AAR4817   Use and Operation of Zero Emission Buildings

BREEAM & LEED:

A study of materials and their life cycle impacts

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1 ABSTRACT

Building construction involves use of various materials as a very important part of the process. In earlier days when technology was not in its advancement, natural materials like stones, timber, bamboo and soil were used in their simplest and original form to build houses without the use of so called fossil fuel for their extraction. As for now, construction industry makes use of various composite materials which are often manufactured with a lot of energy use, in particular fossil fuel. The use of fossil fuel is directly related to CO_2 emissions into the atmosphere. In terms of the manufacture of building products, the release of chemicals into the atmosphere from production processes has been linked to damaging the ozone layer and other effects harmful to the environment and human health.

All materials have embodied carbon over a full life cycle of a building. Some materials like timber are associated with low embodied carbon while others like steel have considerable high embodied carbon. BREEAM considers materials in a separate heading entitled 'Life cycle impacts', to recognise and encourage the use of construction materials with a low environmental impact. In the case of LEED, a separate heading is not specifically defined for materials, but instead is addressed under a number of headings. This essay gives a brief overview of BREEAM and LEED with a particular focus on life cycle impacts of materials.

2 INTRODUCTION

Material selection plays a significant role in sustainable building operations from the construction of a building, through to operation and demolition. During the life cycle of a material, its extraction, processing, transportation, use and disposal can have negative health and environmental consequences such as water and air pollution, destruction of native habitats, and depletion of natural resources. Environmentally responsible procurement policies can significantly reduce these impacts. It is important to consider the relative environmental, social and health benefits of the available choices when purchasing materials and supplies. For example, the purchase of products containing recycled content expands the market for recycled materials, slows the consumption of raw materials, and reduces the amount of waste entering landfills. Use of materials from local sources not only reduces transportation impacts but also supports local economies (U.S.G.B.C., 2009).

In the life cycle of a building, various natural resources are consumed, including energy resources, water, land, minerals and many kinds of pollutants are released back to the regional/global environment. These environmental inputs and outputs result in global warming, acidification, air pollution, etc., which inflict damage on human health, primary production, natural resources and biodiversity. The building sector, constituting 30-40% of the society's total energy demand and approximately 44% of the total material use as well as roughly one-third of the total co_2 emission, has been identified as one of the main factors of greenhouse gas emissions (Li, 2006).

With a claim of sustainable building materials, there is an increase in the number of products with various environmental labelling in the market which has led to considerable market confusion. Investors who want to make investments on manufacturing products with these kinds of labels are sceptical whether or not sustainability efforts will really pay off on the long term. Developers who want to make sure their investments are targeted at the most high-impact projects, look for green products. To reduce these impacts, many levels of government and other types of stakeholders are starting to demand greater transparency with regards to environmental claims in materials. Consequently, there needs to be standard tools to verify these claims. Life Cycle impact Assessment (LCA) is example of such a tool developed to assess the environmental impact of materials. LCA aims to quantify the environmental impacts of a given product throughout its lifecycle in order to identify opportunities for improvement (Deloitte, 2009).

Andrae (2010) has defined Life cycle assessment as a standardized methodological framework for estimating and assessing some of the possible environmental impacts attributable to the life cycle of a product or technology, such as climate change, stratospheric ozone depletion, tropospheric ozone creation, eutrophicaiton, acidification, toxicological stress on human health and ecosystems, the depletion of resources, water use, land use, noise and others.

3 METHOD

How are life cycle impacts of materials dealt in BREEAM and LEED and how is the assessment done and credits awarded under this theme?

To answer the above research question, a thorough literature review was conducted using secondary research sources such as books, paper, electronic materials etc. Published criteria from BREEAM and LEAD were used as a basis for this research work. While going through these certification systems, especially the sections dealing with scoring and rating, and life cycle impacts of materials is looked into.

4 BREEAM

BREEAM (Building Research Establishment's Environmental Assessment Method) is the world's first environmental assessment method and rating systems to assess the sustainability of buildings (Ebert et al., 2011). BREEAM sets the standard for best practice in sustainable building design, construction and operation and has become one of the most comprehensive and widely recognised measures of a building's environmental performance. A BREEAM assessment uses recognised measures of performance, which are set against established benchmarks, to

evaluate a building's specification, design, construction and use. The measures used represent a broad range of categories and criteria from material, energy to ecology. They include aspects related to energy and water use, the internal environment (health and well-being), pollution, transport, materials, waste, and management processes
A certified BREEAM (GreenBookLive) assessment provides clients, developers, designers and others with :

- Market recognition for low environmental impact buildings
- Confidence that tried and tested environmental practice is incorporated in the building
- Inspiration to find innovative solutions that minimise the environmental impact
- A bench mark that is higher than regulation
- A system to help reduce running costs, improve working and living environments
- A standard that demonstrates progress towards corporate and organisational environmental objectives

