# CONSOLIDATION OF MATERIAL AND WASTE MANAGEMENT PARAMETERS FOR DEVELOPMENT OF SUSTAINABLE BUILDING RATING SYSTEMS

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**ABSTRACT**

*Material and waste are important categories as they constitute of more than 60% of the project cost. Building construction and operation is the major sources of waste across human activities. Extraction, processing and distribution of materials leads to GHG emission. Excess consumption of material leads to waste generation and consequently GHG emission. Material consumption and waste generation cannot be separated from construction project, building operation and refurbishment. They can only be reduce and their consumption and generation efficiency be increase. Therefore, having appropriate parameters for assessing the distribution and conservation of material is highly important. The study aim at determining the appropriate parameters for material and waste in green building assessment. This can be achieved by consolidating parameters that will universally covers material and waste management in the assessment of sustainable building life cycle. Eleven rating systems and some selected rating tools within them were reviewed. Specifically, the study elaborate on material and waste category and the extent of parameters and points allocation. The study also review the parameters by considering their measurability, preference, prevalence, relevance and adaptability of parameter to suit the universal concept of sustainable building assessment. Material and waste parameters distribution and points allocation show the variability of the rating systems and their tools in assessing the sustainability of their environment. The study consolidated parameters divide the building life cycle in to strategies for conserving material. The other is appropriate waste management during design, construction and operation phase. They also cover estimation of the building carbon footprint from the embodied energy of the material used and waste generated. The other division is the overall carbon footprint reduction during the period of building operation. The study and the parameters can be important in further research activities and to organisations and countries in developing a new rating systems and tools. Through easier distribution of parameters and points allocation to material and waste category.*

**Keywords:** Assessment, Material and Waste, Rating Tools, Sustainability and Environment.

## 1. INTRODUCTION

Earth provides enough to satisfy everyman's need but not enough for any man's greed. The greediness of human always leads to wastage. All the materials or products have embodied energy from the considerable energy consumed during their productions. These energy comes from fossil fuels responsible for greenhouse gases and climate change. Therefore wastage of such materials and products thus lead to wastage of energy (Soni, 2016; Usman and Abdullah, 2018).

Sustainable building is a building that utilises less water, optimizes energy efficiency, conserves natural resources, consumes less material during construction and generates less waste during construction, operation and refurbishment and provides healthier spaces for occupants (Hedaoo and Khese, 2016). It also involve designing concept that reduces the environmental impact of buildings through innovative land use and construction strategies. Depending on the magnitude of sustainable measures adopted during construction for sustainable operation, appropriate weighing is awarded called points or credits depending on the terms used by the sustainable building rating system. After an appropriate point's allocation, a total score of points assign to each parameters and categories determine the rating of the building. A building that passes through this process (assessment process) is referred to sustainable or green building.

The step by step of these processes and weighted factors (categories and parameters) are documented in a report as paper work or computer programme that is generally called assessment or rating tools. A combination of these rating tools for given country is called rating Systems or systems which can be used interchangeably in this study. These rating systems are developed by government parastatals, green building council (GBC) of the respective country or relevant organisation. The first of this kind of document was developed by the United Kingdom Building Research and Establishment (BRE) who in 1992 published the Building Research Establishment Environmental Assessment Method (BREEAM). This is followed in 1996 by BEAM Hong Kong and LEED United State and subsequently Green Star Australia, NZ and SA, CASBEE Japan, Green Mark Singapore.

This study consider some selected eleven rating systems around the world. This is to determine the extent of material and waste consideration in assessing the sustainability of buildings and its immediate environment. These review is part of the series of research toward development of greenhouse gas emission assessment tool for building. This review help in identifying the most important parameters that will fully covers the building life cycle material consumption and waste generation.

Material consumption in the building industries make building the most important in sustainable of the environment as its construction constitute of about 60% of raw material cost. So reducing the consumption of construction material definitely reduce the overall construction cost (Wu and Chen, 2015). Proper control of construction and operation waste will also reduce landfill waste and consequently reduce LFG.

Green building concept is an integrated approach of layout of the building, architecture, engineering, landscaping/horticulture, maintenance and housekeeping etc. These includes sustainability criterion on site design, water conservation and quality, energy and environment, conservation of materials and resources, and indoor environmental quality. Hence, the concept revolves around conservation of energy, material, utilisation of waste materials and waste water to save depleting conventional resources for sustainable development, simultaneously ensuring building internal comfort (Adegbile, 2013; Hedaoo and Khese, 2016; Soni, 2016).

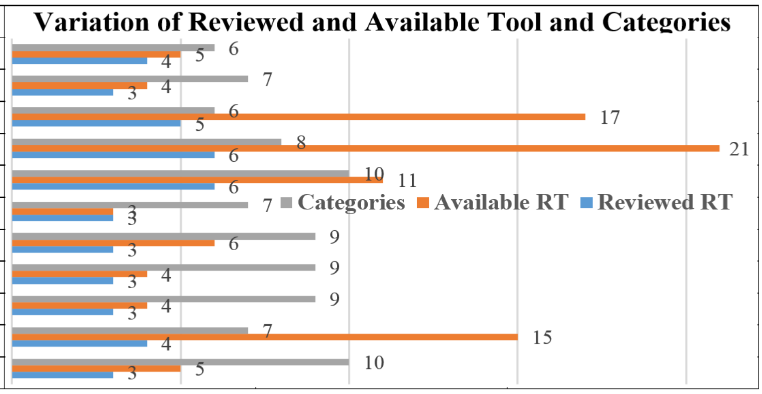
Hence this study revolve around the sustainable building rating systems and tools to determine the appropriate parameters that universally cover material and waste in sustainable building assessment. The consolidation will also cover the GHG emission during the building life cycle in relation to material consumption and waste generation.

