Analysis of the Scope and Trends of Worldwide Green Building Assessment Standards

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***Abstract*—The number of green buildings has steadily increased in recent years, during which various green building assessment standards have evolved to complement the development of green buildings. This study identifies the gaps in scope among different green building assessment standards and discusses the future trends of green buildings for better design and certification planning. This study focuses on the LEED standard in US, BREEAM in UK, BEAM in Hong Kong, Green Mark in Singapore, and Green Star in Australia. After a brief overview on the selected standards, this research analyzes the shift in scope of the different standards since their establishment, and compares the differences and trends among them.**

***Index Terms*—BREEAM, gap analysis, green building, green mark, green star, HK-beam, LEED.**

I. Introduction

Construction has been accused of causing a variety of environmental problems ranging from excessive consumption of global resources, both in terms of construction and building operation to the pollution of the surrounding environment[1]. Research on green building design and materials is already well established and different organizations and research groups have contributed to the development of separate green building assessment standardsto evaluate the environmental friendliness of the building facilities. This study aims at comparing the scope of prominent and developing green building assessment standards to analyze any gaps and to identify the future trends. The comparison will help planners make informed decisions during the design and certification stage of the green building project. Considering the diversity in climate, geography, government policies and building stocks, the following five assessment standards were selected and compared –(1) LEED in the United States, (2) BREEAM in the United Kingdom, (3) BEAM in Hong Kong, (4) Green Mark in Singapore, and (5) Green Star in Australia.

II. Overview of Existing Assessment Standards

Since 1990, there has been extensive development of building environmental assessment methods, many of which have subsequently gained considerable success [2]. The first real attempt to assess environmental considerations in buildings came from the Building Research Establishment (BRE) in the United Kingdom in 1990, where the Building Research Establishment Environmental Assessment Method (BREEAM) was introduced. It was followed by HQE (High Quality Environmental standard) from France in 1996. In 2000, the United States Green Building Council (USGBC) introduced Leadership in Energy and Environmental Design (LEED), which went on to become one of the most popular standards. The start of the 21st century saw the introduction of standards like the Comprehensive Assessment System for Built Environment Efficiency (CASBEE) in 2001 from Japan and Green Star in 2002 from Australia. Based on these successes, many countries adapted the templates of these standards and started developing their own assessment standards. Recent developments in the South Asian regions of Singapore and Hong Kong have led to the development of Green Mark in 2005 and BEAM in 2009, respectively. Fig.1 illustrates the evolution of different green building assessment standards around the world.

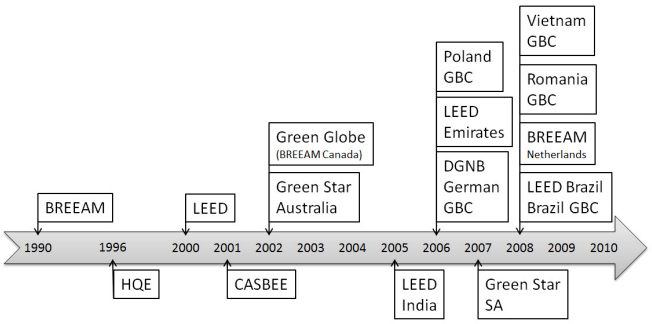

Fig. 1. Evolution of different green building assessment standards around the world (modified from [3])

A. US-LEED

LEED is a voluntary certification program developed in the United States by the USGBC in 2000. Since its inception, it has certified over 10,000 projects worldwide [4]. The certification process is divided into six main categories namely (1) Sustainable Sites (SS), (2) Water Efficiency (WE), (3) Energy and Atmosphere (EA), (4) Materials and Resources (MR), (5) Indoor Environmental Quality (IEQ), and (6) Innovation (Inn). A category called Regional (Reg.) was also introduced in 2009, where projects will be eligible for special regional credits. The evolution of the LEED standards including the number of credits in each category, is tabulated in Table I.

B. UK-BREEAM

This is the oldest certification standard and has certified more than 1,000 projects in the United Kingdom[4].Assessment standards like Green Star and BEAM were developed based on BREEAM. BREEAM is divided into 10 categories – (1) Management, (2) Health and Well-being, (3) Energy, (4) Transport, (5) Water, (6) Material

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Use, (7) Waste, (8) Land Use and Ecology, (9) Pollution, and (10) Innovation. Each category is weighted and the weighted total is used to calculate the final grade. After the successful introduction of BREEAM for office buildings scheme in 1990, BREEAM evolved quickly to existing buildings, courts, school, industrial, healthcare, retail, prison, datacenters and communities.

