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A Comparative Analysis of Gold Leadership in Energy and Environmental Design for New Construction 2009 Certified Projects in Finland, Sweden, Turkey, and Spain

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Received: 24 July 2018; Accepted: 27 August 2018; Published: 31 August 2018

Abstract: The Leadership in Energy and Environmental Design (LEED) is currently intensively applied in several European countries. The aims of the present study were to compare the difference between (i) two countries from the same region (i.e., Finland vs. Sweden or Turkey vs. Spain) and (ii) two European regions (northern Europe [Finland and Sweden] vs. [Turkey and Spain]) when the LEED- New Construction (NC) 2009 Certified rating level certified projects were analyzed. We found that, in the northern and southern parts of Europe, LEED- NC 2009 credit achievements in terms of Sustainable Sites (SS), Water Efficiency (WE), Materials and Resources (MR), and Indoor Environmental Quality (EQ) were similar, whereas credit achievements in Energy and Atmosphere (EA) were different. High achievements were revealed in WE and SS, with values of 80–100% and 70–75%, respectively; intermediate achievements were revealed in EQ, with values of 40–60%; and low achievements were revealed in MR (20–40%). EA achievements were intermediate (60–65%) in northern Europe, while they were low in southern Europe (40%). This evidence can help recognize the categories that are performed with a high number of points and those that are performed with a low number of points.

Keywords: LEED; green building; energy performance; Europe

1. Introduction

In Europe, the Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB, from Germany), the Building Research Establishment Environmental Assessment Method (BREEAM, from the UK), and Leadership in Energy and Environmental Design (LEED, from the US) are the most recognized rating systems [1]. The DGNB places equal emphasis on each of the three classic pillars of sustainability (i.e., the triple bottom line concept), which are expressed through normalized scores: environmental sustainability (22.5%), social sustainability (22.5%), and economy sustainability (22.5%) [2], compared to both BREEAM and LEED, which place more of an emphasis on environmental sustainability (in both schemes, 74.6%), less of an emphasis on social sustainability (16.2% and 18.0, respectively), and a minor or negligible emphasis on economic sustainability (2.3% and 0.82%, respectively) [3].

According to Głuszak [1], DGNB has a dominant position in Germany and Austria, and BREEAM has a dominant position in the United Kingdom, Slovenia, France, Spain, Lithuania, Belgium, Poland, and the Netherlands. However, the LEED has a strong position in Spain, Turkey, Italy, Sweden, and Finland [1]. Therefore, the LEED was the focus of this study. In this respect, several empirical studies of LEED certified projects were revealed [4–9]. These studies analyzed different LEED subsystems and versions. It should be noted that, among the many practiced LEED subsystems, such as Existing Buildings: Operations & Maintenance (LEED-EB), Commercial Interiors (LEED-CI), Core and Shell Development (LEED-C&S), LEED Interior Design and Construction for Retail (LEED ID+C

Retail), LEED Building Design and Construction for Schools (LEED BD+C Schools), LEED Building Design and Construction for Homes (LEED BD+C Homes), LEED for Neighborhood Development (LEED-ND), and LEED Building Design and Construction for Healthcare (LEED BD+C Healthcare), the LEED for New Construction and Major Renovations (LEED-NC) is one of the most requested rating subsystems [10].

Empirical LEED studies [4–9] have revealed prevailing strategies and analyzed certification category achievements. The certification achievement is the total number of points that were received by a project in all seven LEED 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]) at any certification level (certified, silver, Certified, or platinum) [7]. The category achievement is the number of points that are received by a project per the individual categories, such as SS, WE, EA, MR, EQ, ID, or RP [7].

Fuerst [4] studied over 2,000 LEED-NC, LEED-CI, LEED-C&S, and LEED-EB certified projects registered as of March 2009 in the U.S., with low LEED certification levels reported by the author. This result means that the analyzed projects were clustered slightly above the lower thresholds of each certification level, with values of 40, 50, 60 and 80, in Certified, silver, Certified, and Platinum certifications, respectively. However, Fuerst [4] evaluated all types of certified buildings (NC, C&S, and EB) together in one pooling sample without any rigorous statistical analysis.

Ma and Cheng [5] studied LEED-NCv3 certified projects (1000 pooled samples) in the U.S. Again, low certification levels were reported, while the EA category was noted as a category that moved a project from lower to higher certification levels. This outcome means that the difference between, for example, Silver certified projects and Certified certified projects, was mainly due to high achievements in the EA category in Certified certified projects compared to that of Silver certified projects. However, no significance tests were applied in this study [5].

The empirical evidence of LEED certification with applied significance tests was performed by Wu et al. [6], who analyzed 5340 pooled certified projects of the LEED-NCv2.2. Similar low certification levels were reported, and EA was again revealed as a category that moves a project from lower to higher certification levels. However, the LEED-NCv2.2 significantly differs from both the LEED-NC 2009 (v3) and the current LEED-NCv4 in at least two issues: (i) in the LEED-NCv2.2, the total number of points is 69, whereas, in the LEED-NCv3 and LEED-NCv4, the total number of points is 110; and (ii) all credits have the same weighting (1 pt) in the LEED-NCv2.2, whereas different weights are applied to different credits in the LEED-NCv3 and LEED-NCv4. Therefore, examining the LEED-NCv2.2 empirical evidence [6] to suggest new LEED versions seems inappropriate.

However, when examining the LEED 2009 (which preceded the current LEED version 4), the empirical evidence is important because more similarities than differences are evidenced from the comparison of the LEED-NC 2009 and LEED-NCv4 categories, which are described below in chapter 1.2 (“Comparing LEED-NCv3 with LEED-NCv4: similarities and differences”).

Wu et al. [7] used significance tests to analyze the LEED-NC 2009 projects that were certified in several different countries (including the U.S.) for five years and pooled them into two unpaired groups (i.e., the LEED Silver level group and LEED Certified level group) in the same cluster. The sample sizes for both the Silver and Certified LEED certified projects were $n_1 = 1310$ and $n_2 = 1201$, respectively ([7], p. 375, Table 9). The authors concluded that EA, SS, and WE were the credits that moved the projects from a Silver to a Certified certification ([7], p. 375, Table 7). Consequently, if all LEED Silver and Certified levels projects around the world were considered in the same cluster, then the influence of other “green building policies” that are usually applied differently in different countries or states, such as ASHRAE 90.1 (Energy Standard for Buildings Except Low-Rise Residential Buildings), on the performance LEED projects was ignored [8]. This outcome can lead to a misinterpretation in LEED projects results [11].