## 2. REVIEWED RATING SYSTEMS SUMMARY

For the study eleven rating Systems and their respective tools were selected across the regions around the world and reviewed. The summary of this Systems and their tools are shown in the following Figure 1.

Figure 1; Summary of the Rating Systems as well Their Tools and Categories

| SBRS | Country |
|---|---|
| GreenShip | Indonesia |
| GreenRE | Malaysia |
| GBI | Malaysia |
| LEED | United States |
| India GBC | Indian GBC |
| BEAM | Hong Kong |
| GreenStar | South Africa |
| GreenStar | New Zealand |
| GreenStar | Australia |
| GreenMark | Singapore |
| BREEAM | United Kingdom |




Source: Individual Sustainable Building Rating Systems

Several research were carried out to compare some rating systems around the world. The major problems of the Systems is their differences in approach toward assessing the sustainability of their environment. These together with other reason give rise to discrepancies in the review for comparison from other researchers. Some rating Systems assesses the building life cycle from community, new construction, in-use, refurbishment and Infrastructure as in Breeam and Green Star Australia. Other assess building life cycle from residential and non-residential new and existing building. The Systems that uses these approach are Green Mark and GreenRE. The other Systems consider different type of building as separate rating tool among which are GreenShip, Green Star NZ and SA and GBI Malaysia. The BEAM consider building life cycle as new and existing building only while LEED consider it from New, existing, interior and neighbourhood rating tools. These lead to difficulties in selecting a specific type of rating tool that cut across several rating systems for easier comparison. Hence this study consider average parameters and points allocation across selected rating tools in the reviewed rating systems.

## 3. CATEGORIES CONSIDERATION

Different rating systems and tools considered different categories with different names. These categories were sub-divided in to parameters and sub-parameters. Depending on the need of each country, the categories, parameters and points allocation ware given different perspective and consideration. The summary of considered categories with the variation of percentage of parameters and points allocation to each of the selected categories in the reviewed rating systems are describe in previous study and presented in a conference (Usman, *et al,* 2018; Usman and Abdullah, 2018a). This is to describe the consideration of most important categories in the rating systems of which the material and waste category was seen to have appreciable consideration.

The rating systems consider several parameters and allocated several number of points for each of the categories considered. The variation of percentage point's allocation to a number of parameters in the material and waste category against the other parameters and points are describe in (Usman and Abdullah, 2018). To cover the overall building LCA, the other important categories are discussed in our previous and future studies such as Usman, *et al,* (2018). This is among the series of study in research on building life cycle GHG emission assessment.

## 4. MATERIAL AND WASTE CATEGORY REVIEW

The parameters consideration signifies coverage of that category in the sustainability of built environment in the country while the point's allocation defines the extent and significance of that parameters in the determining of the sustainability of built environment. The following discussion will describe the parameters consideration and point's allocation to Material and waste in the sustainable building rating systems.

### 4.1 GREEN SHIP INDONESIA

GreenShip is an assessment rating systems having about five rating tools developed between 2010 to 2015 in Indonesia by an independent organisation established in 2009 called the green building council Indonesia (GBC Indonesia 1, 2016). The rating systems consider building life cycle in the following arrangement: New Building (NB) (2010), Existing Building (EB) (2011), Interior Space (2012), Homes (2014) and Neighbourhood (2015) (GBC Indonesia 2, 2015). For comparability of material aspect of the rating tools, three rating tools were considered which are the new building, the existing building and the homes. Material and cycles as it is named in the rating systems, is considered in all the three rating tools with varying number of parameters as shown in Table 1. The waste parameters were considered in the material resources and cycle category (GreenShip, 2016).

Table 1; Parameters Allocated to GreenShip Rating System's Tools

| Parameters | NB | EB | Homes | Total | Average |
|---|---|---|---|---|---|
| Non ODP Refrigerant | - | - | 1 | 1 | 1 |
| Material Purchasing Practice | - | 3 | - | 3 | 3 |
| Reused & Management Material | 2 | 1 | 1 | 4 | 1 |
| Environmental Friendly Source Material | 3 | - | 2 | 5 | 3 |
| Environmental Friendly Process Material | - | - | 1 | 1 | 1 |
| Non ODS Usage | 2 | 2 | - | 4 | 2 |
| Certified Wood | 2 | - | 1 | 3 | 2 |
| Waste Management Practice | - | 4 | - | 4 | 4 |
| Prefabricated Material | 3 | - | 2 | 5 | 3 |
| Hazardous Waste Management | - | 2 | - | 2 | 2 |
| Local or Regional Material | 2 | - | 2 | 4 | 2 |
| Carbon Footprint | - | - | 1 | 1 | 1 |
| **Total** | **14** | **12** | **11** | **37** | **24** |

Source: (GreenShip, 2016; Usman and Abdullah, 2018)

### 4.2 BEAM HONG KONG

Beam is a rating systems developed in Hong Kong in 1996 initially by the Real Estate Association of Hong Kong (REDA) in collaboration of research by the Hong Kong Polytechnic University and the assessment conducted by the Centre of Environmental Technology Limited (CET). The first two rating tools are launched in 1996 for new and existing air conditioned offices. The beam divides building life cycle in to new (NB) and existing building with the existing being subdivided in to comprehensive (EBC) and selective (EBS) ratings tools (BEAM Plus, 2017). The review consider only three of the rating tools as material and waste aspect and is considered in all the three rating tools and the distribution of parameters and their points allocation are shown in Table 2.