TABLE I: NUMBER OF CREDITS IN EACH CATEGORY IN LEED

LEED Versions		SS	WE	EA	MR	IEQ	Inn	Reg
New Constr.	NC 2001 (2001-2005)	14	5	17	13	15	5	0
	NC 2005 (2005-2009)	14	5	17	13	15	5	0
	NC 2009 (2009-2012)	26	10	35	14	15	6	4
Existing Buildings	EB 2004(2004-2008)	14	5	23	16	22	5	0
	EB 2008 (2008-2009)	9	10	30	14	20	7	0
	EB 2009 (2009-2012)	26	14	35	10	15	6	4
Commercial Interiors	CI 2005 (2005-2009)	7	2	12	14	17	5	0
	CI 2009 (2009-2012)	21	11	37	14	17	6	4
Core & Shell	CS 2005 (2005-2009)	15	5	14	11	11	5	0
	CS 2009 (2009-2012)	28	10	37	13	12	6	4
Schools	2007 (2007-2009)	16	7	17	13	20	6	0
	2009 (2009-2012)	24	11	33	13	19	6	4
Retail	Retail 2009 (2009-2012)	21	11	37	14	17	6	4
	Retail – NC 2009 (2009-2012)	26	10	35	14	15	6	4

C. BEAM

BEAM (Building Environmental Assessment Method) is a green building assessment standard introduced by the Hong Kong Green Building Council (HKGBC) in 2009 to serve Hong Kong and mainland China. It has over 240 certified projects which showed excellence in the following categories, (1) Site Aspects, (2) Water Efficiency, (3) Material Aspects, (4) Energy, (5) Indoor Environmental Quality, and (6) Innovation [4]. New and existing buildings can be certified under this standard.

D. Green Mark

Green Mark, established by the Building and Construction Authority (BCA) of Singapore in 2005 has certified over 1180 projects in Singapore under the categories of (1) Energy Efficiency, (2) Water Efficiency, (3) Sustainable Operation and Management (Materials), (4) Indoor Environmental Quality, and (5) Innovation [5]. After introducing schemes for commercial projects, Green Mark has now evolved into a more comprehensive assessment standard with schemes for residential buildings, parks, restaurants, supermarkets and data centers as of 2013.

E. Green Star

Green Star is the major green building rating standard in the Australian continent. Sharing similarities with BREEAM, Green Star has extended its service to South Africa thus making its mark in the African continent. The assessment standard has eight categories comprising (1) Management, (2) Indoor Environmental Quality, (3) Energy, (4) Transport, (5) Water, (6) Materials, (7) Land Use and Ecology, (8) Emissions, and (9) Innovation. It has certified over 500 projects since its introduction in Australia with more than 7,000,000 m^2 certified [6].

F. Summary

The selected standards have a rich history and a great commitment to drive the green building revolution. They are widely spread across the globe and addresses issues on different climates, topographical conditions, governmental policies and building regulations. Table II compares the categories addressed by different assessment standards.

TABLEII: COMPARISON OF CATEGORIES AMONG DIFFERENT STANDARDS

Categories	LEED	BREEAM	BEAM	Green Mark	Green Star
Sustainable Sites	✓	×	✓	×	×
Management	×	✓	×	✓	✓
Land Use and Ecology	×	✓	×	×	✓
Transport	×	✓	×	×	✓
Water	✓	✓	✓	✓	✓
Energy	✓	✓	✓	✓	✓
Materials	✓	✓	✓	✓	✓
Waste	×	✓	×	×	×
Indoor Environmental Quality (IEQ)	✓	✓	✓	✓	✓
Emissions	×	✓	×	×	✓
Innovation	✓	✓	✓	✓	✓
Regional	✓	×	×	×	×

The following sections compare the scope among different standards in each category and analyze their evolution.

III. COMPARISON OF STANDARDS AMONG DIFFERENT CATEGORIES

Although addressing similar issues, some credits have been listed under different categories in different assessment standards. Categories like sustainable sites, management, land use and ecology and transport; materials and waste; IEQ and emissions share similar credits. Therefore the above mentioned categories are combined for a more clear comparison.