Without a transparent measuring system, claims about the environmental performance of building materials are easy to make but difficult to justify or materialize. It is important to measure the impacts of a construction material not only during its manufacture, but also during production or building system throughout its life. This includes its extraction, processing, use, maintenance and its eventual disposal. It is important to assess materials in order to find out their impacts globally, regionally and locally – in the air, in water and on the land, making an impact on humans and the environment. (BREEAM, 2011a)

Certification can benefit manufacturers by helping them to positively distinguish their products as being 'green' and something purchasers will recognise and accept. Specifiers and designers benefit by being able to will be able to confidently select materials, products and systems in the knowledge that their environmental performance will be as specified. Certified buildings can boast themselves as sustainable buildings and have a reputation in the market(GreenBookLive).

4.1 Scoring and Rating BREEAM assessed buildings (BREEAM, 2011a)
There are a number of elements that determine the overall performance of construction projects assessed in BREEAM as mentioned below:

- The BREEAM rating level benchmarks
- The minimum BREEAM standards
- The environmental section weightings
- The BREEAM assessment issues and credits

BREEAM rating benchmarks

BREEAM Rating	Score (%)
Outstanding	85*
Excellent	70
Very Good	55
Good	45
Pass	30
Unclassified	<30

Table 1: BREEAM rating benchmarks (BREEAM, 2011a)

**There are requirements additional to achieving 85% or more*

According to the benchmark table, a building has to achieve at least 30% to receive a BREEAM ‘pass’. Besides, there are additional mandatory requirements that need to be fulfilled without which BREEAM rating will not be issued even though the building achieves above 30%. Below is the table which gives an overview of the mandatory requirements under each rating.

4.2 Minimum standards

BREEAM has adopted a flexible system to the assessment and rating of building performance. As a result, to achieve a particular level of performance, BREEAM credits can be traded. This approach is called ‘balanced score-card’. Non-compliance in one area can be off-set through compliance in another to achieve the targeted BREEAM rating. However, to ensure that performance against fundamental environmental issues is not overlooked in pursuit of a particular rating, BREEAM sets minimum standards of performance in key areas eg. energy, water, waste etc (BREEAM, 2011a).

BREEAM issue	Minimum standards by BREEAM rating level (credits)				
	PASS	GOOD	VERY GOOD	EXCELLENT	OUTSTANDING
Man 01: Sustainable procurement	1	1	1	1	2
Man 02: Responsible construction practices	-	-	-	1	2
Man 04: Stakeholder participation	-	-	-	1 (Building user information	1 (Building user information
Hea 01: Visual comfort	criterion 1 only	criterion 1 only	criterion 1 only	criterion 1 only	criterion 1 only
Hea 04: Water quality	criterion 1 only	criterion 1 only	criterion 1 only	criterion 1 only	criterion 1 only
Ene 01: Reduction of co_2 emissions	-	-	-	6	10

Ene 02: Energy monitoring	-	-	1 (First sub-metering credit)	1 (First sub-metering credit)	1 (First sub-metering credit)
Ene 04: Low or zero carbon technologies	-	-	-	1	1
Wat 01: Water consumption	-	1	1	1	2
Wat 02: Water monitoring	-	criterion 1 only	criterion 1 only	criterion 1 only	criterion 1 only
Mat 03: Responsible sourcing	criterion 3 only	criterion 3 only	criterion 3 only	criterion 3 only	criterion 3 only
Wst 01: construction waste management	-	-	-	-	1
Wst 03: Operational waste	-	-	-	1	1
LE 03: Mitigating ecological impact	-	-	1	1	1

Table 2: Minimum standards by BREEAM rating level (credits)(BREEAM, 2011a)

These are minimum acceptable levels of performance and so should not be taken as levels that are representative of best practice for a BREEAM rating level.

4.3 Environmental section weightings

Environmental weightings are fundamental to any building environmental assessment method as they provide means of defining, and therefore ranking, the relative impact of environmental issues.

Environmental section	**Weighting**
Management	12%
Health & Welbeing	15%
Energy	19%
Transport	8%
Water	6%
Materials	12.5%
Waste	7.5%
Land Use & Ecology	10%
Pollution	10%
Total	100%
Innovation (additional)	10%

Table 3: Environmental section weightings(BREEAM, 2011a)