Table 2; Parameters and Points Allocation to Material and Waste Aspect

| Parameters | EBS | EBC | Parameters | NB |
|---|---|---|---|---|
| Materials Purchasing Plan | 3 | - | Building Reuse | 3 |
| Materials Purchasing Practice | 20 | 6 | Modular and Standardised Design | 1 |
| Ozone Depilating Substances | 4 | 3 | Prefabrication | 2 |
| Waste Management Plan | 3 | 1 | Adaptability And Deconstruction | 3 |
| Basic Waste Recycling Facilities | 3 | - | Rapidly Renewable Materials | 2 |
| Recycling Facilities for Wastes | 6 | 4 | Sustainable Forest Products | 1 |
| Food Waste Management | 4 | 2 | Recycled Materials | 3 |
| Waste Treatment Equipment | - | 1 | Ozone Depleting Substances | 2 |
| Action to waste Reduction | 7 | 5 | Regionally Manufactured Materials | 2 |
| Used of certified Green Product | - | 2 | Demolition Waste Reduction | 2 |
| Promotional Programme | 2 | - | Construction Waste Reduction | 2 |
| Innovative Technique | 2 | - | Waste Disposal Facilities | 1 |
| **Total** | **54** | **24** | | **24** |

Source: (BEAM Plus, 2017; Usman and Abdullah, 2018)

### 4.3 LEED UNITED STATES

LEED rating systems was developed by the US GBC in 1996. US GBC is a non-governmental organisation established in 1993 to promote sustainability and focused it practices in the building and construction industries (Kshirsagar *et. al*, 2015; USGBC, 2016; Hedaoo and Khese, 2016). The systems consider building life cycle from building design and construction (LEED BD+C), Existing Building Operation and Maintenance (LEED EBO+M), Building interior design and construction (ID+C) and Neighbourhood development (LEED ND) (LEED, 2017). The review consider among others the new construction, existing building (shell and core, hotels, schools and hospitals) rating tools. The distribution of parameter and point for the rating tools are shown in Table 3

Table 3; Parameters and Points Allocation to Materials and Resources in LEED

| Parameters | NC | EB | SC | Hotel | Hospital | School | Average |
|---|---|---|---|---|---|---|---|
| Building Life-Cycle Impact Reduction | 5 | 2 | 6 | 5 | 5 | 5 | 4 |
| Environmental Product Declarations | 2 | - | 2 | 2 | 2 | 2 | 2 |
| Sourcing of Raw Materials | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Material Ingredients | 2 | - | 2 | 2 | 2 | 2 | 2 |
| Construction and Demolition Waste | 2 | 4 | 2 | 2 | 2 | 2 | 2 |
| Mercury, Lead, Copper Reduction | - | - | - | - | 3 | - | 3 |
| Furniture and Medical Furnishing | - | - | - | - | 2 | - | 2 |
| Design For Flexibility | - | - | - | - | 1 | - | 1 |
| **Total** | **13** | **8** | **14** | **13** | **19** | **13** | **19** |

Source: (LEED, 2017; Usman and Abdullah, 2018)

### 4.4 GREEN STAR NZ

Green Star was developed in New Zealand by the NZ GBC established in 2005 dedicated to accelerating the development and adoption of market-based green building practices (Adegbile, 2013; Green Star NZ, 2016). The first rating tool was developed in 2007 for assessing office buildings. Later in 2009 this office building rating tool was reviewed and launched together with rating tools for schools, interior and industries. The review process of this systems consider only three of the tool which are the office, schools and the industrial rating tools. The material is considered in all the rating tools. The parameters and points distribution are shown in Table 4.

Table 4: Parameters and Points Distribution for Rating Tools in Green Star NZ

| Parameters | Office | Industrial | Education | Average |
|---|---|---|---|---|
| Shell and Core or Integrated Fit out | 3 | 3 | - | 3 |
| Building Reuse | 4 | 4 | 4 | 4 |
| Sustainable Materials | 5 | 5 | 5 | 5 |
| Low Emitting Materials | 5 | 5 | 5 | 5 |
| Timber | 3 | 3 | 3 | 3 |
| Concrete and Aggregate | 3 | 3 | 3 | 3 |
| Steel | 3 | 3 | 3 | 3 |
| Recycling Waste Storage | 1 | 1 | 2 | 1 |
| Furniture | - | - | 5 | 5 |
| Waste Management | 3 | 3 | 3 | 3 |
| **Total** | **30** | **30** | **34** | **35** |

Source: (Green Star NZ, 2016; Usman and Abdullah, 2018)

### 4.5 GREEN STAR SOUTH AFRICA

Green Star SA was developed in South Africa with the establishment of GBC SA in 2007. The rating systems currently developed seven rating tools for multi-unit residential, office, public and education, retail centres, existing buildings and socio economic aspect and the new building rating tools. These tools covers a wide range of building types such as community centre, libraries, court building public transport terminals etc. (Green Star SA, 2014). The review of this rating systems cover the four of the tools which are the multi-rise residential, office, public and education and retail centre buildings. The distribution of the parameters and pints are shown in the following Table 5 (Green Star SA, 2014).

