silver (v4), small offices performed better than large offices; whereas, in other cases of certification levels in both versions, the results were reversed indicating the advantage of large offices over small offices.

Table 12. LEED-NC v3/v4 office-type projects, enhanced commissioning credit.

Version	Level	Percentage of Average Score (PAS)		*p*-Value (Effect Size)
		Small	Large	
LEED-NC v3	Certified	38	38	0.8580 (0.00) [b]
	Silver	56	59	0.7099 (−0.13) [b]
	Gold	59	77	*0.0746* (−0.84) [b]
LEED-NC v4	Certified	51	51	1.0000 (0.00) [a]
	Silver	68	57	0.3149 (0.27) [a]
	Gold	63	82	0.1154 (−0.35) [a]

[a] The exact Wilcoxon–Mann–Whitney and Cliff's δ effect size tests were used. [b] The Fisher's exact 2 × 2 with Lancaster's mid-*p*-value and natural logarithm of the odds ratio (ln θ) tests were used.

Thus, it is not surprising that the enhanced commissioning credit was popular in most of the analyzed projects. The high achievements of both small and large offices with respect to the enhanced commissioning credit may be explained by the importance of the issue of high demand in tenant-related indoor air quality, thermal comfort, and operational energy-savings for this type of building. In addition, especially in large projects, the commissioning procedure is a very critical issue due to the more sophisticated centralized method of supplying HVAC services to the whole building [32] (p. 561).

3.8. Operational Energy Metering Credit

The operational energy metering credit is aimed at installing meters that should measure the operational energy at building and system-related levels [28,29]. Table 13 displays the results for the operational energy metering credit. This credit had mostly low PAS values with the only exceptions in large Silver and Gold offices, which had high PAS values. According to the effect size analyses, no particular tendency for any type of office to dominate over another in PAS performance was revealed.

Table 13. LEED-NC v3/v4 office-type projects, operational energy metering credit.

Version	Level	Percentage of Average Score (PAS)		*p*-Value (Effect Size)
		Small	Large	
LEED-NC v3	Certified	15	13	0.16080 (1.16) [b]
	Silver	30	29	0.3868 (0.39) [b]
	Gold	33	36	0.5780 (−0.21) [b]
LEED-NC v4	Certified	33	33	0.8334(0.00) [b]
	Silver	30	80	**0.0216** (−2.23) [b]
	Gold	50	71	0.2001 (−0.92) [b]

[b] The Fisher's exact 2 × 2 with Lancaster's mid-*p*-value and natural logarithm of the odds ratio (ln θ) tests were used.

In Certified (v4), both small and large offices had similar PAS values; in Certified and Silver (v3), small offices outperformed large offices; and in Gold (v3) and Silver and Gold (v4), large offices outperformed small offices. However, according to the *p*-values, the only difference between small and large offices at Silver certification appears to be positive; whereas, in all other cases of the small offices versus large offices, the difference between their performances appears to be negative.

According to the literature, the operational energy metering credit was reported as seldom achieved in LEED-NC v3 Certified, Silver, and Gold projects in the US [13]. This issue was also confirmed in the present study. No clear tendency toward any change in the awarded points according to the project size was revealed.

4. Conclusions

The LEED certification strategy is influenced by many factors, such as the space-type, project size, and building technology. This study considered a homogenic sample of office-type projects in the US with LEED-NC v3/v4 Certified, Silver, and Gold certification to analyze the influence of the project-size factor on EA credit achievements. The main contribution of this study is in providing feedback for LEED-NC v3/v4 practitioners with regard to the dependence of EA credit achievement on office-type project size. Such feedback will help LEED practitioners with similar project types and sizes to more straightforwardly identify a certification strategy that is appropriate for smaller and larger offices due to their financial and scheduling limitations.

The main conclusions drawn are as follows: two groups of EA credit performance were revealed (1) office-size dependent and (2) office-size independent.

(1) The office-size dependent credits were: operational energy, enhanced refrigerant management, and renewable energy. The operational energy credit for LEED-NC v3/v4 Silver and Gold projects showed better achievements with decreasing project size. The correlation between the LEED-NC v3/v4 achievements with respect to the operational energy credit and the project size gradually increased from Certified to Gold via Silver certifications. In contrast, the enhanced refrigerant management credit demonstrated the opposite tendency. In the LEED-NC v3 Gold and LEED-NC v4 Certified and Gold projects, this credit showed better achievements for larger projects compared with smaller projects. However, as with the results of the operational energy credit, the renewable energy credits in the LEED-NC v3 Silver and Gold projects also showed better achievements for smaller projects compared with larger projects.

(2) The office-size independent credits were green power, enhanced commissioning, and operational energy metering credits. The green power credit in only the LEED-NC v4 Silver projects showed better achievements for larger projects compared with smaller projects. A similar tendency was revealed in the enhanced commissioning credit for the LEED-NC v3 Gold projects and in the operational energy metering credit for the LEED-NC v4 Silver projects.

The revealed conclusions allow us to present the following recommendations for LEED practitioners with regard to the EA-relevant certification strategy toward the certification of buildings in the future: small offices have the possibility of high performance of operational energy and renewable energy credits, whereas large offices have the possibility of high performance of enhanced refrigerant management credit. In addition, green power, enhanced commissioning, and operational energy metering credits have the potential to be better implemented in large offices compared with in small offices.

To emphasize the present conclusions with the more robust ones, both (1) office-size dependent and (2) office-size independent credits should be reanalyzed in future studies when a larger sample size of LEED-NC v4 projects is available.

The recommendations are relevant only for small and large office-type building certified with LEED-NC v3 and v4 in the US and cannot be projected on other building types, other certification systems, and other countries. This is due to the high dependence of the certification strategies on the mentioned factors [4].

5. Limitations

Three main limitations of the study can be recognized. The first one is that the LEED-NC v4 office-type projects were collected from the US without considering the separate states in the US. This limitation was due to the small number of LEED-NC v4 office-type projects in individual states.

The second limitation is that only one space-type for the LEDD-NC v3 and v4 projects was analyzed. This limitation was due to the small number of LEED-NC v4 space-type projects.

The third limitation is the lack of analysis of the EA points in LEED-NC certified buildings in terms of the building's "hygrothermal behavior" during the post-occupation phase [37]. In the present time, the performance of such an analysis was not possible as only recently certified offices were considered in this study.

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