Another design structure was presented in the Pushkar and Verbitsky [8] study. The authors reported that the LEED-NC 2009 data were separately collected for each of ten U.S. states (CA, FL,

GA, IL, MA, NY, OH, TX, VA, and WA) in 2016. Each state was defined as an individual cluster. In this context, it was suggested that “any two LEED projects in the same state share more similar green building policy conditions compared to any two LEED projects from different states” [11]. This logic design structure was based on the fact that U.S. energy regulation, such as ASHRAE 90.1, is regulated at the state (i.e., not national) level; therefore, different states adopted different versions of ASHRAE [12]. In this respect, it was shown that the ASHRAE 90.1 version can influence the results of the LEED Silver-to-Certified certifications [8]. Thus, the following three different strategies of certified projects in transition from Silver to Certified were revealed (a) EA-emphasized (e.g., California), (b) SS/EQ-emphasized (e.g., New York), and (c) integrated (e.g., Georgia) strategies [8].

At least one international LEED-NC 2009 application suggested by Wu et al. [13] was recognized throughout the literature. The authors studied LEED-NC 2009 certified projects in China (172 projects), Turkey (86 projects), and Brazil (75 projects) [13]. It was reported that significant differences among the countries were revealed in LEED categories, including SS, WE, EA, EQ, and ID. However, in their study, Wu et al. [13] pooled all projects from all certification levels (certified, silver, certified, and Platinum) into one total sampling pool. Such a comparison of the LEED categories’ achievements among countries [13] is not appropriate because each of the countries had different numbers of certified, silver, Certified, and Platinum projects.

In this study, an additional international LEED-NC 2009 application was examined. In particular, we focused only on the Certified level certification for the LEED-NC 2009 in two different European regions, each with two representative countries. Two different climate-related parts of Europe were (i) northern (humid continental climate with warm to hot humid summers and cold winters) and (ii) southern Europe (Mediterranean climate with warm to hot dry summers and mild to cool wet winters). For northern Europe, Finland and Sweden were selected as the two representative countries, whereas, for southern Europe, Turkey and Spain were selected as the two representative countries. These representative countries were selected due to a sufficient sample size of the LEED certified projects discovered in them. Based on the available statistical samples as of May 2018, the number of LEED certified projects was 165 in Finland, 172 in Sweden, 426 in Turkey and 245 in Spain [14].

The study’s main question is whether northern and southern European countries address international LEED system applications in a similar or different way. The contribution of the study is in determining the current northern and southern European LEED certification strategies. This study may help LEED experts improve further versions of LEED schemes by generally developing more applicable basic categories.

The aims of the present paper were to compare the differences in the LEED-NC 2009 Certified rating level certified buildings for (i) two countries from the same region (i.e., Finland vs. Sweden or Turkey vs. Spain) and (ii) two European regions (northern Europe [Finland and Sweden] vs. [Turkey and Spain]).

2. Materials and Methods

2.1. Comparing the LEED-NCv3 with LEED-NCv4: Similarities and Differences

In this empirical study, the focus was on the LEED-NC 2009 (version 3), one version before the current LEED-NC version 4. This approach is due two reasons: (i) availability of a sufficient sample size of LEED 2009 projects certified in Finland, Sweden, Turkey, and Spain in the US Green Building Council (USGBC) project directory, and (ii) the LEED-NC 2009 and LEED-NCv4 still share more similarities than differences.

(i) Currently (31 July 2018), according to the USGBC site, analyzing LEED-NC 2009 certified projects (four certification levels: certified, silver, Certified, and Platinum) revealed 30 certified projects in Finland, 38 in Sweden, 218 in Turkey, and 74 in Spain [14]. However, when considering projects certified with the LEED-NCv4, Finland has one certified project and one project with a “Certification in progress” status, Sweden has zero certified projects and zero projects with “Certification in progress”

statuses, Turkey has zero certified projects and 14 projects with “Certification in progress” statuses, and Spain has zero certified projects and two projects with “Certification in progress” statuses [14].

(ii) Comparing the LEED-NC 2009 and LEED-NCv4 rating schemes, in general, the following should be noted: the total number of points is the same (110 pts), and the number of points in each category is very similar (Table 1). In particular, the SS category in the LEED-NCv4 was split into Location and Transportation (LT) and SS categories. In the LEED-NC 2009, the SS category includes land usage, green transportation and parking, site usage and rainwater, heat island, and light pollution reductions. In the LEED-NCv4, the LT category includes land usage and protection and green transportation parking, while the SS category includes site usage and protection and rainwater, heat island, and light pollution reductions. In fact, the assessment of SS issues is very similar to the assessment of LT+SS issues.

Table 1. LEED-NCv3 vs LEED-NCv4: categories with allocated points.

LEED-NCv3	Pts	LEED-NCv4	Pts
Not applicable	-	Integrative Process	1
Sustainable Sites	26	Location and Transportation	16
		Sustainable Sites	10
Water Efficiency	10	Water Efficiency	11
Energy and Atmosphere	35	Energy and Atmosphere	33
Materials and resources	14	Materials and resources	13
Indoor Environmental Quality	15	Indoor Environmental Quality	16
Innovation in Design	6	Innovation in Design	6
Regional Priority	4	Regional Priority	4
Total	110	Total	110

The WE category was expanded in the LEED-NCv4, including, in addition to indoor and outdoor water reduction (that were presented in LEED-NC 2009), requirements concerned with the conservation of water used for cooling towers and installation of a water consumption metering system. However, in both versions, the indoor and outdoor water reductions have similarly high weights: 8 pts from the total 10 pts in the LEED-NC 2009 and 8 pts of the total 11 pts in the LEED-NCv4.