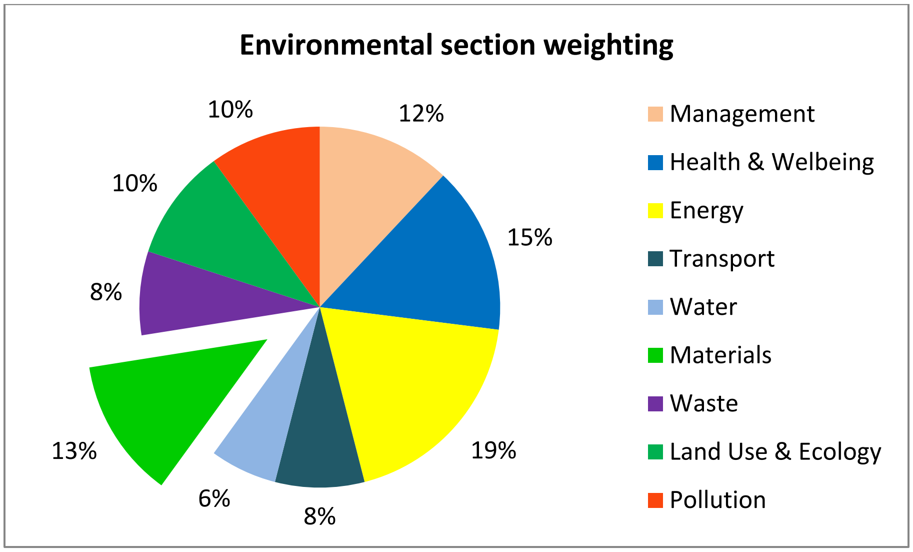

Figure 1: Environmental section weighting chart based on the table 3

Each of the above environmental sections consists of a differing number of assessment issues and accordingly has different BREEAM credits. As a result, each individual assessment issue and credit varies in terms of its contribution to a building's overall score.

4.4 MATERIALS

Materials make up one of the most important composition of building construction and hence have a significant contribution to the life cycle impacts of a building. Materials in BREEAM have in total 12.5% weighting which is the third highest among the environmental sections. This has been distributed into different sub headings as: (BREEAM, 2011a)

Title	**Available credits**
Life cycle impacts	4
Hard landscaping and boundary protection	1
Re-use of Façade	1
Re-use of Structure	1
Responsible sourcing of materials	3
Insulation	2
Designing for robustness	1
Total	13

Table 4: Criteria considered in materials(BREEAM, 2011b)

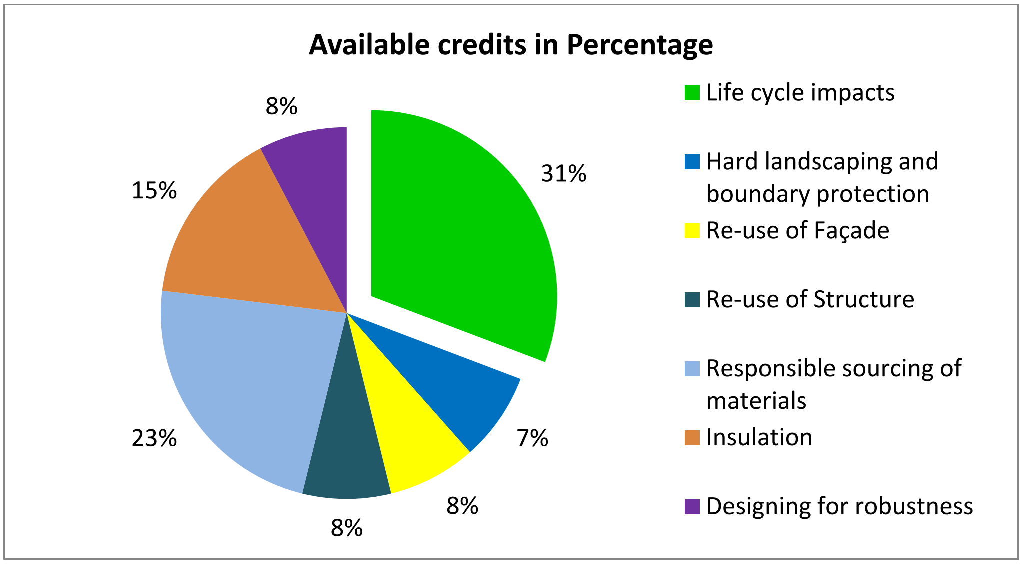

Figure 2: Available credits in Percentage based on table 4

From table-4 and figure-2, it is clear that life cycle impacts section has the highest available credits and is the most important issue under the section – material. As a result, a building using materials which has very little negative impact to the environment is likely to score more. Besides, re-use of materials, materials like timber from responsible source and using materials that last long is encouraged.

4.5 Life Cycle Impacts

This section examines the environmental impacts due to material use in buildings during its life cycle and the allocation of credits accordingly. In addition, it also examines if BREEAM recognizes and encourages the use of construction materials with a low environmental impact (including embodied carbon) over the full life cycle of the building. There are four credits available under this title (BREEAM, 2011a).

4.5.1 Assessment Criteria

BREEAM awards credits on the basis of the building's quantified environmental life cycle impact through assessment of the main building elements as in the table below (BREEAM, 2011a).

