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A COMPARATIVE ANALYSIS OF LEED AND GREEN GLOBES: A CASE STUDY APPROACH TO ENVIRONMENTAL PERFORMANCE ASSESSMENT OF AN EDUCATIONAL CAMPUS FACILITY

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ABSTRACT

The construction industry faces significant challenges in reducing energy consumption and achieving sustainability goals. Green building rating systems (GBRS) have been created to assess and confirm the effectiveness of sustainable construction practices. As buildings strive to reduce energy consumption, a holistic approach to building design, construction, and operation is necessary. The study aims to explore sustainable construction practices and their sustainability in high-performance green buildings (HPGB). The Georgia Tech Life Science Building (GTLSB), designed to serve the life science community in Metro Atlanta, is the chosen case study. Our research will involve (1) examining guidelines and standards for a sustainable building, (2) understanding the use of sustainable criteria, and (3) demonstrating technical expertise. Initially, we conducted a literature review of the current state of the GBRS and analyzed project information as a case study. Our analysis showcases an in-depth understanding of the technologies, methods, and resources required to produce and operate an HPGB. Our findings contribute to the knowledge of sustainable building and provide insights into the utilization of GBRS, focusing on two widely adopted systems, LEED and Green Globes (GG). The study's findings will help promote sustainable construction practices for professionals, policymakers, educators, and researchers and help achieve a more sustainable built environment.

KEYWORDS

Green building rating systems, LEED, Green Globes, Sustainable construction practices, High-Performance Green Building.

INTRODUCTION

The construction industry is one of the world's largest industrial sectors, accounting for about 10% of global GDP (Statista, 2024). However, it is responsible for approximately 40% of global

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energy consumption and carbon dioxide emissions. (*McKinsey,* 2023). As the world faces the effects of climate change, the construction industry has become an increasingly important focus for creating more sustainable and energy-efficient built environments. Green Building Rating Systems (GBRS) is a solution to promote sustainable building techniques by utilizing energy-efficient building materials (Doan et al., 2017), renewable energy sources, and sustainable construction practices, thus reducing the environmental impact of buildings in keeping with lean principles of efficient resource use (e.g., Antonio et al., 2019; Carniero et al., 2012, Holloway and Parrish, 2013; Parrish, 2012). GBRS accelerates the adoption of building practices that result in resource-efficient, healthier, and environmentally sustainable buildings (Matisoff & Noonan, 2022). These systems provide more affordable and realistic measurements than other sustainable building rating systems, which justifies a discussion to replace the term 'green' with 'sustainability.' (Berardi, 2013)

The benefits and challenges of sustainable building practices are essential for the construction industry to achieve a more sustainable built environment. For instance, according to a report Global Data (2022), the US green building market grew 8% between 2017 and 2021. However, the initial cost of constructing green buildings is increasing (Li et al., 2020) due to the changing nature of the construction industry with respect to the environment. Developers usually cover the design costs, which can be over 30%, and use the equity in the early stages of the project (Leskinen et al., 2020). Sustainable building developers also face longer construction times. This is because some eco-friendly materials used in construction have longer lead times than their conventional counterparts (Hayles & Kooloos, 2008). As a result, delays may occur, leading to a longer wait for positive cash flow (Jermak, 2023). A further obstacle to adopting sustainable practices is the need for more knowledge among construction professionals in designing and constructing. Also, building owners, architects, and contractors need more practical guidance on these practices. For instance, obtaining LEED certification can be expensive and time-consuming, which makes it challenging for smaller projects to achieve certification (Carneiro et al., 2012). On the other hand, GG offers a more affordable and practical measurement system than LEED, but it does not have the same level of recognition and market demand (Reed et al., 2009).