In the EA category, the issues of the LEED-NC 2009, such as energy optimization and metering, enhanced commissioning and refrigerant management, and renewable and green energy production are still relevant in the LEED-NCv4. In general, similar weighting is applied to these energy concerns. In particular, the most important energy optimization credit has almost the same weight in both versions: 19 pts of the total 35 pts in the LEED-NC 2009 and 18 pts of the total 33 pts in the LEED-NCv4. Only the weight of enhanced commissioning was increased in LEED-NCv4; 6 pts versus 2 pts in LEED-NC 2009.

The MR category in the LEED-NCv4 has newly introduced a life cycle impact reduction credit for building and material optimization and reusing, which has a high weight of 5 pts in the total 13 pts. Additionally, the direct requirements concerning building reusing and material recycling that were presented in the LEED-NC 2009 were reformulated in the LEED-NCv4, requiring manufacturers’ declarations regarding the source and production of raw materials, building materials and components to be disclosed. However, the issues of concern are still the same in each version, namely, building material reuse and recycling and construction waste management.

In general, the EQ category in the LEED-NCv4 considers issues that were of concern in the LEED-NC 2009: construction and indoor air quality, low-emitting materials, thermal comfort, and interior lighting and daylight with quality views consideration. Only one new credit, acoustic performance, was introduced in the LEED-NCv4.

Thus, more similarities than differences can be noted when comparing the LEED-NC 2009 and LEED-NCv4. Therefore, the findings of this empirical evidence of the LEED-NC 2009 certified projects may help LEED experts improve further versions of LEED schemes by developing more applicable basic categories and credits.

2.2. Design of the Study

Based on Hurlbert's terminology [15], the present study contains two types of design structures: the first is a split-unit design or nested (hierarchical) design structure, and the second is a single-unit design structure.

To correctly describe a two-stage nested structure, the statistical terms "a sampling frame," "a primary sampling unit," "subunits," and "individual subunits" should have been previously determined [16]. According to Picquelle and Mier [16], the sampling frame is a collection of primary sampling units "accessible for sampling in the population of interest". The primary sampling unit was statistically independent of other primary sampling units within the same sampling frame. The primary sampling unit contained two or more subunits. Subunits are nested in the primary sampling unit and were statistically dependent of those primary sampling unit. The subunit has two or more individual sampling units. Measurements were performed on the individual subunits. A single-unit design structure refers to observational studies, in which the primary sampling unit is defined at only one scale [15].

In this context, Europe was the sampling frame. Both northern Europe and southern Europe were the two primary sampling units. In parallel, both Finland and Sweden are two subunits that were nested into northern Europe, and both Turkey and Spain were two subunits that were nested into southern Europe. The EAc1 (i.e., optimize energy performance) credit from the LEED Certified projects were individual subunits. Because the EAc1 credit data were related to interval scale [17], we could use a split-unit design structure and a parametric two-stage nested ANOVA test to determine significant difference between northern Europe and southern Europe [16]. Recently, a two-stage nested ANOVA test was used when split-unit (nested) designs structures were met [18–21]. Thus, the other LEED data (all credits in SS, WE, EA, MR, and EQ categories) are related to the ordinal scale, and we could use a single-unit design structure (i.e., a comparison between Finland vs. Sweden or Turkey vs. Spain) and a non-parametric Wilcoxon–Mann–Whitney (WMW) test [22]. Recently, the WMW test was used when a single-unit design structure was met [11].

2.3. Data Collection

The LEED-NC 2009 Certified certified projects were analyzed in Finland, Sweden, Turkey, and Spain. For this analysis, from the new construction directory of the USGBC website [14], USGBC scorecards of all the available projects in these countries as of May 2018 were downloaded. The number of projects analyzed for each country was as follows: Finland—15, Sweden—23, Turkey—73, and Spain—22. From the scorecards, all required information and the credits that were awarded points in the five main categories—SS, WE, EA, MR, and EQ—were collected. Then, the RP points were also collected and redistributed among the five relevant main categories.

Type and size of the Certified LEED certified projects in each of the four countries. As shown in Table 2, office space type LEED-NC 2009 Certified certified projects had the highest priority in all four evaluated countries: 66.66% in Finland [23], 39.12% in Sweden [24], 27.39% in Turkey [25], and 36.35% in Spain [26]. In both Finland and Sweden, the Health Care space type is the second priority space type, constituting 13.33% and 26.08% in the two nations [23,24], respectively, whereas, in Turkey, the second priority space type was the Multi-Family Residential space type (17.81%) [25], and, in Spain, it was the Datacenter (22.72%) [26].

Table 2. Space type in % of total number of projects and an average of the current project size in (m²).

Space Type	Finland	Sweden	Turkey	Spain
Office	66.66 (16,703)	39.12 (13,247)	27.39 (23,207)	36.35 (12,797)
Multi-Family Residential	—	4.35 (31,793)	17.81 (29,977)	—
Industrial Manufacturing	—	—	12.33 (66,763)	—
Lodging	6.67 (6840)	8.70 (10,098)	13.70 (17,324)	4.55 (23,353)
Public Assembly	6.67 (2016)	—	6.85 (11,731)	4.55 (4775)
Health Care	13.33 (4862)	26.08 (26,569)	—	4.55 (3792)
Higher Education	6.67 (4459)	—	6.85 (19,500)	4.55 (7293)
Datacenter	—	—	2.74 (14,746)	22.72 (7296)
Service	—	—	2.74 (8627)	4.55 (1214)
Educational Facilities	—	—	1.37 (979)	—
Laboratory	—	4.35 (42,825)	2.74 (7659)	4.55 (7708)
Retail	—	8.70 (9494)	1.37 (4251)	4.55 (7791)
Warehouse and Distribution	—	4.35 (10,961)	2.74 (23,463)	—
Other	—	4.35 (8401)	1.37 (2259)	9.08 (1744)

Location of the Certified LEED certified projects in each of the four countries. The LEED Certified certified projects were distributed as follows: (i) in Finland, Helsinki (80%) and the remaining 20% were evenly distributed among three other cities [23]; (ii) in Sweden, Solna-Stockholm urban area (39%), Gothenburg (9%), Malmö (9%), and the remaining 43% were evenly distributed among nine other cities [24]; (iii) in Turkey, Istanbul (47%), Kocaeli Province (11%), Izmir (8%) and the remaining 34% were almost evenly distributed among 23 other cities [25]; and (iv) in Spain, Madrid (23%), Barcelona (14%), Cabanillas Del Campo (14%), and the remaining 49% were almost evenly distributed among 11 other towns [26]. Based on this analysis, the LEED Certified certified projects were typically more frequently used either in the capital of the country and/or a major city in the country in comparison with others cities.