Building Type	**Element Type Assessed**					
	External walls	Windows	Roof	Upper floor slab	Internal walls	Floor finishes/coverings
Office	yes	yes	yes	yes	-	yes
Retail	yes	yes	yes	yes	-	yes

Industrial	yes	-	yes	-	-	-
Education	yes	yes	yes	yes	yes	yes
Healthcare	yes	yes	yes	yes	yes	yes
Prisons	yes	-	yes	yes	-	yes
Courts	yes	yes	yes	yes	yes	yes
Multi-residential	yes	yes	yes	yes	yes	yes
Other buildings	yes	yes	yes	yes	yes	yes

Table 5:Building type and element assessed (BREEAM, 2011a)

Credits are awarded on the basis of the total number of points achieved as set out in the table below and calculated using the BREEAM Mat 01 calculator. The point's score is based on the Green Guide ratings achieved for the specifications that make-up the main building elements.

	Total Mat 01 points achieved						
Points	2	4	5	8	10	12	14
Building Type	available BREEAM credits						
Office	1	1	2	3	4	5	-
Retail	1	1	2	3	4	5	-
Industrial	1	2	-	-	-	-	-
Education	1	1	2	3	4	5	6
Healthcare	1	1	2	3	4	5	6
Prisons	1	1	2	3	4	-	-
Courts	1	1	2	3	4	5	6
Multi-residential	1	1	2	3	4	5	6
Other buildings	1	1	2	3	4	5	6

Table 6: Building Type and available credits(BREEAM, 2011a)

Where an independently verified third-party Environmental Product Declaration (EPD), covering part of or the whole life cycle, is available for a material that forms part of an assessed building element, this can be used to increase the contribution of that element to the building's Mat 01 performance. EPD is defined as environmental label or environmental declaration as a claim which indicates the environmental aspects of a product or service. BRE's Environmental Profile Methodology and Green Guide to Specification is an example of and EPD (BREEAM, 2011a).

Life cycle green house gas emissions (kgCO_2 eq.) for each element are also required to be reported based on a 60-year building life. Where specific date is not available for a product or element, generic date should be used. Generic data can be obtained from the online Green Guide for each element and must be entered in to the BREEAM Mat01 calculator (BREEAM, 2011a).

4.5.2 Exemplary level criteria

Where assessing four or more applicable building elements, the building achieves at least two points additional to the total points required to achieve maximum credits under the standard BREEAM criteria. However when the building elements are less than four, the building achieves at least two points additional to the total points required to achieve maximum credits under the standard BREEAM criteria (BREEAM, 2011a).

4.5.3 Green Guide to Specification (GGS)

The Green Guide(Breglobal, 2011) is a part of BREEAM and contains more than 1500 specifications used in various types of buildings. The environmental rankings are based on Life Cycle Assessments (LCA) using BRE's Environmental Profiles Methodology 2008.The elements covered are external walls, internal walls and partitions, roofs, ground floors, upper floors, windows, insulation, landscaping and floor finishes. The date is set out as an A+ to E ranking system where A+ represents the best environmental performance, ie., least environmental impacts and E the worst environmental performance/most environmental impact. BRE has provided a summary environmental rating – The Green Guide rating, which is a measure of overall environmental impacts which cover issues like climate change, water extraction, mineral resource extraction, stratospheric ozone depletion, human toxicity, ecotoxicity to freshwater, nuclear waste (higher level), ecotoxicity to land, waste disposal, fossil fuel depletion, eutrophication, photochemical ozone creation and acidification.

By evaluating the performance of materials and building systems against these specific environmental impacts, which have also been ranked on an A+ to E basis, it is possible to select specifications on the basis of personal or organizational preferences or priorities, or take decisions based on the performance of a material against particular environmental impact. Perceptions regarding best environmental practice are subject to change as our understanding increases and a clear consensus regarding what is most important and practically achievable emerges. Due to the potential environmental impacts from the production, use and disposal of building materials has grown, many designers, property owners and other construction professionals have sought to take a more environmentally responsible approach to the selection and specification of materials (Breglobal, 2011).

Figure 3: Green guide to specification (Breglobal, 2009)

In GGS, the environmental rankings are based on life cycle assessment studies of environmental impacts. Materials and components are presented in their typical, as built elemental form. They are compared on a like-for-like basis, for 1m^2 of construction, as components that fulfil the same or vary similar functions; important variables such as the mass of a material required to fulfil a particular function are therefore taken into account. For example, a direct comparison between the environmental profile of 1 tonne of structural steel and 1 tonne of structural concrete would be misleading, as less steel would be required to achieve the same structural performance (Anderson et al., 2002).

Materials and components are arranged on an elemental basis: external wall construction, internal walls, floor finishes, etc. So that designers and specifiers can compare and select from comparable systems or materials as they compile their specification. Furthermore, it is meaningless to compare the environmental profiles of, say, concrete floors and a particular type of paint; ratings are therefore based only on product performance within each respective element group (Anderson et al., 2002).