The industry increasingly focuses on sustainable and energy-efficient building design and operation, particularly Lean construction practices. To achieve these goals, current research evaluates and compares the assessment methods of GBRS. The objective is to improve our understanding of how LEED and GG systems can be utilized to promote environmentally responsible and energy-efficient practices. This research will be valuable to construction stakeholders seeking to implement sustainable building practices. Our paper proposes a method for analysing different GBRSs and acting as a green building consultant for the GTLSB project. We aim to evaluate the suitability of two assessment methods, LEED and GG, and suggest improvements to enhance the building's environmental performance. This study intends to answer the following research questions (RQs): RS1: What are the key differences between the LEED and GG certification systems, including their unique strengths and weaknesses? RS2: What are the specific sustainable criteria used in the project? RS3: Which rating system is more appropriate for the project? RS4: What are the potential credit points and strategies to improve the built environment and operational efficiency of the project?

The paper is organized into different sections. The first section introduces GBRS within the context of building construction. The second section is a literature review that describes two assessment methods, LEED and GG. It identifies the most suitable systems for application based on assessment criteria, potential credit points, and strategies to improve the built environment and operational efficiency. Section 3 defines the methodology used for the study. The following section presents data analysis and explores the case study of the GTLSB project.

The results and discussions suggest ways to improve the building's environmental performance. The paper concludes with the final sections: the conclusions and references.

BACKGROUND

COMPARATIVE ANALYSIS OF THE TWO GREEN BUILDING RATING SYSTEMS

The construction industry's sustainable practices have gained significant attention in recent years due to the increasing awareness of the environmental impact of buildings. As a result, two of the most widely recognized rating systems, namely LEED and GG, have emerged to assess a building's environmental performance. The Leadership in Energy and Environmental Design or LEED system, introduced by the United States, has become a widely adopted means of assessing the environmental impact of buildings. LEED is widely recognized and has a larger market share in the green building industry (Kibert, 2016), making it easier to find professionals familiar with the system (Peng et al., 2010). Other countries have created their systems based on LEED or adopted the approach. GG is a Green Building Initiative (GBI) certification program that improves a building's environmental performance. It offers a user-friendly and cost-effective alternative to other green building certification systems, focusing on practicality and flexibility. Recently, GG has evolved to include the latest sustainable building practices. According to Kibert's 2016 research, LEED and GG have strengths and limitations. Both systems share similar categories for evaluation, such as energy efficiency, water conservation, and indoor air quality. Despite their differences in certification approaches, the two approaches aim to promote sustainable and environmentally responsible practices. They provide frameworks for designing, constructing, and operating HPGB and have raised awareness about the importance of the environment in the industry.

To help those who use these rating systems better understand which system would work best for their project quickly, this research proposes a decision framework with ten criteria for comparative analysis. This framework expands upon the framework proposed by Reeder (2010). The selection criteria filter project characteristics, allowing researchers to analyse unique project features and decide which ones to include. These criteria, including Eligible Building Types, Brand Recognition, Rating Building Performance, Third-Party Verification, Ease of Use, Costs of Compliance, Professional Designation, Certification Process, Program Points, and Adaptability, will serve as attributes in a decision support framework that assists stakeholders in identifying the most relevant GBRS in construction projects. They need first to understand the fundamental differences between the two rating systems.

Firstly, both LEED and GG are voluntary certification programs developed by the U.S. Green Building Council (USGBC) and the Green Building Initiative, respectively, to assess the sustainability of High-Performance Green Buildings (HPGB). Both systems employ a point-based evaluation approach, covering categories such as sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation (*Green Building Initiative*, 2023). These systems offer various project types, like commercial, residential, etc., and online tools for project progress tracking. LEED's online certification platform encompasses new construction, major renovations, and continuous improvement of existing buildings, including commercial and multifamily residential projects. GG applies to similar project types, emphasizing an online self-assessment tool that allows users to evaluate projects based on available points, earning certification with a rating from 1 to 4 globes (*Green Building Initiative*, 2023; Reeder, 2010).