Table 5; Parameters and Points Distribution for Material in Green Star SA

| Parameters | MRB | Office | PEB | Retail | Average |
|---|---|---|---|---|---|
| Recycling Waste Storage | 2 | 2 | 3 | 2 | 2 |
| Building Reuse | 5 | 5 | 5 | 5 | 5 |
| Recycled Content & Reused Materials | 3 | 1 | 2 | 1 | 2 |
| Shell and Core Integrated Fit out | - | 1 | - | - | 1 |
| Concrete | 3 | 3 | 3 | 3 | 3 |
| Steel | 3 | 3 | 3 | 3 | 3 |
| PVC Minimisation | - | 1 | - | 1 | 1 |
| Sustainable Timber | 2 | 2 | 2 | 2 | 2 |
| Design For Disassembly | - | 1 | 1 | 1 | 1 |
| Dematerialisation | 2 | 1 | 1 | 1 | 1 |
| Local Sourcing | 2 | - | 2 | 2 | 2 |
| Efficient Dwelling Size | 1 | - | - | - | 1 |
| Masonry | 2 | - | 2 | - | 2 |
| Waste Recycling and Management | 3 | 3 | 3 | 6 | 4 |
| **Total** | **28** | **23** | **27** | **27** | **29** |

Source: (Green Star SA, 2014; Usman and Abdullah, 2018)

### 4.6 GBI MALAYSIA

Green Building Index (GBI) was the first Malaysian green building rating systems developed by MGBC in collaboration with the Association of Consulting engineers Malaysia and the Malaysian Institute of Architect in 2009. This is the achievement from establishment of MGBC in 2007 by several groups of stake holders in the building industries in Malaysia (Lee, 2009; Mun, 2009; GBI, 2016). The GBI systems currently have about seventeen rating tools and seven reference guide for assessing the building life cycle (GBI, 2017). Five rating tools were considered in this review which are industrial new (INC) and existing building (IEB), non-residential new (NRNC) and existing buildings (NREB) and residential new building (RNC) (GBI, 2017). The distribution of points and parameters varied depending on the needs of the different types of building as shown in Table 6.

Table 6; Parameters and Points Distribution for Material and Resources in GBI

| Parameters | INC | IEB | RNC | NRNC | NREB | Average |
|---|---|---|---|---|---|---|
| Materials Reuse and Selection | 2 | 1 | 2 | 2 | 1 | 2 |
| Recycled Content Materials | 2 | 1 | 2 | 2 | 1 | 2 |
| Regional Materials | 1 | - | 2 | 1 | - | 1 |
| Sustainable Timber | 1 | 1 | 2 | 1 | 1 | 1 |
| Storage/Collection of Recyclables | 1 | 3 | 2 | 1 | 3 | 2 |
| Construction Waste Management | 2 | - | 2 | 2 | - | 2 |
| Refrigerants & Clean Agents | 1 | 1 | - | 2 | 2 | 2 |
| Sustainable Purchasing Policy | - | 1 | - | - | 1 | 1 |
| **Total** | **10** | **8** | **12** | **11** | **9** | **12** |

Source: (GBI, 2017; Usman and Abdullah, 2018)

## 4.7 GREEN STAR AUSTRALIA SYSTEMS

Green Star was launch in Australia in 2003 by the GBC Australia for assessing Australian buildings. Green Star currently have four rating tools for different phases of building life cycle. These rating tools are developed for building design, design as build, existing building and the interior decoration with about ten different categories (Say and Wood, 2008; Driedger, 2009; GreenStar, 2016). These tools covered a wide range of building types such as offices, residential, health care centres, education buildings, shopping centres. The review consider three of the rating tools and the material category was considered in all the reviewed tools (Green Star, 2016). Parameters and points allocation varies across the rating tools depending on the building type and needs as shown in Table 7.

Table 7; Parameters and Points Distribution for Material in Some Tools Green Star A

| Materials | Design As Built | Performance | Interior | Average |
|---|---|---|---|---|
| Life Cycle Impacts | 7 | - | 19 | 13 |
| Responsible Building Materials | 3 | - | 2 | 3 |
| Sustainable Products | 3 | 3 | 19 | 8 |
| Construction & Demolition Waste | 1 | 3 | 3 | 2 |
| Operational Waste | 1 | 4 | 1 | 2 |
| **Total** | **15** | **10** | **44** | **28** |

Source: (Green Star, 2016; Usman and Abdullah, 2018)

## 4.8 INDIAN GBC RATING SYSTEM

Indian Green Building Council (IGBC) established in 2001 developed the building assessment rating tools called Indian GBC tools. Currently the system covers building life cycle through developing nine rating tools for new and existing residential and non-residential buildings and for individual and multi dwelling including industrial, township and landscaping (Indian GBC, 2017; Raghu, 2016; IGBC, 2016). The review consider among others five rating tools these are the Green Residential Societies (GRS), Owner and Tenant Occupied New Buildings (OONB and TONB). Other are Green Homes Buildings which are either Individual or Multi-dwelling Residential Units (IRU and MDRU). Waste management was considered only in the Green Residential Societies (GRS) with three parameters and Building Material and resources was not considered in the GRS out of the reviewed rating tools (Indian GBC, 2017). The distribution of parameters and points among the reviewed rating tools for both building material and resources together with waste management were shown in the following Table 8.

