MATERIAL SELECTION FOR SUSTAINABLE BUILDINGS

Walaa S E Ismaeel[1]

Architectural Engineering Department, The British University in Egypt, El Sherouk City - Cairo-Suez Desert Road, Postal No. 11837 - P.O. Box 43, Egypt

The study provides an insightful view on the institutional infrastructure for regulating and guiding sustainable material selection practice, and different approaches for configuring them. It is noted that this should follow the accelerating demands of the real estate market, providing guidelines, measurement criteria, verification methods as well as investigating market potentials and third-party certification requirements. The study investigates two well-known green building rating systems (GBRSs) according to these defined scopes for the efficiency of materials and resources (MR); BREEAM and LEED. These provide a set of guidelines and measurement criteria. A mixed qualitative and quantitative approach was used to investigate and compare the percentage fulfilment for each scope in their latest version developments. In addition, interviews and designed questionnaires were carried to investigate practitioners' opinion about the use of both rating systems for MR in their sustainable projects. This contributes to a broader discussion about the comprehensiveness of available guidelines, reliability of measurement criteria, quality of verification tools as well as availability and price of certified materials and products. The result showed that new versions put more emphasis on verification of the environmental impact of sustainable materials but less is paid for certification and market potentials. This makes it challenging to comply with these criteria and require further consideration and balance from developers as well as more effort for practitioners to acquire related knowledge and practice about life cycle approach. This points out the importance of striking a balance between prescriptive and performance requirements for material selection and procurement in practice, noting that it is still research in process for a standard acceptable method that is both relevant to construction best practices and supported by scientific knowledge.

Keywords: BREEAM; green materials; LEED; sustainable material selection

INTRODUCTION

Sustainable material selection and procurement are considered important pillars in the green building process. This study aims at investigating available guidelines, tools and methods in practices. This is conducted through a qualitative and quantitative approach using content analysis of sustainable criteria recommended by two well-known green building rating systems (GBRSs); BREEAM and LEED, as well as surveying local practitioners. The result showed that practitioners used guidelines obtained from GBRSs to provide a set of prescriptive requirements for material selection. Yet, this operates in quite a simplistic and abstract manner if not considered early in design decisions and complemented with a more robust approach for

[1] Walaa.Salah@bue.edu.eg

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environmental assessment. This explains the evolution of these systems to raise the bar for minimum requirements of building codes and standards and follow the accelerating demands of the real estate market. Challenges may be associated with determining proper guidelines for sustainable material selection and procurement, setting proper benchmarks and measurement criteria, means of verifying performance as well as investigating the market readiness and potentials for green certification requirements (Ismaeel, 2019b). This constitutes the four scopes as shown in Fig 1, which were investigated by a previous study by (Ismaeel, 2019b) as shown in Fig 2.

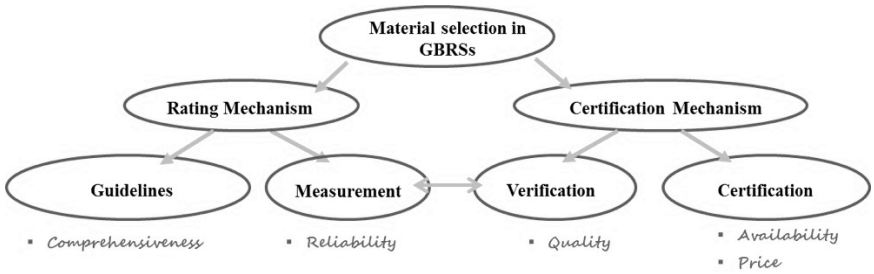


Fig 1: Sustainable material selection using GBRSs, author's elaboration after (Ismaeel, 2019b)

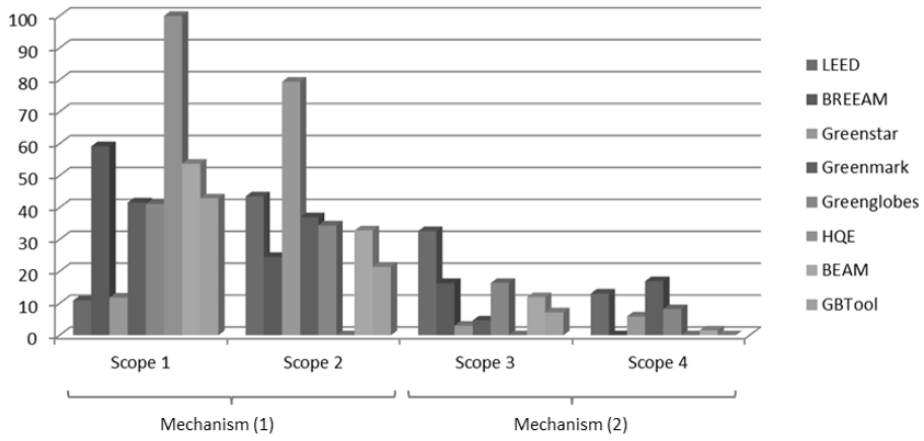


Fig 2: The status of 8 GBRSs according to the four defined scopes (Ismaeel, 2019b)