From another perspective, brand recognition is crucial for developers to highlight sustainability claims, attract tenants, and gain media attention. LEED, the older and more established system with over 150,000 certified projects worldwide, enjoys higher brand recognition than GG (*USGBC*, 2023; *Landscape Management*, 2015). Comparing their comprehensive performance targets, LEED and GG share similar sustainability goals but differ in their approaches. GG introduces the Project Management aspect, focusing on effective project team management. At the same time, LEED incorporates categories like Innovation in Design and Regional Priority to incentivize exceptional credit requirements and address regional priorities. In addition, GG provides a free Life cycle assessment (LCA) calculator tool, while LEED has a task force working on incorporating LCA into its system. Differences also exist in mandatory measures for certification: GG has none, while LEED has specific prerequisites (*Green Building Initiative*, 2023). Similarly, GG offers four paths for energy performance points and five certified wood options, while LEED provides two paths for energy performance points and only considers FSC-certified wood products. Third-party verification is also essential for green building certification. LEED includes design and construction phase reviews, and GG requires mandatory verification at the end of the design phase, followed by a site visit and additional documentation review.

Additionally, ease of use is a consideration when choosing a rating system. The LEED rating system provides several advantages over GG. For instance, LEED has a more detailed scoring system with certification levels ranging from Certified to Platinum *(Landscape Management*, 2015). However, GG is often considered more user-friendly and suitable for "do-it-yourselves" types due to its online application and self-assessment nature. Cost is another critical factor, and LEED costs are determined by project size and complexity. Implementation costs may vary based on the credits pursued, requiring staff time for learning, or hiring a consultant (*Green Building Initiative*, 2023). In contrast, GG is perceived as more cost-effective due to lower consultation fees and a fixed certification fee. Other aspects, such as professional designations like LEED Accredited Professional (LEED AP) and Green Globes Professional (GGP), demonstrate an individual's expertise in green building. Requirements for these designations include a minimum of years of experience and continuing education (*Green Building Initiative*, 2023; *USGBC*, 2023). The certification process involves project teams registering on online platforms (LEED Online for LEED, self-evaluation for GG), submitting documentation, and undergoing third-party verification.

Moreover, from a different standpoint, regarding program points, GG employs a 1,000-point scale compared to LEED's 110 points, with both systems prioritizing categories such as Energy, Water, Materials and Resources, and Indoor Environment. GG emphasizes project management by allocating a substantial percentage of points to progress meetings, coordination, benchmarking, commissioning, and documentation (Wu & Low, 2010). Predesign construction to post-construction stages are evaluated, and points are allocated for assessment (Peng et al., 2010). LEED and GG offer value when evaluating and certifying the sustainability of buildings. While LEED has distinct features and benefits, GG also boasts unique advantages. Ultimately, the decision to choose between the two depends on the specific goals and priorities of the project.

Table 1: Comparative Analysis of two green building rating systems

Criteria	LEED	Green Globes
Project Types Eligible for Certification		
Eligible Building Types	Commercial over 1,000 SF or over 250 SF for LEED-CI	Commercial & Multifamily Residential (4+ stories)
Prerequisites	Yes	No
New Construction/ Renovations	✓	✓
Existing Buildings	✓	✓
Market Penetration		
Year Launched	1998	2004
Number of Buildings Certified	105,000	3,223
Number of square feet Certified	12 billion square feet	600 million square feet
Category Types Considered in Rating Building Performance		
Site Selection & Development	✓	✓
Energy Efficiency	Two paths	Four paths
Water Conservation	✓	✓
Material & Resource Efficiency	✓	✓
Indoor Environmental Quality	✓	✓
Additional Categories	Innovation, Regional Priority	Project management
Forestry Certification	FSC Only	Five options
Point Systems		
Level of Certification	4	4
Total points available	110	1,000
Certification points minimum	Req. 40 pts + prerequisites	Project points: 35%.
Point Minimum or Partial Credit	No	Yes
The accessor visits a project.	Yes	No
Certified Levels	Certified 40 – 49 pts	1-globe 36 – 55%
	Silver 50 – 59 pts	2-globe 56 – 70%
	Gold 60 – 79 pts	3-globe 71 – 85%
	Platinum 80 – 110 pts	4-globe 86 – 100%