Table 8; Parameters and Points Distribution for Material and Waste Management

| Parameters | GRS | OONB | TONB | IRU | MDRU | Average |
|---|---|---|---|---|---|---|
| Waste Segregation | 4 | - | - | - | - | 4 |
| Organic Waste Management | 5 | 2 | 2 | 2 | 4 | 3 |
| E-Waste Management | 1 | - | - | - | - | 1 |
| Construction Waste Material | - | 1 | 1 | 1 | 2 | 1 |
| Green Building Material & Equipment | - | 5 | 5 | - | - | 5 |
| Sustainable Building Material | - | 8 | 8 | 4 | 4 | 6 |
| Reused of Salvaged Waste Material | - | - | - | 4 | 6 | 5 |
| Use of Local Material | - | - | - | 2 | 2 | 2 |
| **Total** | **10** | **16** | **16** | **13** | **18** | **27** |

Source: (Indian GBC, 2017; Usman and Abdullah, 2018)

## 4.9 GREEN MARK SINGAPORE

Building Construction Authority of Singapore was task with the development of Green Mark rating systems in 2005. Generally, the systems currently utilises the new developed tools which start working 2017. The consideration of new approach for the

Singaporean buildings and environment was from the aim of deriving more sustainability out comes. This can be achieved by building high quality, environmentally friendly and sustainable building for future generation (Ahankoob *et. al*, 2013; Hee, 2013; BCA, 2016). The previous building rating tools did not contain a material category but some of the material and waste parameters were considered in the other categories. The new improved rating tools considered the categories in separate (Material and Waste) sub-categories in the Resource Stewardship category. The reviewed rating tools are Residential New and Existing Building (RNB and REB), Non-residential New and Existing Building (NRNB and NREB) (Green Mark, 2017). The point's distribution for the reviewed rating tools are given in the following Table 9.

Table 9; Parameters and Points Distribution for Material and Waste in Green Mark

| Parameters | RNB | NRNB | ENRB | REB | Average |
|---|---|---|---|---|---|
| Sustainable Construction | 8 | 8 | - | 8 | 8 |
| Low Carbon Energy | - | 3 | - | - | 3 |
| Waste Monitoring | - | - | 2 | - | 2 |
| Embodied Energy | 2 | 2 | - | 2 | 2 |
| Sustainable Products | 8 | 8 | 7 | 8 | 8 |
| Promotion of Waste Reduction | - | - | 2 | - | 2 |
| Construction Management Programme | 1 | 1 | - | 1 | 1 |
| Operational Waste Management | 3 | 3 | - | 3 | 3 |
| Recycling Facilities | - | - | 4 | - | 4 |
| **Total** | **22** | **25** | **16** | **22** | **33** |

Source: (BCA, 2016; Green Mark, 2017; Usman and Abdullah, 2018)

### 4.10 GREENRE MALAYSIA

Real Estate and Housing Development Association (Rehda) Malaysia is the organisation that developed GreenRE in 2013 through adopting Green Mark Singapore with some modification to meet the Malaysian needs. The tool currently have four existing rating tools that covers different types of building life cycle. The rating tools are for assessment of new residential non-residential new and existing and the township using five different categories (REHDA, 2013; GreenRE, 2016; GreenRE, 2017). The systems did not consider a separate category for either material or waste management but instead as parameters in some of the categories. Three rating tools were considered for this review which are residential, non-residential new and existing building for which are shown in the following Table 10 (GreenRE, 2017).

Table 10; Parameter and Points Allocated to Material and Waste in GreenRE Systems

| Parameters | RES | NRB | ENRB | Total | Average |
|---|---|---|---|---|---|
| Sustainable Material and Construction | 10 | 10 | - | 20 | 10 |
| Sustainable Products | 8 | 8 | 8 | 24 | 8 |
| Greenery Provision | 8 | 8 | 8 | 24 | 8 |
| Waste Disposal and Management | 1 | - | 4 | 5 | 3 |
| **Total** | **29** | **28** | **20** | **73** | **21** |

Source: (GreenRE, 2017; Usman and Abdullah, 2018)

### 4.11 BREEAM UNITED KINGDOM

BREEAM is the world first sustainable building rating systems developed by Building Research and Establishment (BRE) UK. The Systems has develop and operate a number of BREEAM rating tools which includes BREEAM communities, new construction, in-use, refurbishment and infrastructure to cover building life cycle (Adegbile, 2013; Breeam, 2017). Out of the developed tools, three of the tool are used for the review and all the three considered covers material and waste as a separate categories. Each rating tools have different parameters consideration and point's allocation for the material and waste categories (Breeam, 2017). The distribution of the parameters and the points are shown in the following Table 11.

Table 11; Parameters and Points Distribution for Material and Waste in BREEAM

| Parameters | BNC | BIU | BR | Total | Average |
|---|---|---|---|---|---|
| Life cycle impacts | 6 | 5 | - | 11 | 6 |
| Responsible sourcing of materials | 4 | 4 | 4 | 12 | 4 |
| Insulation | - | - | 1 | 1 | 1 |
| Designing for durability and resilience | 1 | 1 | 1 | 3 | 1 |
| Material efficiency. | 1 | 1 | 1 | 3 | 1 |
| Environmental Impact Material | - | 4 | 6 | 10 | 5 |
| Construction waste management | 4 | 5 | 6 | 15 | 5 |
| Recycled aggregates | 1 | 1 | 1 | 3 | 1 |
| Operational waste | 1 | 1 | 1 | 3 | 1 |
| Speculative floor and ceiling finishes | 1 | 1 | 1 | 3 | 1 |
| Adaptation to climate change | 1 | 1 | 1 | 3 | 1 |
| Functional adaptability. | 1 | 1 | 1 | 3 | 1 |
| **Total** | **21** | **25** | **24** | **70** | **28** |

Source: (Breeam, 2017; Usman and Abdullah, 2018)

## 5. PARAMETERS CONSOLIDATION

From Tables 1 – 11 it can be seen that, the parameters considered varies across the rating systems. The variation defines the uniqueness of the country's and stake holder's need. In order to have a harmonised parameters, the consolidated parameters should cover universally the entire building life cycle. In addition, they should be adequate to comply with every countries need. The parameters are viewed in three building life cycle phases the design, the construction and the building operational phases. The consolidated parameters are discussed in the following pages. For the design and construction phase, the assessment should cover the strategies to reduce GHG emission during building life cycle. While the other parameters assessed the GHG emission during construction and operation of the building.

