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ADAPTABILITY ANALYSIS OF WATER EFFICIENCY ITEMS IN LEED CERTIFICATION UNDER DIFFERENT CLIMATIC CONDITIONS

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Abstract: This research focuses on the extent to which the water efficiency elective items of the LEED certification system adapt to the environmental characteristics of regions with varying climatic conditions. The building industry, is being called upon to promote energy-efficient construction, and the issues surrounding water resources are becoming increasingly severe, underscoring the importance of sustainable water resource management. Based on the hypothesis that, despite its global recognition and widespread adoption, the LEED certification does not always adequately address the environmental realities of all regions, this study analyzed new construction cases certified by LEED in the United States, Japan, and Taiwan from 2019 to February 2024. The analysis revealed regional differences based on water efficiency elective items and certification level trends under different climatic conditions. The findings suggest that the LEED certification system may not fully respond to the environmental situations and water resource issues in all regions, raising concerns about the adaptability of water efficiency items and the potential for similar issues in other evaluation items.

Key words: LEED Certification, Green Building, Climate Adaptation, Water Efficiency, Environmental Conservation

1. INTRODUCTION

In recent years, the increased combustion of fossil fuels has led to a rise in energy consumption and greenhouse gas emissions, exacerbating global warming and its consequences, including higher temperatures, extreme weather phenomena, and rising sea levels [1]. To address this, many countries worldwide have set targets to reduce greenhouse gas emissions to net zero by 2050, with significant reductions required in the residential and building sectors, where energy consumption is substantial [2], [3], [4] . In this sector, certification systems such as LEED, CASBEE, and EEWH are employed to promote energy-efficient construction [5], [6], [7]. Among these, the globally adopted LEED certification faces the challenge of not fully reflecting regional climatic conditions.

Simultaneously, water resource issues are becoming increasingly severe, with reports indicating an increase in the frequency and duration of droughts since 2000 [8]. This has escalated water scarcity from a local to a global challenge, leading to accelerated desertification and the shrinking of habitable areas. These issues underscore the importance of sustainable water resource management and international cooperation.

Therefore, this study focuses on the water efficiency items of the LEED certification system, which enjoys the highest recognition worldwide [9], analyzing new construction cases certified in the United

States, Japan, and Taiwan from 2019 to February 2024. *The goal is to reveal certification trends and the impact on water efficiency items under different climatic conditions, aiming to elucidate the adaptability of the LEED certification system to varying climatic conditions*.

2. RESEARCH PURPOSE

This study aims to analyze the role of the construction industry in combating global warming, with a particular focus on how the LEED v4 certification system adapts to varying climatic conditions around the world. Despite the global recognition and widespread adoption of the LEED certification, it is hypothesized that its environmental standards may not be fully optimized to the climatic characteristics of all regions, potentially not addressing the environmental realities of every area adequately [10].

Amidst a plethora of research comparing various high-energy-efficiency building certification systems globally, which predominantly concentrates on energy efficiency and greenhouse gas emission reduction [11], [12], studies focusing on water efficiency are noticeably scant. Given the limited nature of water resources and their susceptibility to climate change, it's posited that the construction industry's engagement with water efficiency and the optimization of water usage can significantly contribute to environmental preservation [13]. The escalation of global water resource issues, especially in arid regions or areas grappling with severe water shortages, underscores the importance of efficient water use and management in the construction domain. Thus, this study endeavors to analyze the effectiveness of the LEED certification's water environment assessment criteria and to reveal trends among newly certified buildings regarding the water environment.

The regions analyzed in this study include the United States, Japan, and Taiwan, which, while adopting LEED v4 certification, are situated in different climatic zones. By examining new construction cases certified in these regions from 2019 to February 2024, this research seeks to explore the certification trends of buildings according to local climate conditions and investigate the extent to which LEED certification adapts to each region's climatic conditions and how this adaptation affects the certification process.

With these considerations in mind, the goal of this research is to provide new insights into the applicability and effectiveness of the LEED certification system, contributing towards sustainable development in the construction industry. Additionally, it aims to identify trends and impacts of climate conditions on the LEED certification system and propose adaptations for more diverse climatic conditions, thereby promoting the proliferation of sustainable construction practices and certification systems.