**Note: Data and rates are from Feb. 2023 from the Green Building Initiative (2023) and USGBC (2023).*

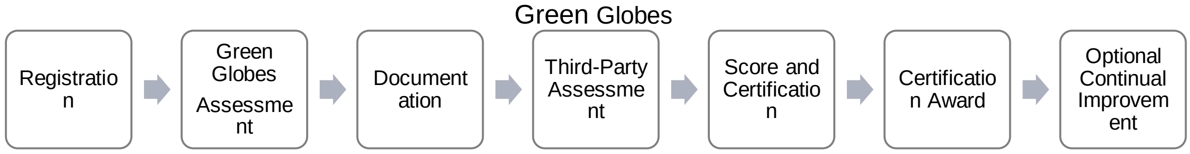
Table 1 (continued): Comparative Analysis of two green building rating systems

Criteria	LEED	Green Globes
Registration and Certification Fees		
Registration Fee for each project	$1,200	$1,500
Assessment and Certification	New Construction: $2,500-$22,000 Existing Buildings: $1,750-$15,000 Consultant Fee: $10,000-$30,000 Testing & Verification: $1,000-$10,000	Pre-Design Review (NC): $3,000 - $12,500 Design Review (NC): $4,635 - $15,500 Final Certification: $4,120 - $15,500

Certification Process

LEED

Green Globes



Program points

Rating systems	Categories	Points	Weight (%)
LEED BD+C	Integrated Process	1	0.91%
	Location & Transportation	16	14.55%
	Sustainable Sites	10	9.09%
	Water Efficiency	11	10%
	Energy & Atmosphere	33	30%
	Materials & Resources	13	11.82%
	Indoor Environment Quality	16	14.55%
	Innovation	6	5.45%
	Regional Priority	5	3.64%
	Total	*110*	*100 %*
Green Globes	Project Management	100	5 %
	Site	150	12 %
	Energy	260	39.5 %
	Water	190	11 %
	Materials & Resources	150	12.5 %
	Indoor Environment	150	15 %
	Total	*1,000*	*100 %*

**Note: Data and rates are from Feb. 2023 from the Green Building Initiative (2023) and USGBC (2023).*

Over the years, GBRS, including LEED and GG, have faced criticism and debates as they attempt to address sustainability in buildings. One of the reviews was the insufficient integration of LCA, which will be included in future rating system versions. Another criticism was that certification could be granted to buildings that were not necessarily energy-efficient, although this flaw was addressed in later LEED versions. To address the issue of energy efficiency further, LEED v4 now requires projects to provide actual energy and water usage performance data to the USGBC for at least the first five years of occupancy. This will allow the USGBC to compare actual building performance to a modeled performance, provide feedback about operations to owners, and potentially offer helpful feedback to design teams (Reeder, 2010). On the other hand, some judges claim that GG lacks transparency, while others argue that LEED is too prescriptive and inflexible. Also, there have been discussions about the minimum percentage of points required for each environmental assessment area that may not fully address all aspects of sustainability (Reeder, 2010). Apparently, the choice between LEED and other rating systems like GG depends on the specific needs and priorities of the building owner or developer, considering factors such as transparency, flexibility, and the level of detail desired in the certification process.

METHODOLOGY

The research project has begun with a literature review of the current state of Green Building Rating Systems (GBRS). This section involved examining the two assessment methods, LEED and GG. Google Scholar database was used to conduct literature research as it showcases a wide range of scholarly literature. Initially, the research used keywords in the ‘Article title, Abstract, Keywords’ field. The search was limited to articles and review papers, and the keywords used in the research field were “LEED,” “Green Globes,” “Green building rating systems,” and “High-Performance green buildings.” A total of 146 documents matching the keywords were obtained. Next, the 146 papers were thoroughly reviewed by evaluating the title and abstract to find relevant papers focusing on GBRS in building construction. The search included 94 publications containing critical terms in titles, author keywords, and abstracts. The full papers of the remaining 94 publications were carefully analysed in the last stage to fully comprehend the relevance of completing the research aim. As a result, 15 papers were identified as relevant for a detailed literature review.