2.4. Statistical Analysis

If data have an interval scale, then descriptive statistics refers to the mean $\pm$ standard deviation (SD) and a parametric two-stage nested ANOVA test was used. If data have an ordinal scale, then descriptive statistics refers to the median $\pm$ interquartile range (IQR, 25th–75th percentile), and the extract significant WMW test was used [27]. In addition, under paired comparison unpaired groups, a non-parametric effect size (Cliff's δ) was also used. Cliff's [28] (p. 495) was expressed as

$$\delta = \#(x_1 > x_2) - \#(x_1 < x_2) / (n_1 n_2) \quad (1)$$

where x_1 and x_2 are scores within group 1 and group 2, respectively; n_1 and n_2 are the sizes of the sample groups, group 1 and group 2, respectively; and # indicates the number of times.

Cliff's δ ranges between -1 and $+1$; positive (+) values indicate that group 1 is larger than group 2, 0 indicates equality or overlap, and negative (−) values indicate that group 2 is larger than group 1 [28].

The effect size is considered (i) negligible if $|\delta| < 0.147$, (ii) small if $0.147 \leq |\delta| < 0.33$, (iii) medium if $0.33 \leq |\delta| < 0.474$, or (iv) large if $|\delta| \geq 0.474$ [29]. A comprehensive interpretation of the effect size was described earlier [11].

p -value (P) was used to accept one of three conclusions: the difference between two countries seems to be positive (i.e., there seems to be a difference between groups 1 and 2); the difference between two countries seems to be negative (i.e., there does not seem to be a difference between groups 1 and

2); and “judgment is suspended” regarding the difference between groups 1 and 2. A “three-valued logic” interpretation 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 [30,31].

3. Results and Discussion

3.1. SS Category

As shown in Table 3. In both northern and southern European countries, achievements in the 12 SS credits were similar, whereas achievements in two credits were different. Specifically, similarly high achievements were revealed for SS1 Site Selection, SS2 Development Density and Community Connectivity, SS4.1–4.4 Alternative Transportation (Public Transportation Access, Bicycle Storage and Changing Rooms, Low-Emitting and Fuel-Effective Vehicles, and Parking Capacity), SS5.2 Site Development—Maximize Open Space, and SS7.1 Heat Island Effect—Nonroof, while similar low achievements were revealed for SS3 Brownfield Redevelopment, SS5.1 Site Development—Protect or Restore Habitat, SS6.2 Stormwater Design—Quality Control, and SS8 Light Pollution Reduction. These results indicate that low-achieving credits were less popular for design teams due to the high financial support required to receive these points.

Table 3. SS achievement: Northern European countries vs. southern European countries.

Credit	Pt	Finland	Sweden	Finland vs. Sweden		Turkey	Spain	Turkey vs. Spain	
		Median $\pm$ IQR [25–75]		<i>p</i>	δ	Median $\pm$ IQR [25–75]		<i>p</i>	δ
SS1	1	1.0 $\pm$ 0.0 ^a	1.0 $\pm$ 0.0 ^a	0.420	0.13	1.0 $\pm$ 0.0 ^a	1.0 $\pm$ 0.0 ^a	0.367	−0.08
SS2	5	5.0 $\pm$ 0.0 ^a	5.0 $\pm$ 0.0 ^a	1.000	0.04	5.0 $\pm$ 5.0 ^a	5.0 $\pm$ 5.0 ^a	1.000	0.00
SS3	1	0.0 $\pm$ 1.0 ^b	0.0 $\pm$ 1.0 ^b	0.586	−0.14	0.0 $\pm$ 0.0 ^b	0.0 $\pm$ 0.0 ^b	1.000	0.00
SS4.1	6	6.0 $\pm$ 0.0 ^a	6.0 $\pm$ 0.8 ^a	0.140	−0.17	6.0 $\pm$ 0.0 ^a	6.0 $\pm$ 0.0 ^a	1.000	0.00
SS4.2	1	1.0 $\pm$ 0.0 ^a	1.0 $\pm$ 0.0 ^a	1.000	0.04	1.0 $\pm$ 0.0 ^a	1.0 $\pm$ 0.0 ^a	0.689	0.05
SS4.3	3	3.0 $\pm$ 0.0 ^a	3.0 $\pm$ 0.0 ^a	1.000	0.02	3.0 $\pm$ 0.0 ^a	3.0 $\pm$ 0.0 ^a	0.689	0.05
SS4.4	2	2.0 $\pm$ 2.0 ^a	2.0 $\pm$ 2.0 ^a	0.899	−0.08	2.0 $\pm$ 0.0 ^a	2.0 $\pm$ 2.0 ^a	0.101	0.20
SS5.1	1	0.0 $\pm$ 0.0 ^b	0.0 $\pm$ 0.0 ^b	0.980	−0.01	0.0 $\pm$ 0.0 ^b	0.0 $\pm$ 1.0 ^b	0.112	−0.20
SS5.2	1	1.0 $\pm$ 1.0 ^a	1.0 $\pm$ 1.0 ^a	1.000	−0.03	1.0 $\pm$ 1.0 ^a	1.0 $\pm$ 1.0 ^a	0.416	0.12
SS6.1	1	0.0 $\pm$ 0.0 ^b	0.0 $\pm$ 1.0 ^b	0.379	−0.17	1.0 $\pm$ 2.0 ^c	0.0 $\pm$ 0.0 ^c	0.001	0.44
SS6.2	1	0.0 $\pm$ 0.0 ^b	0.0 $\pm$ 0.8 ^b	0.073	−0.26	0.0 $\pm$ 1.0 ^b	0.0 $\pm$ 0.8 ^b	0.293	0.15
SS7.1	1	1.0 $\pm$ 0.7 ^a	0.0 $\pm$ 1.0 ^a	<i>0.081</i>	0.31	1.0 $\pm$ 0.0 ^a	1.0 $\pm$ 0.8 ^a	0.458	0.10
SS7.2	1	0.0 $\pm$ 0.0 ^b	0.0 $\pm$ 0.8 ^b	0.279	−0.19	1.0 $\pm$ 2.0 ^c	1.0 $\pm$ 1.0 ^c	0.002	0.42
SS8	1	0.0 $\pm$ 0.0 ^b	0.0 $\pm$ 0.0 ^b	0.680	0.09	0.0 $\pm$ 0.0 ^b	0.0 $\pm$ 1.0 ^b	0.118	−0.18
SS	26	18.0 $\pm$ 3.0 ^a	18.0 $\pm$ 3.0 ^a	0.923	−0.02	20.0 $\pm$ 4.0 ^a	18.0 $\pm$ 5.8 ^a	<i>0.045</i>	0.28