### 5.1 LOCAL OR REGIONAL MATERIAL APPLICATION

This parameter encourage the use of material or products produce with the country or very closed to the country. This will facilitate the economic aspect of sustainability by money recycling within the country. The other importance is the reduction in the scope three emission i.e. the GHG emission for transporting and distributing the product to project site. This can be assessed by comparing the amount spend on these materials with the total project cost. The data for this computation will be obtained from bills of quantity for both design and the exact.

### 5.2 SUSTAINABLE MATERIAL APPLICATION

This parameter encourage the use of sustainable material fully declare by appropriate body in the country. Sustainable material are materials that have less embodied GHG emission. Material produce from renewable sources such as timber and trees. Others are from recycling of waste or produce from process with less impact on the environment. It encourage the use of material with reduced product life cycle emission (i.e. scopes 1, 2 and 3 emissions). This can be assessed by comparing the amount spend on these materials with the total project cost. The data for this computation will be obtained from bills of quantity for both design and the exact.

### 5.3 RECYCLING OF CONSTRUCTION WASTE:

This parameter encourage reduction in construction waste and using it for other activities that will reduce the purchase of new material. Since the quantity of new material purchase is reduce, therefore it reduce the embodied GHG emission from al the scopes for the new material. This parameter can be assessed by percentage of cost reduction from recycling of construction waste. The data for the computation can also be obtained from the bill of quantity for the project and the waste management reports for the entire construction period.

### 5.4 WASTE RECYCLING FACILITIES EQUIPMENT

This encourage the provision of appropriate waste containers for different types of waste for easier identification and recycling. This must cover the construction and operation phases of building life cycle. By recycling of these waste the net avoided GHG emission will definitely be less that the product scopes 1 to 3 emission. Hence it reduces the carbon footprint of the building from material purchases. This parameter can be assessed by providing waste storage facilities for different types of waste for easier recycling. The data for this computation can be obtained from design drawing and provision.

### 5.5 DESIGN FOR OPERATIONAL WASTE MANAGEMENT

This cover the adoption of using the appropriate waste storage and recycling during the operational phase of the building life cycle. The assessment of this parameters involve providing the building with all the waste storage facilities during operation of the building. The information for this can be obtained and assessed by locating the physical position of all the design facilities.

### 5.6 NON-RECYCLABLE WASTE REDUCTION

This encourage monitoring and reducing the waste that will not be recycled during the construction and operation. These waste can only be transferred to landfills and consequently releases LFG to the atmosphere. This can be assessed by comparing the quantity of non-recyclable waste with the total waste produced. The data for this computation can be obtained from waste management report for construction project and operational phase.

### 5.7 MATERIAL PURCHASING POLICY

This parameters encourage complying with the sustainable development policy and standards of the country. By complying with this policies, the building will have less negative impact on the environment. The assessment of this parameters consist of abiding by certain regulation in the government policies and standards. This policies and standard were there to sustainably monitor the built environment.

### 5.8 LOW EMITTING MATERIALS

This encourage the use of construction material with less hazardous volatile mater emission. The hazardous maters destroys the internal environmental air quality for the occupant and the construction employees. The parameter can be assessed providing evidence of purchase of these material for the benefit of better indoor air quality. The data to be used for this assessment is from the bill of quantity for the material used during construction, operation and rehabilitation.

### 5.9 CARBON FOOTPRINT ASSESSMENT

To cover the quantity of direct GHG emission from building construction and operation, emission from various component of the phases will be determined and add up together to give the overall GHG emission. These components includes carbon footprint of major material purchased and used during construction and operation. These material include cement and concrete, steel and other metallic products, glasses and plastics products, flooring, tiling and carpet, wood and fibre board etc. The other component is the emission from construction waste management. This component comprises emission from site preparation waste, building and road construction, landscaping and parking space and emissions other waste types.

The assessment of this parameter for construction and operation involve computing the total carbon footprint from the two phases. This comprises of material used and the un-avoided footprint from construction waste generation. The other is the carbon footprint per project cost and building total floor area or total number of building occupant respectively.

### 5.10 CARBON FOOTPRINT REDUCTION

This parameter encourage the reduction in the yearly carbon footprint during the building operation period. The operational phase emission for this category consist of only emissions from recycling of operational waste and operational landfill waste. These components measure only the net avoided carbon footprint. Assessment of this parameter utilises yearly carbon footprint from material and waste generated during building operation. This can be used to determine the percentage reduction from a base line period. It is computed to account for the carbon footprint reduction during the periods of operation of the building.

## 6. DISCUSSION

This study describe the importance and significance of considering material as one of the major category in determining the sustainability of the built environment. The category was considered in all the rating systems except Green Mark and GreenRE. The material aspect was considered in Green Mark and GreenRE as parameters in the other categories. The study also show that, the waste was considered only in BREEAM and LEED and combine with material in BEAM rating systems. Even though the category was not considered as separate category in the remaining rating systems but it is there as parameters in the remaining categories as shown in Table 1-11. The appreciable points given to the waste aspect signifies its importance in the rating systems.