GBRS And Material Selection

GBRSs assess the projects' environmental performance according to defined parameters and present certified third-party statements (Ismaeel, 2019a). Some GBRSs include prescriptive guidelines while others provide a performance-based approach using Life Cycle Assessment (LCA) for the sustainability of materials and resources (MR)- this includes all inputs and outputs for a material/product. The former is easier for practitioners to use, based on physical material properties (area, weight and volume) while the latter provides accountable results for their environmental impacts along the project's life cycle (Ismaeel and Ali, 2020).

On one hand, Building Research Establishment Environmental Assessment Method BREEAM (BREEAM) is a leading GBRS, developed in the United Kingdom and applied worldwide. Its two latest version developments cover MR under two categories; Materials and Waste (Breeam.com). It was the first to require LCA and Environmental Product Declarations (EPDs) to compare materials' profiles (Ismaeel, 2018). On the other hand, the Leadership in Energy and Environmental Design-Materials and Resources category (LEED MR) is another international GBRS. It

discusses several issues that support material selection and minimizing waste during building construction and operation. In earlier versions, it presented a set of prescriptive guidelines for material selection but the latest development incorporated LCA with more emphasis on disclosure and optimization (USGBC.org).

Sustainable Materials

Guidelines

Several attempts were carried to support sustainable material selection e.g., index-based methods, multi-objective optimization, cost-benefit analysis and ranking methods (Sirisalee *et al.,* 2004; Giudice, La Rosa and Risitano, 2005; Castro-Lacouture *et al.,* 2009). Also, some guidelines are found in different GBRSs which can create synergies with other sustainable criteria, these include:

- Designing for robustness, disassembly and adaptability as well as paying due consideration for material durability and resilience. It also includes designing for speculative floor and ceiling finishes and material efficiency.
- Promoting onsite and offsite recycling activities. It is noted that the former is more sustainable. Dedicating a recycling area in the building should be planned in advance to reduce landfill, primary materials cost, energy use and maintenance saving. The latter should associate the source and recycling location. It should also consider the mass of the recycled object- the energy used for recycling- distance for recycling location, in addition to transportation (energy used for transportation and waste emitted). Nevertheless, both types count on the proximity to recycler hauliers and working with local jurisdictions as incentives.
- Promoting the use of local/ regional materials reduces the impact of transportation and promotes local products. This includes proximity to extraction, harvesting and manufacturing locations e.g., LEED specifies 500 miles of the project site.
- Promoting the use of rapidly renewable materials (e.g. cork, bamboo, natural rubber, wheat, and cotton) look at raw materials favouring plants with a short harvesting cycle. LEED specifies 10-year or shorter.
- Promoting the use of reused materials (include salvaged, refurbished, or reused materials) reduces the demand for virgin materials and reduces waste. This minimizes the impact resulting from extraction and processing stages. Examples include reusing structural beams, flooring, doors, cabinetry, brick…etc.
- Promoting the use of recycled content materials reduces the demand for raw materials and resources e.g., masonry, concrete, metals, gypsum wallboard, tile, carpet and insulation. This includes pre consumer content (manufacturing waste) and post consumer content (consumer waste)- considering greater environmental benefit for the latter. It is noted that the National Institute of Standards and Technology argues LEED guidelines which account for the cost of materials (Scheuer and Keoleian, 2002).
- Promoting the use of low emitting materials minimizes health associated problems arising from indoor building materials and products. LEED specifies limits of volatile organic compounds and urea-formaldehyde for composite wood and agrifiber products. Nevertheless, these should be benchmarked against third party certification for a broader list of manufacturing standards' emission requirements e.g., American National Standards Institute.

- For construction waste, mixed waste is separated and recycled in waste management facilities. Then, reports and declarations for the list and percentage of recycled content are generated. Special concern is also paid for dealing with hazardous materials onsite according to local regulations.

Many practitioners were able to comply with these direct guidelines in terms of material selection and calculations. Also, manufacturers and contractors were able to provide declarations stating that materials comply with the requirements, reporting quantities, cost, harvesting and manufacturing distances, recycled contents as well as recycling hauliers. This witnesses market change for more availability with competitive rates. Nevertheless, this depends on project location and feasibility. It also lacks scientific proof about their environmental impacts.