In the Case Study analysis, a set of criteria for comparative analysis will be developed through a literature review to identify suitable systems for application. The chosen systems will be evaluated based on assessment criteria, potential credit points, and strategies to improve the built environment and operational efficiency. Research practices should be used to ensure the accuracy and reliability of findings to make informed decisions. The next step will use a case study research design focusing on three main aspects. Firstly, explore the sustainable criteria used in the Georgia Tech Science Square project and their contributions to sustainability. Secondly, it provides fragments of an in-depth understanding of the technologies, methods, and means required to produce and operate high-performance green buildings (HPGB) in the project. Lastly, we suggest improvements to enhance the building's environmental performance in the recommendation section. The study will utilize evidence from a literature review and a case study to address research questions and provide recommendations for utilizing GBRS and promoting sustainable construction practices.

CASE STUDY

To compare the effectiveness of different GBRS, we conducted a case study with the Life science building project. In this project, the authors intended to investigate the sustainability aspects of the building design and construction practices during the preconstruction and construction stages. The choice of a GBRS for a project depends on its specific needs and the stakeholders' preferences. This study uses the later Proposed Criteria (Table 3) to evaluate which systems are most suitable for project certification. The findings of this study will be helpful for construction professionals, policymakers, and researchers interested in promoting sustainable construction practices and achieving a more sustainable built environment.

PROJECT DESCRIPTION

Georgia Institute of Technology has announced its plans to apply for green building assessment and certification for the Science Square Building on North Avenue near Northside Drive. The building is part of a new development complex called Science Square at 387 Technology Circle NW, Atlanta, GA 30313. This 18-acre complex will comprise a mixed-use residential and commercial community. The community already has a few existing buildings, including the Biotech Innovation Lab and an office building constructed in the early 2000s. The development is a five-phase project expected to cost over a billion dollars. Phase 1A, the life science project, includes an office building, residential components, and a parking lot. The Science Square Building has a total square footage of 750,000, which includes 285 residential apartments and a six-floor, 1,000-spot parking deck. This combines the two buildings and provides parking for the district. The construction comprises all the MEPs, structure, skin, lobby, and core restrooms. The tenants occupying the space have design input on the interiors, and the owners will lend them a hand. This is known as the Core & Shell portion. The construction began in April 2022 and is expected to be completed by Fall 2024.

SPECIFIC SUSTAINABLE CRITERIA AND UNIQUE FEATURES USED IN THE PROJECT

Table 2: Comparison Table of Scorecard between LEED and Green Globes

Categories/ Sustainable Criteria	Life Science Building project - Unique Features	LEED	GG
	Project Management	1	98
Integrative Process	Contract type: Cost-plus		
	Collaboration with Perkins & Will for Green Certification		
	Accountability for Design and Construction elements		
	Location & Transportation	15	N/A
Location	Convenient location near Belt Line, Midtown, and Stations		
Transportation	Bicycle facilities, EV parking deck, charging stations		
	Sustainable Sites	4	86
Pollution Prevention	Maintain the record forms during construction.		
Habitat Protection	Consideration of preserved open space & rainwater Mngt.		
Bioretention Areas	Handling stormwater and preventing city line overload		
Existing Water Detention Vault	Reaching max capacity, requiring extra bioretention areas		
Rainwater Management	New construction requiring a new detention vault		