GGS can be used within BREEAM to assess the credits for materials specification. It is also one of a suite of tools produced by BRE which provide guidance to designers and specifiers on the environmental impacts of building and their construction materials (Anderson et al., 2002). However, a defined set of criteria seems missing on how the elements have been rated as A+ to E. It is the element and not a single material that has been rated, which of course give rise to questions like what if a particular material is missing in the element we choose; how will we rate this element?

4.5.4 Calculation Procedure

The calculation procedure is used to determine the number of BREEAM credits achieved as a result of each element's Green Guide rating. The green guide uses an A+ to E rating system to rate the materials. These ratings relate to the relative life cycle performance of a specification in comparison with other types of specifications available for a particular building element type(BREEAM, 2011a).

1. Translation of Green Guide Rating into points as in the chart below:

Green Guide Rating	Mat 01 Points
A+	3
A	2
B	1
C	0.50
D	0.25
E	0

Table 7: Green Guide Rating and corresponding points(BREEAM, 2011a)

The maximum number of points available for an assessed building is a product of the number of elements assessed multiplied by three. For example, for a commercial building if 5 elements are assessed, there are a maximum of 15 points available; furthermore twelve of those fifteen points must be achieved to award all five BREEAM credits. However, the actual maximum number of points available for a particular element will depend on the impact of the element type compared with the other elements present and assessed. This is because the issue assesses the life cycle impact of the whole building, taking in to account the relative performance and therefore contribution of the main building elements towards the building's overall performance (BREEAM, 2011a).

2. Weighting the performance of individual specifications within an elemental category:

Where an element consists of several different specifications, the overall points achieved for that element are weighted according to the relative area and Green Guide rating of each of the individual specifications as illustrated below for an external wall element consisting of three different types of external wall specification. This adjustment is made to ensure the contribution of points is balanced in accordance with the life cycle performance of each specification (BREEAM, 2011a).

Element Type	Specification	Area (m^2)	% of element type	Generic Green Guide Rating	Points	Area weighted points
External wall	Type 1	300	30	A+	3	0.9
	Type 2	500	50	C	0.5	0.25

	Type 3	200	20	B	1	0.2
Element Total		**1000**	**100**			**1.35**

Table 8: Element type and area weighted points(BREEAM, 2011a)

3. Weighting the performance of individual elements relative to all elements assessed
This is completed in two parts:
i. Weights the performance of the building elements based on its area relative to the overall area of the different elements. This is done by multiplying the area of each element by the weighted Green Guide score, adding the total for all elements and then dividing by the total area of the assessed elements.
ii. The range of impacts, measured using Ecopoints[1], for each of the elements will differ and therefore so will the increments between each Green Guide rating level. (BREEAM, 2011a)

Where a specific Environmental Product Declaration (EPD) is available for a material, the calculation procedure is as illustrated below. The Green Guide online provides design teams and clients with information on the relative life cycle environmental impacts for a range of different building elemental specifications like wall, roof, floor, openings etc. (BREEAM, 2011a)

Green Guide points uplift by EPD type:

Existing Green Guide Rating	**Generic Green Guide rating points**	**EPD Tier 1 max. points uplift**	**EPD Tier2 max. points uplift**
A+	3	1	0.75
A	2	1	0.75
B	1	1	0.5
C	0.5	0.5	0.25
D	0.25	0.25	0.125
E	0	0	0

Table 9: Green guide points uplift by EPD(BREEAM, 2011a)

Example of EPD points uplift calculation for a theoretical external wall specification with a generic Green Guide C rating:

[1] The Ecopoint used in the Green Guide online is single score that measures the total environmental impact of a product or process as a proportion of overall impact occurring in Europe. One hundred Ecopoints is equivalent to the impact of a European Citizen. Green Guide ratings are derived by sub-dividing the range of Ecopints/m^2 achieved by all specifications considered within a building element.

External wall specification	Proportion of element impact	EPD tier	Point uplift
Load bearing concrete cladding	65%	1	0.325
Limestone finish	17%	0	0
Medium density solid block	10%	1	0.05
Plasterboard & paint	5%	2	0.0125
Insulation	3%	0	0
Total point uplift			**0.3875**
Total points achieved for element			**1.3875**

Table 10: EPD points uplift calculation(BREEAM, 2011a)

5 LEED

LEED (leadership in Energy and Environmental Design) (Ebert et al., 2011) is a certification programme which is intended to define high quality, ecological building methods for healthier, more environmentally-friendly and profitable buildings. The aim of the system is to provide building owners and operators with a structured framework to identify and implement practical and measurable solutions for the design, construction, operation and maintenance of sustainable buildings. LEED was developed by the USGBC (U.S. Green Building Council), a non-profit organisation with a motivation for a demand for a system which could be used to assess and compare buildings according to their sustainability. LEED covers all ecological and socio-cultural aspects of sustainability. It focuses mainly on energy and water efficiency, the reduction of CO_2 emissions, a healthy and comfortable indoor climate and the conservation of resources, assesses the building operations as well as the quality of site(Ebert et al., 2011).