^a Similar high achievements, ^b similar low achievements, ^c different achievements. The *p* values: bold font—seems to be positive, ordinal font size—seems to be negative, italic font—judgment is suspended.

It should be noted that there were some exceptions from this similarity. In improving onsite stormwater and installing cool white collar roofs and vegetated roofs (SS6.1 Stormwater Design—Quantity and Control and SS7.2 Heat Island Effect—Roof), Turkey’s achievements were better than Spain’s achievements. Considering the two northern European countries, both Finland’s and Sweden’s achievements were worse in terms of SS6.1. An additional example is the case of SS5.1 Site Development—Protect or Restore Habitat, in which Finland and Sweden achievements were similarly low.

Such credit achievements (similar high achievements were revealed in eight credits and similar low achievements were revealed in five credits) resulted in high (70–75%) SS category achievements. A high SS achievement (70–80%) was revealed early by Pushkar and Verbisky [8], who analyzed LEED-NC 2009 certified projects in 10 U.S. states. Thus, such reproduction of SS high-achievements for different countries (ten US states and four European countries) can serve as empirical evidence of a fairly good design of this category.

3.2. WE Category

As shown in Table 4 In both the northern and southern European countries, achievements in one WE credit were similar, whereas achievements in two credits were different. Achievements in WEc1 Water Efficient Landscaping were high but different in the four countries. In particular, Sweden's achievement was better than Finland's, and Spain's achievement was better than Turkey's. In WEc3 Reducing Water Use, Finland's achievement was higher than Sweden's, whereas Spain's achievement was higher than Turkey's. Eventually, similar high achievements were revealed only for WEc2 Innovative Wastewater Technologies (WEc2).

It should be noted that for earlier reported WE achievements for other nations, the U.S. and the entire world were approximately 60% [8]. However, in the northern and southern European countries analyzed in our study, the WE category achievement was higher (80–120%), demonstrating that water resources were an important issue in these countries.

In this respect, despite both groups of countries, especially Finland and Sweden, having large amounts of water resources [32,33], each of the two groups of countries will have different vulnerabilities to climate change in the near future. In northern Europe, climate change could change the precipitation pattern (the total precipitation volume could increase by 40% during winter while decreasing by 20% during summer). As a result, it was predicted that a water shortage will not be a problem in this region in the near future [33].

However, for the southern Europe group, a high vulnerability to climate change was predicted [34,35] to increase in future decades. Specifically, climate change could damage water resources in the countries of the Mediterranean Basin. According to hydrological models, in the Mediterranean region, total yearly precipitation volumes could decrease due to increasing ambient temperatures [34,35]. In particular, high water stress in Turkey could be a problem for the western and southern parts of the country, which are located in the Mediterranean basin [34]. In Spain, unequal water distribution and water scarcity throughout the entire country have been reported, but high water scarcity is predicted in its Mediterranean area [35].

Table 4. WE achievement: Northern European countries vs. southern European countries.

Credit	Pt	Finland	Sweden	Finland vs. Sweden		Turkey	Spain	Turkey vs. Spain	
		Median $\pm$ IQR [25–75]		<i>p</i>	δ	Median $\pm$ IQR [25–75]		<i>p</i>	δ
WEc1	4	4.0 $\pm$ 4.0 ^c	5.0 $\pm$ 1.0 ^c	0.013	−0.47	4.0 $\pm$ 3.0 ^c	5.0 $\pm$ 1.5 ^c	0.003	−0.39
WEc2	2	3.0 $\pm$ 1.0 ^a	3.0 $\pm$ 1.0 ^a	0.839	0.04	2.0 $\pm$ 1.0 ^a	3.0 $\pm$ 3.0 ^a	0.134	−0.20
WEc3	4	4.0 $\pm$ 1.0 ^c	2.0 $\pm$ 4.0 ^c	0.028	0.41	4.0 $\pm$ 1.0 ^c	5.0 $\pm$ 0.0 ^c	0.001	−0.58
WE	10	8.0 $\pm$ 3.0 ^a	8.0 $\pm$ 2.0 ^a	0.732	−0.07	10.0 $\pm$ 3.0 ^c	12.0 $\pm$ 4.5 ^c	0.003	−0.39

^a Similar high achievements, ^b similar low achievements, ^c different achievements. The *p* values: bold font—seems to be positive, ordinal font size—seems to be negative, italic font—judgment is suspended.

3.3. EA Category

As shown in Table 5. In the northern and southern European countries, achievements in three EA credits were similar, whereas achievements in three credits were different. In particular, similar high achievements were revealed for EAc4 Enhanced Refrigerant Management, whereas similarly low achievements were revealed for EAc2 On-site Renewable Energy and EAc6 Green Power.