3. METHODOLOGY

In this research, data on the average annual precipitation and average temperature by state and city in the United States, Japan, and Taiwan were organized, and a total of 382 reports [14] on newly constructed buildings that received LEED v4 certification were collected. During the period from 2019 to February 10, 2024, reports on new buildings certified by the U.S. Green Building Council (USGBC) were surveyed through the USGBC website in each country. This enabled the calculation of trends and point ratios for newly constructed buildings that received LEED certification, facilitating an international comparative analysis based on these findings.

3.1. CREDIT CATEGORY OF A SURVEY

The LEED certification system is composed of the following ten elements: Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials & Resources, Indoor Environmental Quality, Innovation, Regional Priority Credits, Location & Transportation, and Integrative Process Credits. The distribution of points across these elements is explicitly presented in Figure 1. Furthermore, the evaluation process is founded upon a series of criteria applicable to all projects, delineating two principal categories: mandatory items, which must be fulfilled for certification, and elective items, which are evaluated through initiatives selected and executed by the project team. Mandatory items, defined by specific evaluation criteria, function as benchmarks to ensure projects uphold fundamental environmental responsibilities. Conversely, elective items, lacking specific evaluation criteria and assessed based on the unique efforts of the project team, provide opportunities for pursuing distinct sustainability goals and enhancing certification levels through their achievements. To secure LEED certification, it is requisite to amass points from these ten categories, thereby gauging the building's environmental performance.

This study delves into elective items related to Water Efficiency, susceptible to influences from average annual precipitation and climatic conditions, to investigate the extent to which the certification system adapts to the local environmental realities under diverse climatic conditions. Initially, the LEED certification system has established Regional Priority Credits, divided into four categories—Water Efficiency, Energy and Atmosphere, Materials and Resources, and Indoor Environmental Quality—to mitigate the impacts on different regions, yet these account for merely 3.8% of the total points. *This research is predicated on the hypothesis that the challenges arising from regional differences cannot be adequately addressed with merely four points*.

Central to this study's focus on Water Efficiency are mandatory items, including Indoor Water Use Reduction, evaluating strategies to achieve specified reduction percentages; Outdoor Water Use Reduction, assessing strategies aimed at reducing unnecessary water use and preserving and improving the existing natural environment; and Building-level Water Metering, analyzing water usage patterns based on data collected through water meters to identify measures for reducing wasteful water use. These three items are pivotal.

The elective items under scrutiny in this research account for approximately 10% of the total points. Among these are Rainwater Management, evaluating rainwater management and the imitation of natural water cycles to reduce urban flood risks; Cooling Tower Water Use, assessing water-saving technologies and management strategies to minimize water use in cooling towers; Water Metering, evaluating water metering to prevent wastage and monitor usage for efficiency; Outdoor Water Use Reduction, assessing water use reduction in outdoor landscapes and irrigation systems; and Indoor Water Use Reduction, evaluating the efficiency of indoor water use. Cumulatively, these items correspond to 14 points in the LEED v4 certification, providing a foundation for analyzing certification trends in newly constructed buildings under various climatic conditions.

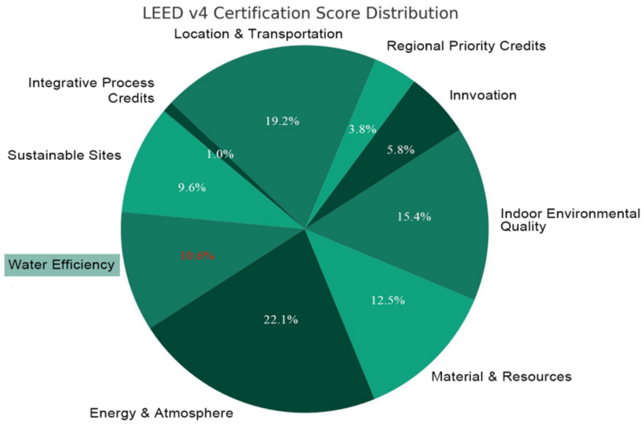

Figure 1

3.2. OBJECT OF A SURVEY

In this study, the United States, Japan, and Taiwan were selected as the regions of investigation based on average annual precipitation and average temperature, with data collected and organized for each state and city within these areas. The results are presented in Figure 2.
As illustrated in Figure 2, the United States, with its vast territory and diverse topography, exhibits significant differences in average annual precipitation and climatic characteristics [15]. Given this backdrop, our study focuses on the different climatic zones and average annual precipitation levels