Measurement

Previous literature investigated the following measurement criteria for sustainable materials (Castro-Lacouture *et al.,* 2009; Ismaeel, 2018, 2019b):

- Area accounts for the space dedicated for recycling activities compared to the total building area. It is also used to account for building reuse areas, floor, facades and internal divisions.
- Weight (or mass) is used to measure diverted construction waste from landfill.
- Volume is also used to measure diverted construction waste from landfill.
- Material cost is used to measure the percentage of reused, recycled content, renewable and local materials in the project.
- Emission level is used to determine the maximum emission limits of materials according to international standards.
- Environmental impact is used to determine and compare low impact materials for material selection. Also, for solid waste planners, the Waste Reduction Model developed by the Environmental Protection Agency may assist in tracking and reporting the effect of using different waste management practices to reduce greenhouse gas emissions.

Verification

Verification tools and methods vary according to the aim and scope of sustainable criteria. These may be used for external communication, decision-making and internal development (Ismaeel, 2019c; Morsi, Ismaeel and El-Hamed, 2020). The list may include the following:

- Applying LCA to support decisions related to material selection, building reuse as well as construction and demolition waste management plans. This accounts not only for the physical properties of materials (e.g., weight, area or volume) but above all their environmental impact (Ismaeel and Ali, 2020). Nevertheless, material inventory databases should be checked for information consistency.
- Investigating synergies and trade-off relations with energy efficiency when choosing materials.
- Investigating the direct effect of building materials on Indoor Air Quality (IAQ) and buildings' environmental impact. There are several health-associated problems including short term and long-term effects. This can be investigated through a post occupancy evaluation and continuous monitoring and follow-up measures.

- Verification and management procedures include setting management plans by including inventories to reduce harmful environmental impact as well as follow up process to confirm regular maintenance and inspection practices.

Certification

Material quantity and quality require further investigation for market availability and prices of green-certified materials (Ismaeel, 2019b). Certification schemes may address the following.

- Investigating market potentials for the availability and prices of reused, recycled, renewable and local materials as well as their functional requirements.
- Accordance with third party certification for sustainable management of resources e.g., Forest Stewardship Council's, Sustainable Forestry Initiative and the American Tree Farm System.
- Providing meaningful and consistent information about the environmental impact of a product using ISO 14020 (2000) e.g., EPD. This is required by BRE 'Environmental Profile' and LEED V4.0.

METHOD

The study adopted a mixed qualitative/quantitative approach to discuss the problem in previous literature and track its implication in practice. Guidelines for material selection were obtained from two well-known GBRSs; BREEAM and LEED. The two systems were compared in terms of structure and measurement criteria as well as the weighting assigned for MR category in each (Ismaeel, 2018, 2019b). The two recent versions for both LEED 'Materials and resources' and BREEAM 'Materials' and 'Waste categories' were analysed. This includes one category from LEED and two from BREEAM, but the results were normalized as a percentage of the overall score rate for each rating system. The research method followed the following steps:

1- Tracing MR in BREEAM and LEED: content analysis and deducting information about the fulfilment of each scope as shown in Table 1.

2- Comparing the percentage fulfilment for each scope in the latest version developments of BREEAM and LEED: quantitative comparative analysis

3- Conducting structured interviews and designed questionnaires for practitioners in selected projects of BREEAM and LEED certification in The United Arab Emirates (UAE). This includes Al Zahia Residential Development and Lulu -Regional Office in Dubai, Kempinski Mall of Emirates and INSEAD Middle East Campus. This step investigates practitioners' opinions about the benefits and challenges of using both rating systems for material selection in their sustainable projects.

Table 1: Tracing MR in BREEAM and LEED

Guidelines	Measurement	Verification	Certification
Prescriptive recommendations for material selection along the project life cycle During design: promoting the use of recycled, reused and natural materials. During construction: performing construction waste management plan During building operation: promoting onsite recycling activities.	Following quantitative measurement criteria using calculations based on building's area, weight or volume of waste and salvaged building materials as well as material cost.	Using LCA and setting emission reduction levels.	Recommending the second and third level certified building materials and products, as well as discussing the availability and price of green materials and products.

The study used guidelines from BREEAM and LEED rating systems referring to a previous study by (Ismaeel, 2019b). This provides a breakdown analysis for their role in the building process, providing; guidelines, measurement methods, verification criteria as well as certification and market-related value- as shown in Table 2.