EAc2 and EAc6 require that renewable and green sources of energy, such as solar, wind, geothermal, hydro or biomass sources, be used instead of fossil fuels, such as coal, gas, or oil. It is interesting that the achievements of the two groups of countries were similarly poor in the renewable and green energy credits, despite their high share of available renewables. In Finland, renewable energy represented approximately 30% of the total electricity production and consists of mainly hydropower (28%) and wind, solar, and biofuel power (3%) [36]. In Sweden, the same energy sources were used: hydropower (42%), wind power (7%), biofuel power (6%), and solar power (1%), resulting in a total of 56% of renewables [37]. In Turkey, renewable energy represented approximately 20% of the total

electricity production and contained mainly hydropower (16%), wind power (3%), and other power sources (solar, geothermal, and biofuel power) (1%) [38]. In Spain, the energy sources were involved relatively different: wind power (19%), solar power (5%), and other (biomass, cogeneration, and the remaining) (11%), resulting in the total 35% of renewables [39].

Different achievements were revealed for EAc1 Optimize Energy Performance (Finland's and Sweden's achievements were the best, whereas Turkey's and Spain's achievements were the worst), EAc3 Enhanced Commissioning (Finland's achievement was the best, whereas Sweden's achievement was the worst; Spain's achievement was the best, whereas Turkey's achievement was the worst), and EAc5 Measurement and Verification (Turkey's achievement was the best, whereas those for Finland, Sweden, and Spain were the worst).

Thus, the EA achievements of the two northern European countries were twice (approximately 90–105%) the achievements of the two southern European countries (approximately 40–50%). It should be noted that the achievements of Turkey and Spain confirmed the same intermediate level of the EA achievement (40%) previously revealed by Wu et al. [7], who performed an overall combined evaluation of LEED-NC 2009 projects certified in the U.S. and throughout the world. An overall evaluation, however, can hide the specifics of the LEED certification in different groups of countries [8], which was confirmed by our study, where different regions, namely, southern Europe and northern Europe, were evaluated separately. Due to the separate evaluation, initially a very successful energy performance optimization was revealed in Finland and Sweden. These results are quantitatively confirmed by the conclusions of the qualitative study presented by Heiskanen and Matschoss [40], who analyzed the public and social acceptance of low-energy buildings in nine countries located in different parts of Europe, including western Europe, southern Europe, central and eastern Europe, and northern Europe, and concluded that northern European countries, such as Finland and Sweden, are the countries with significant energy use concern [40].

Table 5. EA achievement: Northern European countries vs. southern European countries.

Credit	Pt	Finland	Sweden	Finland vs. Sweden		Turkey	Spain	Turkey vs. Spain	
		Median $\pm$ IQR [25–75]		<i>p</i>	δ	Median $\pm$ IQR [25–75]		<i>p</i>	δ
EAc1	19	17.0 $\pm$ 7.0 ^a	20.0 $\pm$ 3.0 ^a	0.055	−0.36	8.0 $\pm$ 4.0 ^b	9.0 $\pm$ 9.0 ^b	0.676	−0.06
EAc2	7	0.0 $\pm$ 0.0 ^b	0.0 $\pm$ 0.0 ^b	0.250	0.16	0.0 $\pm$ 2.0 ^b	0.0 $\pm$ 0.0 ^b	0.248	0.13
EAc3	2	2.0 $\pm$ 2.5 ^c	0.0 $\pm$ 2.0 ^c	0.004	0.38	0.0 $\pm$ 2.0 ^c	2.0 $\pm$ 2.5 ^c	0.004	−0.37
EAc4	2	2.0 $\pm$ 0.0 ^a	2.0 $\pm$ 2.0 ^a	0.057	0.32	2.0 $\pm$ 0.0 ^a	2.0 $\pm$ 2.0 ^a	0.273	0.14
EAc5	3	2.0 $\pm$ 2.7 ^a	3.0 $\pm$ 4.0 ^a	0.232	−0.22	3.0 $\pm$ 0.0 ^c	3.0 $\pm$ 2.0 ^c	0.005	0.35
EAc6	2	0.0 $\pm$ 2.0 ^b	0.0 $\pm$ 0.0 ^b	0.396	0.18	0.0 $\pm$ 0.0	0.0 $\pm$ 0.0	1.000	0.02
EA	35	22.0 $\pm$ 5.8	23.0 $\pm$ 2.8	0.359	−0.18	15.0 $\pm$ 7.0	15.0 $\pm$ 9.5	0.883	0.02

^a Similar high achievements, ^b similar low achievements, ^c different achievements. The *p* values: bold font—seems to be positive, ordinal font size—seems to be negative, italic font—judgment is suspended.

Due to the differences in the descriptive statistics of EAc1 performances between northern and southern European countries (Table 5), an inferential statistical analysis comparing these groups of countries was evaluated, and the results are presented in Figure 1. It was concluded that the achievements of the northern European countries and southern European countries were different ($F_{(1,2)} = 60.861$, $p = 0.016$).

Figure 1. The EAc1 Optimize Energy Performance: Northern European countries vs. southern European countries. A red dashed line refers to the maximum possible points.

3.4. MR Category

As shown in Table 6. In the northern and southern European countries, achievements in seven MR credits were similar, whereas achievements in one credit were different. In particular, similar high achievements were revealed for MRc2 Construction Waste Management and MRc5 Regional Materials, whereas similar low achievements were revealed for MRc1.1 and MRc1.2 Building Reuse (Maintain Existing Walls, Floors and Roof and Maintain Existing Interior Nonstructural Elements), MRc3 Materials Reuse, MRc6 Rapidly Renewable Materials, and MRc7 Certified Wood. Different achievements were revealed for MRc4 Recycled Content (Sweden's achievement was the best, whereas Finland's achievement was the worst; and Turkey's achievement was the best, whereas Spain's achievement was the worst).

Thus, only two (that are usually easy for achievement) credits were high-achieving: Waste Management and Regional Materials, whereas seven low-achieving credits were low-achieved, resulting in low MR category achievement (20–30% in northern European countries and 40% in southern European countries). In this respect, it should be noted that MR is a well-known low-achievement category because it is very difficult to reduce virgin building materials and replace them by reusing or recycling materials [8]. Thus, in previous studies concerning the LEED-NC 2009 projects certified in the U.S. and across all the world [7] and the LEED-NC 2009 projects certified in 10 U.S. states [8], a similar low-achieved MR category was reported at 39% [7] and 40–45% [8], respectively. Such rich empirical confidence in the low-achieved MR category requires further attention of LEED experts to low-popular difficult MR credits that represent reusing material options.