The LEED certification is based on a point system, points are awarded for the fulfilment of individual credits. The system divides the predetermined credits into seven categories. The weighting of the categories differs slightly between the rating systems. Apart from the minimum number of points required for the level of LEED certification aimed at, there are so-called prerequisites which must be met(Ebert et al., 2011).

5.1 Credit Weightings and Certification Criteria:

The allocation of points between credits in LEED 2009 is based on the potential environmental impacts and human benefits of each credit with respect to a set of impact categories. The impacts are defined as the environmental or human effect of the design, construction, operation, and maintenance of the building, such as GHG emissions, use of fossil fuel, toxins and carcinogens, air and water pollutants and indoor environmental conditions. A combination of approaches, including energy modelling, life-cycle assessments, and transportation analysis, is used to quantify each type of impact. The resulting allocation of points among credits is called credit weighting. Each credit is allocated points based on the relative importance of the building-related impacts that it addresses (U.S.G.B.C., 2009).

The assessment is based on a point system with only whole points awarded for the fulfilment of the issues considered in the credits. There are no points for meeting the mandatory minimum requirements (Ebert et al., 2011, pg.44). The maximum number of points attainable depends on the project type for eg, LEED-NC (new construction) the maximum points achievable is 69(Ge, 2011) while for LEED-EB (existing building) it is 92 (Houlihan Wiberg, 2009) .In relation to this, the certification levels LEED certified, silver, gold, and platinum are awarded.

LEED rating benchmarks (New Construction, Core & Cell and Schools)
100 base points; 6 for Innovation in Design and 4 for Regional priority.

LEED Rating	**Points**
Certified	40-49
Silver	50-59
Gold	60-79
Good	80 and above

Table 11: LEED rating benchmarks(U.S.G.B.C., 2009)

5.2 Categories and Minimum standards:

A project, in order to eligible for certification under LEED, a minimum program requirement set by LEED to be compiled with.

Categories	**Prerequisite**
Sustainable Sites (SS)	i. Construction activity pollution prevention ii. Environmental Site Assessment*
Water Efficiency (WE)	Water use reduction
Energy and Atmosphere (EA)	i. Fundamental commissioning of building energy systems ii. Minimum energy performance iii. Fundamental Refrigerant management
Materials and Resources (MR)	Storage and collection of recyclables
Indoor Environmental Quality (IEQ)	i. Minimum Indoor Air Quality Performance ii. Environmental tobacco smoke (ETS) control iii. Minimum Acoustical Performance*

Table 12: Categories and minimum standards (U.S.G.B.C., 2009)

*Credit not applicable to all Rating Systems

5.3 MATERIALS AND RESOURCES:

The category incorporates recycling during the construction phase and the development of a recycling concept for the duration of the building's useful phase. Due to the statutory requirements and the cost saving that can be achieved through recycling, a recycling rate of 75% for construction waste can be achieved for projects in Germany, all quantities of waste must be recorded and registered. A central site waste management system simplifies this process considerably. The second focus of this category is on the reuse of existing building components and the selection of materials with a large proportion of recyclable of regional material (Ebert et al., 2011).

5.4 Life cycle-oriented design process

The involvement of competent partners and specialists is necessary from the very beginning of a project in order to deal with aspects such as comfort, energy efficiency, environmentally friendly technologies and the smooth commissioning and operation of the building. Additional and increasing requirements in relation to building services, safety and security, material efficiency and barrier-free access influence the design. At the same time, it is necessary to provide and adhere to reliable cost plans for the construction and operation of the building. Alongside the design of a property, it is therefore necessary today to plan and control the construction process and to consider the entire life cycle of the project from day one. The consideration of the life cycle is gaining considerable importance in the assessment and certification of sustainable buildings. The service life of a property can naturally never be determined in advance and the assessment is therefore based on average values, which vary according to the building type and selected construction materials (Ebert et al., 2011).