within the U.S. Specifically, we categorize the regions into three: areas with less than 1000mm of annual rainfall, typically classified under desert climates where water resource utilization is particularly crucial; regions receiving moderate rainfall between 1000mm and 1599mm, situated in humid subtropical and continental climates; and areas with more than 1600mm of rainfall, characteristic of the tropical monsoon climate, where abundant precipitation during certain periods is notable. For each state, an analysis of LEED v4 certified new construction cases was conducted.

Conversely, Japan and Taiwan are characterized by their relatively uniform distribution of rainfall throughout the year, with average annual precipitation commonly exceeding 1000mm to 2400mm in cities, making water scarcity issues less severe compared to certain arid regions of the United States.

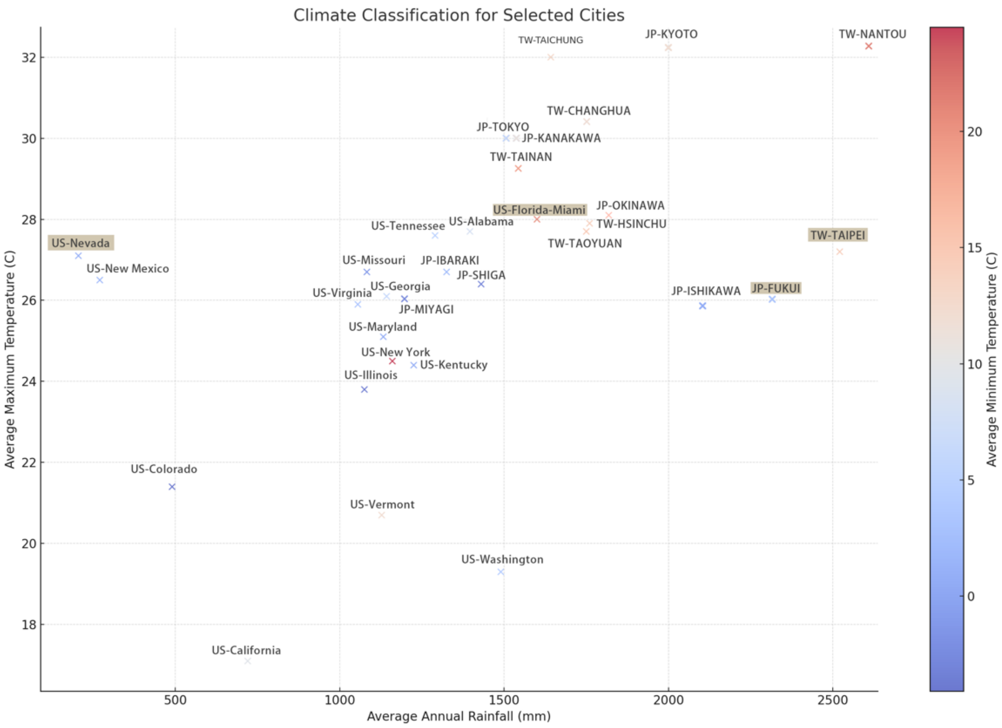

Figure 2

3.3. CASE COMPARISON

In this study, we first organize cases of buildings that have achieved LEED v4 Gold certification, focusing on specific examples. We selected instances from Nevada and Florida, representing the driest and the most precipitation-abundant areas in the United States, respectively. Additionally, cases from Japan and Taiwan were chosen based on their average points scored in the Water Efficiency category, aligning with the overall data trends. Based on these selected examples, discrepancies in water efficiency within the same Gold certification level are illustrated in Table 1.