Table 2: Comparing the four scopes for the recent versions of BREEAM and LEED

BREEAM 2016	Total	Guide lines	Measur ement	Verification	Certification
Materials					
Life cycle impacts	7			7	
Responsible sourcing of materials	3			3	
Designing for robustness	1	1			
Waste					
Construction waste management	4		4		
Recycled aggregates	1	1			
Operational waste	1	1			
Speculative floor and ceiling finishes	1	1			
Total	18	4	4	10	0
		22	22	56	0
BREEAM 2018					
Materials					
Environmental impacts from construction products - Building life cycle assessment (LCA)	7			7	
Environmental impacts from construction products - EPD	1				1
Responsible sourcing of construction products	4			4	
Designing for durability and resilience	1	1			
Material efficiency	1	1			
Waste					
Construction waste management	5		5		
Use of recycled and sustainably sourced aggregates	1	1			
Operational waste	1	1			
Speculative finishes (Offices only)	1	1			
Adaptation to climate change	1			1	
Design for disassembly and adaptability	2	2			
Total	25	7	5	12	1
		28	20	48	4
LEED V3.0					
Materials and Resources					
Storage and Collection of Recyclables	-	*			
Building Reuse—Maintain Existing Walls, Floors and Roof	3	3			
Building Reuse—Maintain Existing Interior Non-structural Elements	1	1			
Construction Waste Management	2		2		
Materials Reuse	2	2			
Recycled Content	2	2			
Regional Materials	2	2			
Rapidly Renewable Materials	1	1			
Certified Wood	1				1
Total	14	11	2	0	1
		79	14	0	7

LEED V4.0 Materials and Resources						
Storage and Collection of Recyclables		-	*			
Construction and Demolition Waste Management Planning		-	*			
Building Life-Cycle Impact Reduction		5			5	
Building Product Disclosure and Optimization - Environmental Product Declarations		2				2
Building Product Disclosure and Optimization - Sourcing of Raw Materials		2			2	
Building Product Disclosure and Optimization - Material Ingredients		2			2	
Construction and Demolition Waste Management		2		2		
	Total	13	0	2	9	2
			0	15	69	15

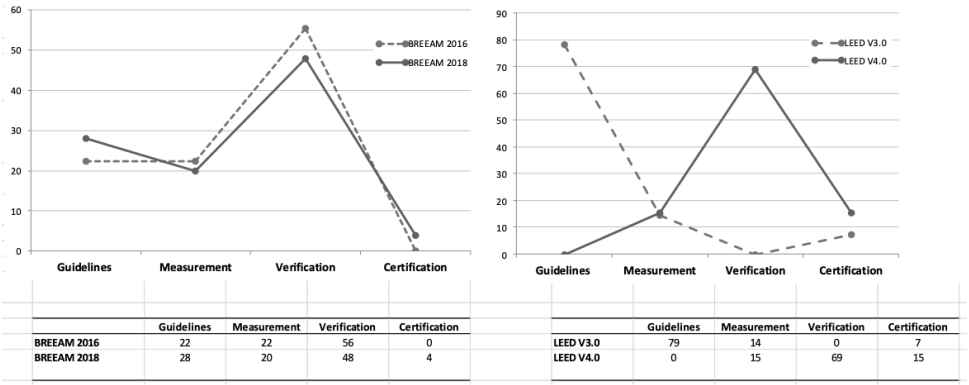
The development of BREEAM and LEED shows different approaches for sustainable MR; more consistent for the former and witnessing a huge change in the latter. This includes prescriptive guidelines; a) design guideline e.g., dedicating onsite area for storage and collection of recyclables and building reuse, b) construction practices e.g., waste management plan and c) specifications for materials e.g., reused, recycled, regional and renewable. Measurement criteria for MR credits are continuously changing according to guidelines. Nevertheless, these are always related to practitioners' best practices and require time and money. Verification methods are paid more concern-particularly for materials' environmental impact. It is also noted that credits' requirements are associated with materials' availability and price for BREEAM 2016, 2018 and LEED V3.0 as well as materials' data disclosure for BREEAM 2018 and LEED V4.0. Also, the two version developments mandated conducting a CWM plan and a whole building LCA.

Then an online web-based questionnaire for a sample of 54 participants in UAE and structured interviews with other 32, investigated practical experience for applying MR criteria according to the predefined scopes. These were carried from Jan-March 2021 through the following link http://www.esurveyspro.com/Survey.aspx?id=bdab1d67-cbc2-40ac-817e-0f39672266bc. The survey received 32% responses from different participants' specialisations: engineering and construction, management and consultancy, research and development as well as designing and planning. It included 26 questions (3 open ended as well as single and multiple choices). This started with general questions for the benefit of using the two rating systems for material selection in the international and local context. Each participant indicated which system he/she had applied in their project and their opinion about their latest version developments to address sustainable issues. Then they answered specific questions concerning the requirements of each MR related credit in light of the four defined scopes.