Figure 1 and Table 1-11 show the variation of total and percentage parameters and points allocation to material and waste category. The Figures show that, the highest parameters allocation to material and waste was in Green Star SA. This is followed by Green Ship and BEAM, GBI and BREEAM. The allocation of parameters by GreenShip and Green Star SA was from the high need for material conservation. The major problems of these countries are excess use of material in most of the daily activities which lead to lot of waste generation. The other is poor waste management strategies which consequently leads to high GHG emission in to the atmosphere. Hence the higher the number of parameters and points allocation in a category the higher the coverage for that category in the rating systems and tools. Which leads to better conservation of the environment from the consequences of such category. The BEAM and Green Mark higher allocation of parameters and points and consequently the points in Green Star NZ was from high need of land conservation. Other is lack of adequate land and construction material and other resources. Hence the parameters and point allocation signifies the stake holders need and policies demands of countries for which the tools were developed.

Table 1 to 11 show the distribution of parameters in each of the reviewed rating tools in the rating systems. It can be deducted that, the parameters allocation varies between different rating systems. Even though they all aim at same objective assessing the use of sustainable material usage and waste management. It is also due to individual difference in understanding the concept of sustainability in relation to sustainable built environment. Other is the differences in stake holder's requirement and government policies requirement. This requirements depend on the availability of natural resources for building material and processing. Others are energy and it source need of the countries and their sustainability quarter by the United Nation. These factors among others adversely affect the sustainability of their environment. If the sustainable material conservation and waste management was properly implemented by different countries around the world, the GHG emission associated with the raw material extraction and new material processing and transportation will be reduce. This will consequently reduce the overall GHG emission to the atmosphere. As material production and distribution for building and other activities is among the major contributor to GHG emission.

The study consolidate the parameters in to ten parameters to cover the building life cycle assessment. Certain factors were considered during the selection of the consolidated parameters. These factors are the measurability, preference, prevalence, relevance and adaptability of a parameter to be used for assessing building life cycle. The design and construction aspect was covered in the seven of the parameters. These parameters discussed the strategies to avert the consequences of built environment on the climate change. These stage of assessment occurs during design and construction but have the major impact during operation of the building. Another two cover the GHG emission estimation and reduction over the period of operation. These parameters discussed and assessed the estimation of the GHG emission associated with building construction and operation. The emission is estimated from the carbon footprint of the major material consumed and secondary material produced during construction. The other is the net avoided emission from waste generated during construction and building operation. They also estimate emission reduction over a certain period of operation. The last one assess the building in term of abiding by the national policy and standards of the country.

## 7. CONCLUSION

Green or sustainable buildings are types of buildings that are environmentally, socially and economically friendly. This was due to their design, construction and operational phase uniqueness which allow them to get more advantages over conventional buildings. There are currently various rating systems which are good enough to be used for building assessment but only in certain part of the world as they are not universal. Also the existing rating systems are quite complex in nature and do not necessarily give a clear idea of the project's effectiveness and policy consistency for every country. From the review, all of these rating systems pointing to a single similar objective that is the implementing the principles of conserving the material usage and reducing the excessive supply of waste to landfill. Obviously the differences among these tools are also significant and is highly dependent on the region, local need government policies and need. Therefore, it is imperative to have a specific rating tool for a specific region. Such assessment systems drive not only engineers, designers, builders and building owners towards green building and environment. It also derive other stakeholders in the construction industry such as construction material manufacturing and distributing industries.

Material conservation is a factor that can be defined and considered only during design and construction or refurbishment phase. The waste management can be extended to the operational phase. The distribution of parameters and points to the material and waste category in the rating systems is an important variation to describe the uniqueness of rating systems for every region or country. Hence the category is very important when developing a rating systems. Therefore, it is very necessary and important to know how effective a project is in term of material consumption efficiency and waste minimisation efficiency. For every country undergoing sustainable environment assessment tools, these analyses and review will be of high importance when it comes to parameters and points consideration.

The consolidated parameters covers the complete building life cycle in terms of material consumption and waste generation. They cover the design and construction through innovative strategies for averting climate change due to consequences of built environment. For construction and operational phases through parameters for estimating the GHG emission in the form of carbon footprint. The carbon footprint reduction over the operational year can also be use in estimated using the parameters. They can be useful to researchers, organisations and governments in developing a new sustainable building assessment tool. It can also be important in estimating the quantity of GHG emission in the form of carbon footprint of the building. The can also be useful in estimating the GHG emission of a community, town or country as a whole.

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**REFERENCES**

Adegbile, M. B. (2013). Assessment and Adaptation of an Appropriate Green Building Rating System for Nigeria. *Journal of Environment and Earth Science, 3*(1), 1-11.

Ahankoob, A., Moeshedi.E, S. R. and Rad, K. G. (2013). A Comprehensive Comparison between LEED and BCA GreenMark as Green Building Assessment Tools. *The International Journal of Engineering And Science (IJES), 2*(7), 31-38.

Azapagic, A. (2004). Developing a Framework for Sustainable Development Indicators for the Mining and Minerals Industry. *journal of Clean Production, I2*, 639–662.

BCA. (2016, January). *Green Mark*. Retrieved from Building and Construction Authority,: https://www.bca.gov.sg/GreenMark/green_mark_buildings.html

BEAM Plus. (2017). *BEAM Plus Building Assessment Tools.* Hong Kong: BEAM Society Limited. Retrieved from https://www.beamsociety.org.hk/en

Berge, ,. B. (2009). *The Ecology of Building Materials, 2nd ed.* Italy: Elsevier.

Breeam. (2017). *Breeam Rating System Technical Manual.* Watford, Hertfordshire: BRE GLOBAL Limited. Retrieved from www.breglobal.com, www.greenbooklive.com, https://www.breeam.com/

Driedger, M. (2009). Choosing the Right Green Building Rating System: An Analysis of SixRating Systems and They Measure Energy. *Perkins+Will Research Journal, 1*(1), 22-41.