Table 1

Country	State/Region	Project Name	Annual Precipitation (mm)	Certification Year	Scored	Level	Rainwater Mgmt	Cooling Tower Water Use	Water Metering	Outdoor Water Use Reduction	Indoor Water Use Reduction
US	Nevada	Project Russell	165~245	2023	65	Gold	0	0	1	1	2
US	Florida	NCL Cruise Terminal B	1600	2021	62	Gold	3	1	1	1	4
JP	Fukui	Fukui Head Office Building	2300~2350	2022	68	Gold	3	0	1	2	6
TW	Taipei	CTCI 2nd HQ Building	2521	2022	61	Gold	3	2	1	2	5
						Total Points	3	2	1	2	6

Analysis of Table 1 reveals that "Project Russell" in Nevada, situated in a dry zone with annual precipitation ranging from 165 to 245 mm, is a mixed-use building that has shown the lowest achievement rate in the Water Efficiency category of LEED certification, particularly lacking points in the Rainwater Management criterion. In contrast, "NCL Cruise Terminal B" located in Florida, with the highest average annual precipitation in the United States, is a 189,010 sq ft terminal that has secured points in Rainwater Management and Cooling Tower Water Use, demonstrating superior water efficiency outcomes compared to the Nevada case. *This indicates regional disparities in water-related initiatives among buildings attaining the Gold certification level within the USA*.

Meanwhile, the "Fukui Head Office Building" in Fukui Prefecture, Japan, with high annual precipitation of 2300 to 2350 mm, is a 1,191 sq m office building that has received high evaluations in the Water Efficiency category. Similarly, the "CTCI 2nd HQ Building" in Taipei, Taiwan, records the highest average annual precipitation of 2521 mm among the four cases and, as a 268,668 sq ft office building, shows a high rate of point acquisition in water efficiency. These cases in the Asian region indicate a strong emphasis on the sustainable management of water resources.

Moreover, it is noteworthy that all cases have achieved Gold certification with scores ranging from 61 to 68, suggesting that regions with lower scores in water efficiency (e.g., Nevada) may compensate with higher scores in other categories. Conversely, regions with high scores in water efficiency (e.g., Japan and Taiwan) may still achieve Gold certification despite lower scores in other categories. This result implies that *the uniform standards provided by the LEED certification system may not fully align with the realities of each region, allowing for potential differences in the application of certification according to local climatic and environmental conditions*.

Considering these observations, in arid regions, initiatives such as rainwater harvesting and water-saving measures become increasingly important due to the challenge of securing water resources. In contrast, in regions with abundant rainfall, greater emphasis may need to be placed on water quality management and impacts on ecosystems, suggesting that establishing evaluation criteria tailored to the climatic and environmental conditions of each region could enable more equitable assessments.

3.4. RESULTS

To grasp the current state and challenges of water efficiency criteria within the LEED certification, this study organized data on 382 newly certified buildings in the United States, Japan, and Taiwan, focusing on the instances where zero points were awarded in the water efficiency criteria. The evaluation results are presented in Table 2. In the United States, due to its vast territory and diverse topography, the analysis categorized the cases into three climate categories based on average annual precipitation and climate zones: regions with dry climate characteristics receiving less than 1000mm, areas situated in typical climate zones with 1000-1599mm of precipitation, and regions with the highest rainfall exceeding 1600mm. By analyzing the number and proportion of cases scoring zero points, the study could identify trends within each evaluation criteria and uncover specific challenges faced.