RESULT

The result shown in Fig 3 indicates that with the development of new versions of BREEAM and LEED, more emphasis is put on verification of the environmental impact of sustainable materials but less is paid for certification and market potentials. This makes it challenging to comply with these criteria and require further consideration and balance from developers of these GBRSs as well as more effort for practitioners to acquire related knowledge and practice. This was expressed during the survey to be the result of insufficient knowledge about applying LCA and the timely and complex procedure it requires. Also, practitioners indicated specific challenges for each defined

scope. This includes the risk of misinterpretation of the system's guidelines and following a point chasing approach, inaccurate measurements and unreliable information. They also indicated that risk factor should be considered for every verification method. This is in addition to incomplete documentation relating to the green features of a product. Furthermore, failure to meet sustainable standards or expectations may compromise other sustainable aspects e.g., IAQ. Last but not least, they highlighted the uncertainty due to the use of new and untested materials or from traditional products being used in new and untested ways.



	Guidelines	Measurement	Verification	Certification
BREEAM 2016	22	22	56	0
BREEAM 2018	28	20	48	4

	Guidelines	Measurement	Verification	Certification
LEED V3.0	79	14	0	7
LEED V4.0	0	15	69	15

Fig 3: Comparing the four scopes for the two latest developments of BREEAM and LEED

DISCUSSION

This study provides know-how for practitioners for proper material selection. This 4-tier framework can be used by practitioners at early stages to categorize and classify MR related criteria and understand their contribution to the sustainable project. Also, it enables comparing different GBRSs based on common ground and accordingly, resolves most of the associated conflict in the academic area. Similarly, it enables comparing buildings based on the four scopes which provide a better understanding of their environmental performance. Point gaining can be planned and managed according to the proposed framework as well. This shall facilitate the proper management of certified projects. It can also be associated with other project management research to facilitate allocation of time, money and resources and investigate which aspects require more investment, be it; guidelines for using green materials, carrying field measurements, verification using standard methods, or obtaining materials with the required green material specifications.

For the purpose of this study, only BREEAM and LEED were discussed, being the most widely used GBRSs but this study can be replicated for other rating systems as well. The study was limited to materials and resources for new construction excluding residential buildings. Hence, some credits were excluded which do not fall under this scope. Furthermore, a similar context (UAE) was selected to be able to compare the effect of using the latest versions of the two rating systems and how this affected practitioners' experience. This normalized all variations associated with material availability and cost in the local market.

CONCLUSION

The study presents an insightful study on the institutional infrastructure for regulating and guiding sustainable material selection practice, and different approaches for configuring them in light of using two well-known GBRSs e.g., BREEAM and LEED. This compares them in terms of how they address the sustainability of materials and

resources using qualitative and quantitative approaches. The research notes that MR should follow the accelerating demands of the real estate market-defined in four scopes. This includes 1) providing guidelines, 2) measurement criteria, 3) verification methods as well as 4) investigating market potentials and third-party certification requirements. Hence, the research investigates and compares the percentage fulfilment for each scope in their latest version developments therein. These may vary according to the type of guidelines and the significant importance they put for sustainable criteria, nevertheless, they all put MR as a major concern for any sustainable project. Some criteria may provide prescriptive requirements in the form of guidelines along the project life cycle. Other criteria describe measurement methods which are important to define why, what, when and how to measure along the building process. Using standard agreed-upon verification methods such as LCA indicates the environmental impact of materials and products. It also discusses third party certification systems, and how international initiatives for green material certification can play a major role in streamlining the green building certification process in sum. It is also important to mention the need for a continuous update about market potentials and best practices.

The survey indicated associated problems in practice, e.g., the comprehensiveness of available guidelines, reliability of measurement criteria, quality of verification tools as well as availability and price of certified materials and products. Furthermore, tracing point-weighting allocation showed that new versions put more emphasis on verification of the environmental impact of sustainable materials but less is paid for certification and market potentials. This makes it challenging to comply with these criteria and require further consideration and balance from developers of these GBRSs as well as more effort for practitioners to acquire related knowledge and practice about the life cycle approach. Hence, the study points out the importance of striking a balance between prescriptive and performance requirements for material selection and procurement in practice. It is still research in process for a standard acceptable method that is both relevant to construction best practices and supported by scientific knowledge. This also contributes to a broader discussion about the comparability of GBRSs and green-certified projects.

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