Table 2 (continued): Comparison Table of Scorecard between LEED and Green Globes

Categories/ Sustainable Criteria	Life Science Building project - Unique Features	LEED	GG
	Water Efficiency	4	113
Indoor Water Reuse	Lab Office building with three cooling towers		
HVAC System	Convective system for water recycling		
Plumbing Fixtures	Low-flow mechanisms, sustainable materials		
Hot Water System	Four boilers on the top meet specified criteria.		
	Energy and Atmosphere	20	124
Energy Metering System	Monitoring individual-level energy consumption		
Electrochromic Glazing	5,000 panels of smart glass for UV light control		
LEED Certification	Two-for-one deal with Electrochromic glazing		
Glass Control System	QR codes, low-voltage wires, EMS system control		
	Materials and Resources	5	56
Recycled Material	82% recycled content for LEED certification		
Construction Waste Mngt.	Professional handling of recycled materials		
Raw Material Sourcing	Meeting EPD standards, concrete mix design		
Raw Material Availability	Easy availability in Metro Atlanta's local market		
Carbon Emissions	Concrete usage remains despite LEED incompatibility.		
	Indoor Environmental Quality	7	84
Indoor Air Quality Mngt.	Blue cellophane wraps over ducts, post-installation cleaning.		
Daylight Improvement	Electrochromic glazing for better daylight		
Quality Views	Strategic placement of labs and offices		
Low-emitting Materials	Use of materials with low emissions		
Cleanable Surfaces	Polished concrete and cleanable walls instead of carpet		
	Innovation in Design	6	N/A
Innovative Features	Electrochromic glazing, convective mechanical system		
Certification	Pursuing LEED gold certification with a score of 64		
	Regional Priority	2	N/A
	Total	*64*	*561*

**Notes: Sustainable Criteria above are based on LEED and GG certification categories. The project achieved LEED Gold certification with 64 out of 110 points (58%), compared to achieving 2-Globe certification with 561 out of 1000 points (56%) for Green Globes.*

CRITERIA PROPOSAL

Each building has different characteristics that could influence the stakeholders' selection of different GBRSs. Based on a literature review of published studies, this research suggests ten criteria for comparative analysis (Table 3). Selection criteria were included to filter the project's attributes and help improve data analysis. The decision support framework uses these criteria to enable stakeholders to make transparent decisions when selecting Green Building Rating systems for construction projects. When evaluating green building assessment systems, there are several factors to consider. For example, eligible building types refer to buildings certified under a specific green building assessment system (Reeder, 2010). In addition, significant factors like market penetration, brand recognition, reputation, and credibility refer to people's awareness and familiarity with a particular brand or organization (Reeder, 2010; *Landscape Management*, 2015). Rating building performance involves evaluating its energy efficiency, water efficiency, indoor environmental quality, and other sustainability-related factors (Manoj Katiyar et al., 2020). Moreover, third-party verification is necessary for all green building rating systems to ensure that the certification process is objective and credible (Reeder, 2010). Ease of use, compliance costs, professional designation, certification process, program points, and adaptability are essential factors when selecting a green building assessment system. The research used the proposed criteria to compare two examples of GBRS, LEED and GG. A decision support framework was used to apply these criteria as a filter, which helps stakeholders select the most suitable green building assessment system for their project.

PROJECT CERTIFICATION SYSTEMS EVALUATION & RESULTS

Choosing the appropriate assessment system is a crucial first step in the green building assessment process. The choice should be based on the unique needs and objectives of the project, as well as the preferences of the building owner and design team. The choice of a green building assessment system for a project depends on its specific needs and the stakeholders' preferences. This study uses the Proposed Criteria to evaluate which systems are most suitable for project certification. Factors such as eligible building types, brand reputation, rating building performance, third-party verification, ease of use, compliance costs, professional designation, certification process, program points, and adaptability are considered when evaluating suitable systems for project certification. The project team will use the Proposed Criteria to make their evaluation correctly.

Table 3: Evaluate the suitable systems for project certification using Proposed Criteria

#	Criteria Analysis	LEED	Green Globes	Justifications (based on the GTLSB project)
1	Eligible Building Types	✓	✓	All building types.
2	Brand Recognition	✓		Widely used, with over 105,000 compared with 3,223 certified projects worldwide.
3	Rating Building Performance	✓	✓	LEED has a prescriptive approach, with specific requirements for each credit. GG offers flexibility and can choose strategies that best fit the project's goals.
4	Third-Party Verification	✓	✓	Both Required. GG: Site visit
5	Ease of Use		✓	LEED: This can be complex and time-consuming. GG: Easier to use and less time-consuming.
6	Costs of Compliance	✓		LEED: Structured based on project size and more complexity in cost.GG: More cost-effective in a less complex process.
7	Professional Designation	✓	✓	LEED Accredited Professional (LEED AP) Green Globes Professional (GGP)
8	Certification Process	✓	✓	LEED can take several months. GG can be completed in a shorter timeframe. GT is familiar with the LEED process.
9	Program Points	✓		Based on Scorecard, LEED gold compared with 2-Globe certified
10	Adaptability	✓	✓	LEED: Global, adaptable framework for sustainability. GG: Adaptable, user-friendly sustainability assessment.
	Total	*9*	*7*	