Table 6. MR achievement: Northern European countries vs southern European countries.

Credit	Pt	Finland	Sweden	Finland vs. Sweden		Turkey	Spain	Turkey vs. Spain	
		Median $\pm$ IQR [25–75]		<i>p</i>	δ	Median $\pm$ IQR [25–75]		<i>p</i>	δ
MRc1.1	3	0.0 $\pm$ 1.5 ^b	0.0 $\pm$ 0.0 ^b	0.157	0.21	0.0 $\pm$ 0.0 ^b	0.0 $\pm$ 1.5 ^b	0.003	−0.23
MRc1.2	1	0.0 $\pm$ 0.0 ^b	0.0 $\pm$ 0.0 ^b	1.000	0.00	0.0 $\pm$ 0.0 ^b	0.0 $\pm$ 0.0 ^b	1.000	0.01
MRc2	2	2.0 $\pm$ 0.8 ^a	2.0 $\pm$ 0.0 ^a	0.616	−0.09	2.0 $\pm$ 1.0 ^a	2.0 $\pm$ 0.8 ^a	0.870	−0.03
MRc3	2	0.0 $\pm$ 0.0 ^b	0.0 $\pm$ 0.0 ^b	1.000	0.00	0.0 $\pm$ 0.0 ^b	0.0 $\pm$ 0.0 ^b	1.000	−0.02
MRc4	2	0.0 $\pm$ 0.0 ^c	1.0 $\pm$ 1.0 ^c	0.005	−0.50	2.0 $\pm$ 0.0 ^c	1.0 $\pm$ 1.8 ^c	0.001	0.42
MRc5	2	2.0 $\pm$ 2.0 ^a	2.0 $\pm$ 2.0 ^a	0.872	0.04	2.0 $\pm$ 0.0 ^a	2.0 $\pm$ 0.0 ^a	0.141	0.11

Table 6. Cont.

Credit	Pt	Finland	Sweden	Finland vs. Sweden		Turkey	Spain	Turkey vs. Spain	
		Median $\pm$ IQR [25–75]		<i>p</i>	δ	Median $\pm$ IQR [25–75]		<i>p</i>	δ
MRc6	1	0.0 $\pm$ 0.0 ^b	0.0 $\pm$ 0.0 ^b	1.000	0.00	0.0 $\pm$ 0.0 ^b	0.0 $\pm$ 0.0 ^b	0.110	0.14
MRc7	1	0.0 $\pm$ 0.0 ^b	0.0 $\pm$ 0.0 ^b	1.000	0.00	0.0 $\pm$ 0.0 ^b	0.0 $\pm$ 0.0 ^b	0.111	−0.33
MR	14	3.0 $\pm$ 3.0 ^b	4.0 $\pm$ 3.0 ^b	0.682	−0.08	6.0 $\pm$ 1.0 ^b	6.0 $\pm$ 2.0 ^b	0.641	−0.06

^a Similar high achievements, ^b similar low achievements, ^c different achievements. The *p* values: bold font—seems to be positive, ordinal font size—seems to be negative, italic font—judgment is suspended.

3.5. EQ Category

As shown in Table 7. In the northern and southern European countries, achievements in the 13 EQ credits were similar, whereas achievements in two credits were different. In particular, similar high achievements were revealed for EQc2 Increased Ventilation, EQc3.1 and EQc3.2 Construction Indoor Air Quality (IAQ) Management plan (During Construction and Before Occupancy), EQc4.1 and EQc4.2 Low-Emitting Materials (Adhesives and Sealants; Paints and Coatings), EQc6.1 Controllability of Systems—Lighting, and EQc7.1 and EQc7.2 Thermal Comfort (Design and Verification), whereas similar low achievements were revealed for EQc4.3 and EQc4.4 Low-Emitting Materials (Flooring Systems and Composite Wood and Agrifiber Products), EQc6.2 Controllability of Systems—Thermal Comfort, and EQc8.1 and EQc8.2 Daylight and Views (Daylight and Views). Different achievements were revealed for EQc1 Outdoor Air Delivery Monitoring (Finland's achievement was the best, whereas Sweden's achievement was the worst; and Spain's achievement was the best, whereas Turkey's achievement was the worst) and EQc5 Indoor Chemical and Pollutant Source Control (Finland's, Turkey's, and Spain's achievements were the best, whereas Sweden's achievement was the worst).

Table 7. EQ achievement: Northern European countries vs. southern European countries.