A. Sustainable Sites/Management/Land Use and Ecology/Transport

This section focuses on the site upon which a building is to be constructed, the land used, and its location with respect to local transport and amenities. Although addressing the same issues, credits are widely spread into Sustainable Sites in LEED and BEAM, Management in Green Mark, and Management, Land Use and Ecology and Transport in BREEAM and Green Star. The common focuses of the categories are:

- Building Orientation and Site Conservation
- Alternative Transportation
- Environmental Assessment
- Light Pollution
- Noise Pollution
- Reduced Heat Effect

From conserving sites and reducing environmental impacts by providing alternative transportation, standards have evolved to control pollution, density, storm water, etc. Introduction of new schemes have led to addition of special credits such as tenant participation, security and encouraging recertification. Public buildings like schools and hospitals have been encouraged to share their facilities with neighboring communities in LEED and BREEAM. Credits like Tenant Feedback in Green Mark and Project Management in BREEAM are unique and are not available in

other standards. The unique focus on life cycle costing in BREEAM, which eventually included service planning after 2009, was a notable change in trend. Certain credits like Storm Water Management although not being present in most standards in this category have been included in other categories such as, Water.

TABLE III: UNIQUE CREDITS OF THE SITE MANAGEMENT CATEGORY

Scope	LEED	BREEAM	BEAM	Green Mark	Green Star
Construction Activity Pollution	✓	×	✓	×	✓
Erosion Control	✓	✓	×	✓	✓
Age of Building	✓	×	×	×	×
Density	✓	×	×	×	×
Storm Water	✓	×	×	×	×
User Guide	✓	✓	✓	×	✓
Tenant Feedback	×	×	×	✓	×
Security	×	✓	✓	×	×
Project Mgt.	×	✓	×	×	×
Life Cycle Costing	×	✓	×	×	×
Service Planning	×	✓	×	×	×
Shared Facilities	✓	✓	×	×	✓
Certified Building	✓	×	✓	×	✓

B. Water

Water conservation is a basic requirement of any environmentally friendly facility. In this category every standard addresses the different ways for reducing the water used in a facility. Some of the common strategies adopted by all the selected standards are:

- Storm Water Management
- Water Metering
- Efficient Irrigation and Landscaping Methods
- Efficient Equipment for Water Use
- Plumbing and Leakage Detection
- Water Recycling

TABLE IV: UNIQUE CREDITS OF THE WATER CATEGORY

Scope	LEED	BREEAM	BEAM	Green Mark	Green Star
Cooling Tower	✓	×	×	✓	×
Water Audit	✓	×	✓	✓	×
Water Use Reduction in Tanks, Pools	✓	×	×	✓	✓
Effluent Discharge	✓	✓	✓	×	×
Water quality Survey	×	×	✓	✓	×

The scope for the Water category eventually advanced from reduced water use in buildings to reduced water use in building equipment and amenities. Introduction of new schemes have also led to the addition of special credits like water use reduction in water tanks, swimming pools, cooling tower, healthcare equipment, etc. Some standards have also focused on credits like water audits, water management plans and water quality surveys, as tabulated in Table IV. Such transitions have led the trend of water category from just reduced usage to better strategy planning and practice based on user needs for significant future improvements.

C. Energy

Conserving building energy is a long-term concern for construction practitioners. Building assessment standards have been developed to help reduce a significant amount of the energy consumed and to reduce operation costs. The common areas in the Energy category among the selected standards are:

- CO_2 Emissions
- Energy Metering and Monitoring
- Optimized Energy Performance
- Renewable Energy Usage
- Efficient Lighting Equipments
- Building Commissioning
- Use of Energy Efficient Equipment

TABLE V: UNIQUE CREDITS OF THE ENERGY CATEGORY

Scope	LEED	BREEAM	BEAM	Green Mark	Green Star
Staff Education	✓	✓	×	×	×
Cost Impacts	✓	×	×	×	×
Home Office	✓	✓	×	×	×
Energy Policy and Plans	✓	×	×	✓	×
Embodied Energy	×	×	✓	×	×
Clothes Drying Space	×	✓	✓	×	×
Building Layout	×	×	✓	✓	×

This category has more possibilities for innovation in its operation, since clients can adopt the best practices in saving energy use with respect to buildings. The initial scope was the installing or upgrading of equipment to consume less energy. Common strategies include efficient HVAC, lighting, and electrical appliances. Overtime, the scope shifted towards optimizing energy use based on tenant usage, using better building elements and orientation. Table V shows the credits in the Energy category unique to some of the selected standards but not all of them. Introduction of new schemes has also led to the addition of special credits like energy saving methods in industry, hospitals, supermarkets, etc. Multi-residential schemes introduced in BREEAM and LEED encourages the provision of office spaces in residential buildings to reduce the users' work commute thus saving fuel costs and emissions. Credits like documenting cost impacts can be used as a learning resource for future projects. In addition, consideration and measurement of embodied energy of materials are suggested in BEAM.