**Note: The number of remarks for each criterion shows how important they are for the proposed study. A higher number of remarks means that the chosen system is a better fit. The table shows LEED scored 9/10 points, while GG only scored 7/10 points.*

RESULTS, DISCUSSIONS, AND RECOMMENDATIONS

RESULTS ON SELECTING THE SUITABLE GREEN BUILDING RATING SYSTEMS

After analysing the criteria presented in Table 3, it was concluded that LEED is the most suitable choice for the project. This decision was made based on several key factors. LEED and GG were deemed eligible for all building types, but LEED stood out due to its widespread recognition, with over 150,000 certified projects worldwide compared to GG. Additionally, LEED's prescriptive approach with specific requirements for each credit aligned well with the project's goals and expectations. Both systems meet third-party verification requirements, but GG includes a site visit as part of its verification process, providing an additional layer of assurance. GG is considered more straightforward and less time-consuming than LEED, which may be crucial for a streamlined and user-friendly certification process. However, LEED's structured costs based on project size and complexity may impact the decision based on budget constraints. LEED outperforms GG in terms of program points, achieving a higher level of recognition with LEED Gold compared to 2-Globe certified for GG. The difference in recognition between the two rating systems can impact the decision-making process for building owners and developers. LEED's higher level of recognition might be a decisive factor in favor of selecting it over GG, especially if achieving a prestigious certification level is a priority. When considering these factors collectively, the overall recommendation for LEED is well-supported by its brand recognition, alignment with project goals, and professional designation, among other important considerations.

RECOMMENDATIONS FOR IMPROVING ENVIRONMENTAL PERFORMANCE

The project evaluated in Table 1 showed that several areas of environmental performance need improvement. The Sustainable Sites and Water Efficiency categories scored the lowest percentage from the total points available, receiving a 4/11 score (36%) each. The lack of on-site rainwater management, failure to protect or restore habitats, and limited heat island reduction measures were some of the most significant issues of environmental performance observed in the category. These issues resulted in zero on-site rainwater management and habitat protection points, while only one out of two points was awarded for heat island reduction measures. Additionally, no points were awarded for light pollution reduction.

To improve the project's environmental performance from a site perspective, incorporating a robust green roof could address almost all the issues in the Sustainable Sites category. Water-absorbent plants across the building's footprint can significantly reduce stormwater runoff. Creating habitats for animals such as bee hives, birdhouses, and bat boxes requires thorough planning, installation, and maintenance to ensure that they help to preserve biodiversity without causing any harm or inconvenience. If done correctly, these habitats can be integrated into green roofs, improving ecological performance and earning credits. A green roof can also contribute to reducing the heat island effect. However, practical concerns such as cooling towers, mechanical ventilation, and specialized exhaust systems must be integrated into the overall design to ensure they do not interfere with the green roof's functionality or harm the local ecosystem. The construction phase must consider weight loads by reinforcing the structure, but it is a viable option with a suitable investment. The only aspect of Sustainable Sites that a green roof would not overcome is light pollution reduction, which is caused by exterior lighting systems and affects wildlife and health (Kibert, 2016). However, one solution is to limit the opacity of electrochromic glazing after sunset or install light-reducing window coatings and shades to reduce night glow. Reducing light pollution in such an urban environment is less practical (given current technology and safety standards) than other options listed in this section.