Credit	Pt	Finland	Sweden	Finland vs. Sweden		Turkey	Spain	Turkey vs. Spain	
		Median $\pm$ IQR [25–75]		<i>p</i>	δ	Median $\pm$ IQR [25–75]		<i>p</i>	δ
EQc1	1	1.0 $\pm$ 1.0 ^c	0.0 $\pm$ 0.9 ^c	0.008	0.34	0.0 $\pm$ 1.0 ^c	1.0 $\pm$ 1.0 ^c	0.004	−0.37
EQc2	1	1.0 $\pm$ 0.0 ^a	1.0 $\pm$ 0.8 ^a	0.279	0.19	1.0 $\pm$ 1.0 ^a	1.0 $\pm$ 0.0 ^a	<i>0.046</i>	−0.23
EQc3.1	1	1.0 $\pm$ 0.0 ^a	1.0 $\pm$ 0.0 ^a	1.000	0.04	1.0 $\pm$ 0.0 ^a	1.0 $\pm$ 0.0 ^a	1.000	−0.02
EQc3.2	1	1.0 $\pm$ 1.0 ^a	1.0 $\pm$ 0.7 ^a	0.426	0.19	1.0 $\pm$ 1.0 ^a	1.0 $\pm$ 0.8 ^a	0.131	−0.20
EQc4.1	1	0.0 $\pm$ 1.0 ^a	1.0 $\pm$ 1.0 ^a	0.793	−0.10	1.0 $\pm$ 0.0 ^a	1.0 $\pm$ 1.0 ^a	<i>0.061</i>	0.23
EQc4.2	1	1.0 $\pm$ 0.0 ^a	1.0 $\pm$ 0.8 ^a	0.604	0.13	1.0 $\pm$ 0.0 ^a	1.0 $\pm$ 0.0 ^a	0.293	0.09
EQc4.3	1	0.0 $\pm$ 1.0 ^b	0.0 $\pm$ 0.0 ^b	<i>0.058</i>	0.31	0.0 $\pm$ 1.0 ^b	0.0 $\pm$ 1.0 ^b	0.761	−0.06
EQc4.4	1	0.0 $\pm$ 0.0 ^b	0.0 $\pm$ 0.0 ^b	0.680	0.09	0.0 $\pm$ 0.0 ^b	0.0 $\pm$ 0.0 ^b	0.483	−0.06
EQc5	1	1.0 $\pm$ 1.0 ^c	0.0 $\pm$ 0.0 ^c	0.015	0.45	1.0 $\pm$ 1.0 ^a	1.0 $\pm$ 1.0 ^a	0.756	0.06
EQc6.1	1	1.0 $\pm$ 1.0 ^a	1.0 $\pm$ 1.0 ^a	1.000	−0.03	1.0 $\pm$ 1.0 ^a	1.0 $\pm$ 1.0 ^a	1.000	−0.02
EQc6.2	1	0.0 $\pm$ 1.0 ^b	0.0 $\pm$ 1.0 ^b	1.000	0.01	0.0 $\pm$ 1.0 ^b	0.0 $\pm$ 1.0 ^b	0.526	0.10
EQc7.1	1	1.0 $\pm$ 0.0 ^a	1.0 $\pm$ 0.7 ^a	<i>0.068</i>	0.43	1.0 $\pm$ 0.0 ^a	1.0 $\pm$ 0.0 ^a	1.000	0.02
EQc7.2	1	1.0 $\pm$ 0.3 ^a	1.0 $\pm$ 0.9 ^a	<i>0.045</i>	0.39	1.0 $\pm$ 2.0 ^a	1.0 $\pm$ 0.8 ^a	<i>0.032</i>	0.26
EQc8.1	1	0.0 $\pm$ 1.0 ^b	0.0 $\pm$ 0.0 ^b	0.276	0.19	0.0 $\pm$ 1.0 ^b	0.0 $\pm$ 1.0 ^b	0.157	−0.22
EQc8.2	1	1.0 $\pm$ 1.0 ^b	0.0 $\pm$ 1.0 ^b	0.689	0.12	0.0 $\pm$ 1.0 ^b	1.0 $\pm$ 1.0 ^b	0.196	−0.18
EQ	15	9.0 $\pm$ 3.8 ^c	6.0 $\pm$ 2.0 ^c	0.001	0.61	9.0 $\pm$ 4.0 ^a	10.0 $\pm$ 4.0 ^a	0.307	−0.14

^a Similar high achievements, ^b similar low achievements, ^c different achievements. The *p* values: bold font—seems to be positive, ordinal font size—seems to be negative, italic font—judgment is suspended.

Thus, eight EQ credits were high-achieving, whereas five credits were low-achieving, resulting in an intermediate achievement EQ category (40–60% in northern European countries and 60–65% in southern European countries). EQ is a well-known intermediate-achievement category due to approximately half of the EQ credits (such as those related to Increased Ventilation, IAQ, low-emission Adhesives and Paints, and Thermal Comfort) that have good possibilities for achieving points. Such EQ achievements were previously confirmed in other research related to LEED-NC 2009 certified projects

throughout the world and in the U.S. Wu et al. [7] reported 60% EQ performance, and Pushkar and Verbitsky [8] reported a 60–65% EQ performance.

4. Conclusions

In the northern and southern European groups of countries, similar and different category achievements were revealed. (i) in the SS, MR, and EQ categories, most of the credits were achieved in a similar way; (ii) in the WE category, most of the credits were achieved in a highly different way; and (iii) in the EA category, approximately half of the credits were achieved in a similar way, whereas the other half of the credits were achieved in a different way.

(i) In the SS, the total resulting achievements was high (70–75%), indicating a well-designed SS category; in the MR, the total resulting achievements were low (20–30%) in northern Europe countries and 40% in southern Europe countries, suggesting that low-popular MR credits should be improved in their further design; in the EQ, the total resulting achievements were intermediate (40–60%) in northern Europe countries and 60–65% in southern Europe countries, leaving space for EQ credit improvements in their further design.

(ii) In the WE category, all three credits were achieved well, resulting in a high category performance, at approximately 80% in northern Europe countries and 100–120% in southern Europe countries, demonstrating high water saving concerns in these countries.

(iii) In the EA category, among the similarly achieved credits in four countries, despite renewable and green energies in high use in four countries, these credits had low achievements. The energy optimization credit in northern European countries was achieved to a much higher degree (90–105%) than that in southern European countries (40–50%), thereby demonstrating empirical evidence of higher energy saving concerns in northern Europe. Thus, the resulting EA category achievements were 60–65% and 40% in northern and southern European countries, respectively.

5. Contributions

This empirical evidence from the analyzed LEED-NC 2009 may help LEED experts correct low-performed categories (MR for reducing virgin construction material consumption and EA for increasing renewable and green energies) in further versions of the LEED-NC toward a proper balance among the performances of the LEED categories. In addition, the findings of this study may help researchers dealing with LEED empirical studies to use better statistical methods, thereby obtaining more appropriate conclusions for green building development.

6. Limitations

Two main limitations of the study can be recognized. The first one is the LEED version that was used. We analyzed projects certified under version 3 (LEED-NC 2009) and not under the current version 4 (LEED-NC v4). This is because in empirical studies such as the present study, project certification became possible only after a relatively long time period (on average, two to three years are required to design and build a building). Thus, there was an insufficient sample size of certified projects that were designed under the current LEED-NCv4 that were revealed in the USGBC project directory.

The second limitation is the number of European countries that were studied. Only four of the 27 European countries were analyzed. Again, a sufficient sample size of certified projects was only available for this empirical study in the analyzed four countries.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

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