GBC Indonesia 1. (2016). *About GBC Indonesia.* Jakarta: Green Building Council Indonesia.

GBC Indonesia 2. (2015). *GreenShip Rating and Certification Tool Summary.* Jakarta: Green Building Council Indonesia.

GBI. (2016). *Green Building Index*. Retrieved 04 23, 2016, from Green Building Index: www.greenbuildingindex.org

GBI. (2017). *Green Building Index Rating Systems.* Kuala Lumpur: Green Buuilding Index Bhd, Sdn. Retrieved from Green Building Indes: www.greenbuildingindex.org

Green Mark. (2017). *BCA Green Mark Assessment Scheme.* Singapore: Buildin and Construction Authority. Retrieved from https://www.bca.gov.sg/greenmark/green_mark_buildings.html

Green Star. (2016). *Green Star Australia Rating Systems.* Sydney: Green Building Council Australia. Retrieved from www.new.gbca.or.au

Green Star NZ. (2016). *Green Star New Zealand - Technical Manual Version 3.1.* Wellington: New Zealand Green Building Council.

Green Star SA. (2014). *Green Star South Africa Building Rating Systems.* Cape Town: Green Building Council South Africa. Retrieved from https://www.gbcsa.org.za/green-star-sa-rating-system/

GreenRE. (2016, September). *About us.* Retrieved April 23, 2016, from Green Real Estate: www.greenre.org

GreenRE. (2017). *GreenRE Rating Systems.* Kuala Lumpur: Real Estate and Housing Development Association of Malaysia. Retrieved from www.greenre.org

GreenShip. (2016). *GreenShip Indonesia Building Rating Systems.* Jakarta: Green Building Council Indonesia. Retrieved from http://gbcindonesia.org/greenship

GSA 1. (2014). *Green Star South Africa - Public & Education Building v1: Rating Tool Fact Sheet.* Johanesburg: Green Building Council South Africa.

GSA 2. (2014). *Green Star South Africa - Public & Education Building v1: Rating Tool Score Sheet.* Johanesburg: Green Building Council South Africa.

Hedaoo, M. N. and Khese, S. R. (2016). A Comparative Analysis of Rating Systems in Green Building. *International Research Journal of Engineering and Technology (IRJET), 3*(6), 1393-1399.

Hee, L. (2013). *Greening Singapore's Built Environment.* Singapore: Building and Constrcution Authority.

IGBC. (2016, September). *Green Building Movement in India*. Retrieved from Indian Green Building Council: https://igbc.in/igbc/r

Indian GBC. (2017). *IGBC Green Building Rating Systems.* Hyderabad: Indian Green Building Council.

Kshirsagar, B., Mane, V., Saharkar, U. and Salumke, H. (2015). Comparative Analysis of Green Building Rating Systems. *International Journal of Engineering Technology, Management and Applied Sciences, 3*(2), 287-296.

Lee, J. (2009, August 24). *Green Building Index Malaysia.* Retrieved April 23, 2016, from Integrated Environmental Solutions Limited Blog: wwwblog.iesve.com/index.php/2009/08/24/green-buildin-index-malaysia

LEED. (2017). *LEED Rating Tools for Different Types and Stages of Buildings.* Washington: United State Green Building Council. Retrieved from https://www.usgbc.org/resources/grid/leed

Mun, T. L. (2009, April 23). *The Development of GBI In Malaysia.* Retrieved 04 23, 2016, from Green Bulding Index Malaysia: www.greenbuildingindex.org

Raghu, M. (2016, September). *Home Page/About IGBC*. Retrieved from Indian Green Building Council: https://igbc.in/igbc/

REHDA . (2013, 03 27). *REHDA launches its own GreenRE rating tool.* Retrieved 04 23, 2016, from Star Property Malaysia: www.starproperty.my

Ruuska, A. and Häkkinen, T. (2014). Material Efficiency of Building Construction. *Building, 4*, 266-294. doi:doi:10.3390/buildings4030266

Say, C. and Wood, A. (2008). Sustainable Rating System Around the World. *Council on Tall Buildings and Urban Habitat (CTUBH) Journal, 11*, 18-29.

Soni, K. M. (2016). Waste to Resource for Sustainable Development. *Indian Journal of Science and Technology, 9*(5), 1-6.

USGBC 1. (2016, September). *History of USGBC*. Retrieved from United State Green Building Council: http://www.usgbc.org/about

Usman, A. M. and Abdullah, K. (2018a). Water Management and Efficiency for Construction Industries in Green Building Rating Systems. *Proceeding – 4thd Putrajaya International Built Environment, Technology and Engineering Conference*, (pp. 27-28). Kuala Lumpur.

Usman, A. M. and Abdullah, K. (2018). Review on Material and Waste Management Assessment in Sustainable Building Rating Systems. *Proceeding – 4thd Putrajaya International Built Environment, Technology and Engineering Conference (PIBEC4)*, (pp. 418-431). Kuala Lumpur.

Usman, A. M., Abdullah, K. and Batcha, M. F. M. (2018). Comparative Study on Energy Management and Efficiency Category in Sustainable Building Rating Schemes. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences (ARFMTS)*, Accepted for publication.

Wu, Z. and Chen, X. (2015). The Material COnsumption Estimation of Frame Shear Wall Structures. *Journal of System and Management Sciences, 5*(1), 38-51.

Yates, A. (2016). *The International Code for a Sustainable Built Environment and Future BREEAM Products.* Hertfordshire: BRE Global Limited.