Table 2

Country/Region	Annual Precipitation (mm)	Total Cases	Rainwater Mgmt	Cooling Tower Water Use	Water Metering	Outdoor Water Use Reduction	Indoor Water Use Reduction
United States	Less than 1000	78	59(76%)	71(91%)	32(41%)	11(14%)	4(5%)
United States	1000 to 1599	268	184(69%)	216(81%)	93(35%)	10(4%)	14(5%)
United States	1600	6	2(33%)	4(67%)	1(17%)	0	0
Japan	-	13	6(46%)	9(69%)	0	0	0
Taiwan	-	17	4(24%)	5(29%)	3(18%)	0	0

According to Table 2, in regions within the United States where the annual precipitation is less than 1000mm, there is a notable prevalence of cases scoring zero points in Rainwater Management and Cooling Tower Water Use, indicating significant challenges in rainwater management and cooling tower water use efficiency in arid regions. Additionally, in areas with average annual precipitation ranging from 1000 to 1599mm, a high proportion of cases also scored zero points in these categories, highlighting a need for improvements in water use efficiency. Conversely, in regions with more than

1600mm of annual precipitation, the rate of scoring zero points in water efficiency categories is lower compared to arid and intermediate precipitation regions.

In contrast, cases from Japan and Taiwan, located in climates with higher average annual precipitation, show fewer instances of scoring zero points in Rainwater Management compared to the United States, suggesting higher efficiency in rainwater management and water reuse. Furthermore, there are no cases in both Asian countries scoring zero points in Outdoor Water Use Reduction and Indoor Water Use Reduction, indicating a heightened awareness or fewer challenges related to water use efficiency both outdoors and indoors in these regions.

The analysis across all cases also reveals a tendency for Japan and Taiwan, areas with higher average annual precipitation, to score higher in water efficiency-related elective items, suggesting a trend where it is easier to gain points in the LEED certification's water efficiency categories in regions with abundant rainfall. However, this trend raises questions about the adaptability of the LEED certification system, as it allows for easier point acquisition in rainy regions, despite a relatively lower necessity to conserve water resources compared to arid areas. This issue is attributed to the regional discrepancies arising from the *LEED certification system being primarily designed based on the environmental realities of the United States and not fully considering the conditions in regions outside the United States, especially Japan and Taiwan, where the average annual precipitation exceeds that of the United States*.

These observations suggest that the LEED certification system's water efficiency categories yield different outcomes depending on regional climate and environmental conditions, indicating a need for further adjustments to adapt to the diverse environmental realities worldwide. Specifically, the introduction of flexible evaluation criteria based on regional climate conditions and water resource availability is called for to reflect the unique water resource management challenges and demands in both rainy and arid regions. This implies that the *LEED certification system should consider the specific conditions of regions and possess adaptability under different climatic conditions*.

4.CONCLUSION

This study focuses on the role of the construction industry in combating global warming, specifically analyzing how the LEED v4 certification system adapts to various climatic conditions worldwide. The analysis suggests that the distribution of points earned in water efficiency items and certification levels of LEED-certified new constructions in the United States, Japan, and Taiwan *does not necessarily indicate that the LEED certification system fully addresses local climatic conditions and water resource challenges*.
In particular, the analysis of water efficiency items across different average annual precipitation categories in the U.S. revealed that the certification system may not adequately reflect the environmental realities of certain regions.

It became evident that *the uniform standards provided by the LEED certification system do not flexibly accommodate the specific climatic conditions and water resource situations of different regions*. The cases from Japan and Taiwan demonstrated that the unique warm and humid climates of these areas are closely associated with high water efficiency practices, underscoring the necessity for LEED certification to consider regional environmental characteristics more thoroughly. Furthermore, the identified issues regarding the adaptability of water efficiency items suggest a need for the LEED certification system to more deeply consider regional characteristics across its entire framework. *This adaptability issue could similarly arise in other evaluation items*, such as ENERGY & ATMOSPHERE, MATERIAL & RESOURCES, and INDOOR ENVIRONMENTAL QUALITY.

Indeed, during the case analysis, a challenge emerged due to the USGBC reports not specifying the types of buildings certified, making it difficult to compare across different building types.

Therefore, for further improvement and evolution of the LEED certification system, it is crucial to gain a deeper understanding of regional climatic characteristics and the current state of water resources, reflecting these insights in the standards, and to specify building types. This approach would enable LEED certification to more effectively contribute to promoting sustainable building practices across a broader range of regions, while also strengthening the role of the building sector in adapting to and mitigating climate change.

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