D. Materials/Waste

This section guides clients to focus on the type of materials to be used, purchased and recycled. It also discusses extensive waste management methods and practices. Some common key issues of this category are

- Waste Recycling
- Sustainable Product Purchase
- Responsible Selection of Materials
- Recycled Material Usage
- Adaptable and Maintainable Design

This category focuses on different type of material selection and reuse. Additional attention is now given to occupant comfort. As shown in Table VI, BREEAM introduced unique credits for including more robust materials for safety. Reduced refrigerant usage is not included in this category but is found in other categories.

TABLE VI: UNIQUE CREDITS OF MATERIALS AND RESOURCES CATEGORY

Scope	LEED	BREEAM	BEAM	Green Mark	Green Star
Refrigerants	×	×	✓	×	×
Facility Alterations	✓	×	×	×	✓
Ongoing Consumables	✓	×	×	×	×
Durable Goods	✓	×	✓	×	✓
Waste Mgt. Plans	✓	×	✓	×	×
Energy Policy and Plans	✓	×	×	×	×
Insulation	✓	✓	×	×	×
Construction Waste Reduction	✓	✓	✓	×	×
Robustness in Materials	×	✓	×	×	×

E. Indoor Environmental Quality (IEQ)/Emissions

This category assists in maintaining the quality of indoor environment for better living. Important issues addressed include,

- Thermal Control
- Indoor Pollutant Control
- Ventilation Control
- Air Delivery Monitoring and Exchange
- Acoustic Performance
- Daylighting

TABLE VII: UNIQUE CREDITS OF THE IEQ CATEGORY

Scope	LEED	BREEAM	BEAM	Green Mark	Green Star
Tobacco Smoke Control	✓	×	×	×	×
Entryway Systems	✓	×	×	×	×
IAQ Management Plans	✓	×	✓	✓	×
Inclusive Design	×	✓	✓	×	×
Waste Disposal	×	×	×	✓	×
Indoor Plants	✓	✓	×	×	✓
Art in Health	×	✓	×	×	×

Indoor Environmental Quality (IEQ) ensures the building has proper ventilation, is pollution free and provides occupant comfort by allowing controlled lighting and sound. Over the years progressive standards have introduced strict restrictions onbiological contamination and the emission of volatile organic compounds. This category shares credits with certain other categories and can be able to obtain multiple credits. Introduction of new schemes brought in special credits like Art in Health for hospitals to improve patient comfort, Inclusive Design to provide access to disabled persons and laboratory specific standards for industries, schools and hospitals.

F. Scoring and Grade Award

The scoring and final grade award varies with each standard. The different scoring procedures will be discussed in the following section.

LEED has the simplest scoring system, in which the total numbers of credits earned from all categories are calculated for the final grade award. BREEAM includes weight age to all its categories and the weighted total will be calculated to award the final grade. BEAM also has individual weight age to its categories. Besides considering the overall weighted total, BEAM also considers the individual weighted scores of Sustainable Site category, the Energy category, and the Indoor Environmental Quality. BEAM also has a criteria for innovation credits to obtain the final grade. Green Mark gives points based on the building's performance, and the total points are calculated for final grade. Green Star follows a similar method to BREEAM. Each category is weighted and the weighted total issued for determining the final award. Each assessment standard has specific criteria for the final grade award, as tabulate in Table VIII.

TABLE VIII: GRADE AWARD CRITERIA

LEED (max. 110)	BREEAM (max. 122)	BEAM (max. 127)	Green Mark (max. 190)	Green Star (max 143)
80 Points (Platinum)	85% (Outstanding)	75% (Platinum)	90 and above(Platinum)	75 Points (6 Star)
60-79 Points (Gold)	70% (Exceptional)	65% (Gold)	85 to <90 (Gold Plus)	60-74 Points (5 Star)
50-59 Points (Silver)	55% (Very Good)	55% (Silver)	75 to <85 (Gold)	45-59 Points (4 Star)
40-49 Points (Certified)	45% (Good)	40% (Bronze)	50 to <75 (Silver)	×
×	30% (Pass)	×	×	×

Versions: LEED v2009, BREEAM v2011, HKBEAM 2010, Green Mark 2010, Green Star 2008

The weightages assigned to different categories in BREEAM, HK-BEAM and Green Star are tabulated in Table IX. As shown in Table IX, LEED and Green Mark do not weigh their categories.