In a lifecycle analysis, reference projects are used to determine and calculate the expected effects of ageing and depreciation over the entire service life of the building. As part of this for example, strategies for renovation and conversion are considered from the very beginning in an attempt to eliminate or cushion the effects of any future problems which may arise. The life cycle of a building is structured according to the following phases:

Product phase (products and building)

Utilisation phase (Operation and upkeeping)

End-of-life phase (deconstruction) (Ebert et al., 2011)

5.5 Certification and life cycle

The early phases of the design process, in particular, have a considerable impact on the appearance, the costs, the total life cycle and the ability of a building to meet future needs. The first service phases of a building, the brief, the preliminary design and the final design, are the most important for the implementation of sustainability objectives in building. The greatest potential to optimise the building in terms of sustainability is in these early design phases. This applies particularly to the influence that can be exerted on costs, construction, materials and the concepts for energy efficiency and building operation (Ebert et al., 2011)

Life Cycle Analysis (LCA)

Upto now, a life cycle analysis (LCA) is only a requirement for the latest BREEAM (Ebert et al., 2011). LEED admittedly makes some provisions for materials, i.e. certain environmental aspects have to be considered within a LEED certification as below:
The implementation of low-emitting materials (VOC)
Reuse of building components and the implementation of recycled materials
The Use of Regional materials
The use of certified timber products

These requirements however, refer, exclusively to the choice of material and not to the total life cycle of the building. In order to establish the idea of a life cycle approach in the assessment process and to develop a uniform national standard for the life cycle analysis in the context of LEED certification, the USGBC set up a work group in 2004 and started with a pilot credit (test criterion) in 2009, However, a uniform national basis has not yet emerged (Ebert et al., 2011).

In BREEAM, the life cycle assessment is dealt with in the category " Materials" Mat1. The results of the LCA are assessed in 13 criteria according to predetermined component catalogues and environmental databases. Aspects of relevance range from green-house gases and eutrophication to acidification. The results are expressed in units such as kg CO_2 equivalent and then transformed into the categories A+, A, B to E for the BREEAM assessment. To date, the life cycle analysis only refers to the construction materials implemented in the respective building. Further life cycle phases, such as the operation (energy demand and upkeep) or the demolition are not yet considered (Ebert et al., 2011).

Environmental life cycle assessment can not only quantify the environmental burden caused by buildings, but can also show reduction measures. Discussion on reducing the building's EB is mainly concentrated on the use of recycled materials, prolongation of service life, and selection of low or non-pollution energy systems, etc., and does not include the effects of the location and structural form of the building etc(Li, 2006).

In order to really appraise the overall environmental impacts of buildings, all the life cycle stages should in fact be encompassed by also including the embodied energy and environmental interventions related to the construction materials, construction activities, dismantling operations and the end of life of the materials.

6 LEED and BREEAM Material rating comparison chart

LEED	Points	Mandatory
Storage and collection of recyclables	Mandatory	yes
Building Reuse-maintain existing walls, floors, and roof	1 to 3	
Building Reuse- maintain interior non-structural elements	1	
Construction waste management	1	
Materials reuse	1 to 2	
Recycled content	1 to 2	
Regional materials	1 to 2	
Rapidly renewable materials	1	
Certified wood	1	
BREEAM	**Credits**	
Life cycle impacts	2 to 6	
Hard landscaping and boundary protection	1	
Re-use of Facade	1	
Re-use of Structure	1	
Responsible sourcing of materials	3	Criteria 3
Insulation	2	
Designing for robustness	1	

Table 13: LEED and BREEAM Material rating comparison chart based on the information above

In the table above, LEED has included 'storage and collection of recyclables' and 'construction waste management under 'materials'. Since these are more to do with wastes than materials, I personally feel that they should be included under 'waste' as in BREEAM. But in my opinion this must have been done to encourage the use of recycled materials. As the concern over environmental impacts of the construction sector grows, more attention is being paid to those building materials that prove to be more environmentally friendly, namely materials that better meet twofold objective of reducing both consumption of non-renewable resources and general pollution throughout their entire life cycle. In such a context, secondary materials from demolition and building waste recycling deserve interest (Gian Andrea, 2009).

LEED has also emphasized building reuse as of maintaining existing walls, floor and roof and maintaining non-structural element in order to extend the life cycle of existing building stock. Points have been awarded in 'reuse of materials' in order to reduce the demand for virgin materials. To reduce emissions from transportation, use of local material is encouraged.

In case of BREEAM material, 'life cycle impacts' is much emphasized and credited which is not the case in LEED. Even for the specification of materials for boundary protection and external hard surfaces, low environmental impact is considered, taking into account the full life cycle of the materials used. Insulation which is not taken into consideration in LEED is awarded two credits in BREEAM when these have low embodied environmental impact relative to its thermal properties and has been responsibly sourced. 'Designing for robustness' is basically to protect the outdoor element of the building so that they last long and reduce the demand for virgin materials.

So, comparing the materials for environmental assessment; BREEAM comparatively has more diversification and has emphasized life cycle impacts of materials much more. It has also made 'responsible sourcing of material' as a mandatory criteria for achieving BREEAM certification.