The project receives partial credit in many areas in the LEED category of Water Efficiency. The project must reduce indoor and outdoor water usage to obtain high scores. Half of the points can be earned through reduced water use, while the other half is earned by optimizing water use processes. As such, the project can expand the planned greywater-recycling cooling towers and recycle water for additional cycles before using it to rinse green spaces and roofs. Low-flow water fixtures are installed; future tenants must agree to use similar fixtures to earn credits.

The project had un-awarded points in Energy and Atmosphere (E&A), 61% of the total points, and Materials and Resources, 36%. Some credits were partially awarded from the E&A category, but Advanced Energy Metering received no points. To address this issue, the owner can install more energy metering devices on the large lab equipment, fulfilling metering requirements and allowing more manageable maintenance and energy optimization. Additionally, windmills could be installed to complement the solar array on the roof, reducing the necessary space for solar panels and enhancing the ecological performance of the project.

The largest area of lost points in Materials and Resources was related to reducing the impact of the life cycle. While the proposals above could have partially focused on this issue, a more comprehensive LCA of all materials used in the project, especially the Sourcing Raw Materials, would have been necessary earlier in the construction phase. These points may be lost now, but undertaking these areas for future phases of Science Square is essential.

DISCUSSIONS

The research findings presented offer valuable insights into evaluating GBRS, explicitly focusing on comparing LEED and GG within HPGB. The study's project analysis provides a practical application of sustainable construction principles. It highlights the importance of integrating sustainable criteria, innovative technologies, and continuous improvement strategies in building design and operation. One key finding of the research is identifying areas for improvement in environmental performance within the project. By pinpointing inefficiencies, the study reveals that the Sustainable Sites and Water Efficiency categories scored the lowest percentage points, indicating opportunities to enhance on-site rainwater management, habitat protection, and heat island reduction measures.

Moreover, the research emphasizes the significance of practical considerations, such as cooling towers, mechanical ventilation, and structural reinforcement, in effectively implementing green roof systems. Addressing these technical challenges and ensuring compatibility with building systems and local ecosystems is crucial to optimizing environmental performance in HPGB projects. This finding underscores the need for a multidisciplinary approach to sustainable construction practices, requiring collaboration among architects, engineers, and environmental specialists.

Furthermore, Lean Construction principles focus on maximizing value and minimizing waste throughout the construction (Alarcón et al., 2013). This study contributes to Lean Construction by providing a comparative analysis of LEED and GG within the context of environmental performance assessment for an educational campus facility. This study emphasizes efficiency, sustainability, and continuous improvement in construction, aligning with Lean principles of optimizing resource utilization and enhancing project outcomes. The research suggests a sustainable framework integrating guidelines, standards, and technical expertise to achieve green building. Analyzing GG and LEED within environmental performance assessment allows construction stakeholders to select the most suitable GBRS that best aligns with project goals, sustainability objectives, and performance criteria.

CONCLUSIONS

The construction industry is transitioning towards sustainable building practices and reduced energy consumption. This shift is driven by various factors, including environmental concerns and the demand for more energy-efficient and environmentally friendly buildings. As the demand for sustainable buildings grows, sustainable building practices and rating systems like LEED and GG will become more important in promoting a sustainable environment for future generations. Our research contributes to the body of knowledge by providing an in-depth understanding of developing sustainable construction practices and the long-term sustainability of HPGB. Our study suggests that using GBRS and a comprehensive approach to building design, construction, and operation can help solve significant challenges the construction industry faces, such as energy consumption reduction and achieving sustainability goals. These approaches can promote a more sustainable built environment for future generations, benefiting both people and the planet. Our study proposes a sustainable decision framework that integrates guidelines and standards, sustainable criteria, and technical expertise, advancing prior works. The Georgia Tech Life Science Building is an excellent example of sustainable building practices, with its energy-efficient systems, natural light and ventilation, eco-friendly materials, and responsible waste management practices. Our study benefits professionals and academics by providing a valuable resource for comparative analysis and promoting the implementation of GBRS. Although there are some limitations, our findings are helpful to construction professionals, policymakers, and researchers interested in enhancing sustainable construction practices and achieving a more sustainable built environment.

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