TABLE IX: WEIGHTAGE OF DIFFERENT CATEGORIES

Scope	LEED	BREEAM	BEAM	Green Mark	Green Star
Sustainable Sites	×	×	25%	×	×
Management	×	12%	×	×	8%
Land Use and Ecology	×	10%	×	×	7%
Transport	×	8%	×	×	10%
Water	×	6%	12%	×	15%
Energy	×	19%	35%	×	25%
Materials	×	12.5%	25%	×	10%
Waste	×	7.5%	×	×	×
Indoor Environmental Quality (IEQ)	×	15%	20%	×	20%
Emissions	×	10%	×	×	5%
Total	×	100%	100%	×	100%
Innovation	×	10%	×	×	×

In Table VIII, LEED Platinum and Green Star 6-Star are shown on the same row. However, it does not mean that a LEED Platinum building is as sustainable as a Green Star 6-Star building. Instead, TABLE IX only shows that they are the highest grades achievable for LEED and Green Star, respectively. Reed et al.[3] compared LEED, BREEAM, Green Star, and CASBEE, and indicated that the highest grades in those green building standards have different levelsof sustainability. For example, a Green Star 6-Star building (the highest possible Green Star rating) is less

sustainable than a LEED Platinum building (the highest possible LEED rating), when being assessed using the same set of criteria.

IV. Discussion on Analysis Results

From the comparison, it can be seen that the five selected assessment standards have evolved broadly over the years. Introduction of new schemes has brought in additional credits that improved the performance of buildings in recent years. Building specific schemes, like Hospitals, Schools, Retail, etc., address specific building related energy issues and occupant comfort. Developing standards should adapt as early as possible to the growing demands and improve their rating standards for better assessment in the future. Tenant participation has been given major importance in recent standards and has allowed buildings audits, and attracts feedback from the community to improve its operation. Issues on energy and water use have included different building components and equipment in addition to the entire building consumption. Material selection and waste management have brought in the usage of innovative materials rather than its conventional counterparts. Building type specific credits has continued to evolve in specific standards, making them unique. For example, the Life Cycle Costing credit in BREEAM has evolved and included service planning since 2009. For another example, the Art in Health credit improves patient comfort in hospital buildings and probably enhances the recovery of patients. The developments have changed the way green buildings are built and designed. These changes could pave ways for a multi-dimensional design approach, where the buildings not only interact with tenants but also with the surrounding environment. This would revolutionize the design and operation of green buildings leading to higher levels of achievement in the future.

Environmental assessment standards have multiple purposes. One of the basic purposes is to provide guidelines for energy conservation and cause less environmental impacts. Zhou et al. found that certain standards achieve less energy savings than expected even after receiving a high final grade [7]. Standards should understand their roles and design schemes committed to conserve energy. Credits for Storm water Management and Refrigerant Management are examples of credits with similar scope but placed in different categories. Such differences should be identified and standardized to avoid repetition of similar issues in different categories. Certified buildings should be re-commissioned at regular intervals and assessed to monitor energy usage. Renewing certification at regular intervals will help a certified building maintain its appropriate grade award over time. This can help stakeholders understand the assessment process better and promote the development of green buildings.

V. Conclusion

Five popular and well established green building assessment standards widely spread around the world were chosen for comparison. Previous comparative studies on green building assessment standards have neither compared the overall structure of the standards or have suggested possible ways to design a new standard based on the different credits available in each standard. The point of departure of this study was to make a detailed comparison of individual scope addressed in all categories of different standards, including its various schemes and evolution. This study will not only help to identify future trends in the green building industry but also to understand the specific scope of each assessment standard. Such comparison helps to identify the key areas of focus during green building design and certification planning. The tables illustrate the special scope shared by different standards, which are useful for multiple certification planning. The study identified that there is a moving trend in tenant participation and material selection in green building design and construction. Standards have evolved quickly addressing multiple building types and specific building related energy and occupant issues. As each standard has its own purpose and is committed to certain roles, their independence should not be disturbed. However, a common benchmark could be set for easy comparison and adaptability. Multiple certification of a facility will be more frequent, thus attracting more market attention, thereby leading to a greener society.

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