7 ANALYSIS AND CONCLUSION

BREEAM in its latest edition have elaborately taken up issues related to life cycle impacts of materials. As described above, it is the Green Guide to Specification that specifies different materials by analysing the materials as per their life cycle impacts and accordingly credits are awarded in BREEAM. As such this specification is fundamental for BREEAM to award credits. In case of LEED, there is not a defined or specific category to look into the life cycle impacts of materials. However, it is given emphasis in a number of other categories such as recyclable materials, building and material reuse.

In these certification systems, life cycle impact is not a mandatory criterion for eligibility towards achieving credits and certification. Therefore, achieving certification doesn't necessarily mean that a project has low adverse impacts to the environment. Since, the contribution of building sector to global warming is around 40%, the objective of building certification should be to provide an award to a building that it has good environmental performance. Accordingly, we should expect that BREEAM / LEED certified buildings have low embodied carbon to the environment. However, this is not always true even though these certification systems have been able to address many issues relating to sustainable and green architecture. This is mainly because issues related to life cycle impacts are not mandatory to be fulfilled. Hence, it is likely that the buildings may be BREEAM or LEED certified without them actually performing well in favour of the environment. So, I am not fully convinced that these certification systems are really guiding to use materials with less embodied carbon in buildings.

Problem also arises in case a designer uses a material that is actually 'green' but is not specified. It is not intended to buy 'green' products/materials all the way from the UK or USA to build a certified house in some parts of Asia. A building is actually not 'green' even though it uses certified materials transported from so far a place owing to the emissions in transportation. There must be possibilities to use local 'green' materials and certification systems like BREEAM and LEED must be able to pave a way out in certifying buildings using such materials that are actually not listed. With the flexibility in use of materials that are environmental friendly in their entire life cycle in buildings anywhere around the globe, the reliability and credibility of these certification systems will boost even further.

References:

Anderson, J., Shiers, D. E. & Sinclair, M. 2002. *The Green Guide to Specification: An Environmental Profiling System for Building Materials and Components* [Online]. Available: http://onlinelibrary.wiley.com/book/10.1002/9780470690666;jsessionid=C172503209DAB609F47533C281A629CE.d02t02 [Accessed 19 November, 2011], pp.2-30.

Andrae, A. S. G. 2010. *Global Life Cycle Impact Assessments of Material Shifts* [Online]. Available: http://books.google.no/books?id=JF0xdOgpf88C&pg=PA24&dq=definition+of+LCA&hl=en&ei=q0fiTsWLPKLm4QT1s_2cBQ&sa=X&oi=book_result&ct=result&redir_esc=y#v=onepage&q=definition%20of%20LCA&f=false [Accessed 29 November, 2011].

BREEAM. 2011a. *BREEAM New Construction* [Online]. BRE Global Limited. Available: http://www.breeam.org/page.jsp?id=109 [Accessed 15 October, 2011], pp.13-31, 230-273.

BREEAM. 2011b. *Pre-assessment estimator* [Online]. Available: http://www.breeam.org/page.jsp?id=87.

Breglobal. 2009. *The Green Guide to Specification: Flooring and Internal Partitioning* [Online]. London. Available: http://www.bre.co.uk/filelibrary/greenguide/presentations/Presentation_SurfaceDesignShow_Feb09_FlooringInternalPartitioning.pdf [Accessed 17 November, 2011.

Breglobal. 2011. Available: http://www.bre.co.uk/greenguide/page.jsp?id=2069 [Accessed 14 November, 2011.

Deloitte. 2009. *Life Cycle Assessment: Where is it on your sustainability agenda?* [Online]. Available: http://www.deloitte.com/assets/Dcom-UnitedStates/Local%20Assets/Documents/us_es_LifecycleAssessment.pdf [Accessed 12 November, 2011.

Ebert, T., EBig, N. & Haurer, G. 2011. *Green Building Certification Systems* pp.30-121.

Ge, T. 2011. *LEED Certification & Case Study in GEL.* Shanghai Jian Tong University.

Gian Andrea, B. 2009. Life cycle of buildings, demolition and recycling potential: A case study in Turin, Italy. *Building and Environment* [Online], 44. Available: http://www.sciencedirect.com/science/article/pii/S0360132308000450 [Accessed 2 November, 2011], pp.319-330.

GreenBookLive. *What is BREEAM?* [Online]. Available: http://www.greenbooklive.com/search/scheme.jsp?id=8 [Accessed 18 October, 2011.

Houlihan Wiberg, A. A.-M. 2009. *An Analysis of the Performance of Certification Schemes in the Hotel Sector in terms of CO_2 Emissions Reduction.* PhD, Cambridge.

Li, Z. 2006. A new life cycle impact assessment approach for buildings. *Building and Environment* [Online], 41. Available: http://www.sciencedirect.com/science/article/pii/S0360132305001903 [Accessed 5 November, 2011], pp.1414-1422.

U.S.G.B.C. 2009. *Green Building Design and Construction, LEED Reference Guide for Green Building Design & Construction,* USA, pp.i-xiv, 335-400.