Research essay

Assessing the environmental impact of building materials:

The scoring system in BREEAM certification

By

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ABSTRACT

The materials used to build our homes can have significant health and environmental impacts. These often extending far beyond the specific context of their end-use. Usually the impact of materials is dictated by the processes adopted to extract, process and transport them to the site. Therefore careful analysis and selection of the materials used and the way they are combined can guide to make more environmentally responsible choices in order to reduce negative impacts. Life Cycle Assessment (LCA) is a well known method used to measure these impacts over the total life span of the materials. The evaluation, and afterwards the choice, of building materials with a low environmental impact plays an important role also in the BREEAM building certification scheme which sets the standard for a good practice in the sustainable design. The BRE Green Guide to Specification is a tool included in the scheme which helps to assess materials according to their impact (using the Life Cycle Assessment tool).

A review of the basic working principles of the BREEAM scheme and the scoring of the building materials, together with the potential contribution of the Green Guide tool towards a reduction of the environmental impacts of building materials is included herein. Then, this theory is discussed, weaknesses and strengths of the scoring system within the guide are pointed out in order to understand if it can be used as a guidance when selecting low impact materials. As overall is concluded that the Green Guide data and science are a good basis for such a project. Nevertheless, improvements could be added within the following aspects: mandatory criteria in the section of materials, transparency and accessibility of information that allow to understand the methodology behind, adaptability of the guide to enable comparison among the assessment of building materials.

Keywords: Building Materials, Environmental Impact, LCA (Life Cycle Assessment), BREEAM Certification, Green Guide to Specification.

INTRODUCTION

With the rapid development of the construction industry in the last decades, the human living condition has been greatly improved. As a kind of high resource and heavy pollution industrial product, buildings on one hand provide countless benefits to society, but on the other they also have significant negative impacts on the environment and health during each stage of their life cycle (Dixit, Fernandez, Lavy and Culp, 2010). In terms of the total impact on environment, the one caused during the production process of building materials has an important role as it involves the consumption of raw materials and energy, producing emissions and solid waste (Esin, 2006).

Buildings require approximately 40 to 50 % of the total energy consumption in Europe. Building materials have a significant share (10–15 %) in this (Esin, 2006). Therefore, decrease the pollution attributed to the latter, together with the promotion and use of green building materials are crucial factors to reduce the energy demand and the negative environmental impact, and improve the human living environment (Esin, 2006).

A careful analysis, selection and specification of the materials used is needed and the way they are combined can yield significant improvements in the comfort, cost effectiveness and energy efficiency of a building (Clark, 2010). Furthermore it can guide to make more environmentally responsible choices in order to reduce negative impacts without substantially increasing the cost (Clark, 2010). Thus it is important to measure or evaluate the environmental impacts of a material from the cradle to the grave (i.e. taking into account its full life cycle). Methods for measuring these impacts, all referred as Life Cycle Assessment (LCA), have been developed and are being improved. This includes extraction, manufacture, transportation, use or operation and eventual disposal or re-use (Dixit, Fernandez, Lavy and Culp, 2010). LCA can be applied to a whole product (house or unit) or to an individual element or process included in that product.

Nowadays there is a much greater focus on evaluating environmental impacts of building materials also through the building certification schemes. They are used for measuring the environmental performance and assessing the sustainability of a building in order to provide the construction industry with tools necessary to design, build and operate with high degree of performance (Ebert, Essig and Hauser, 2011). In the last two decades the number of assessment and certification systems, as well as the total number of certified buildings has increased worldwide (Ebert, Essig

and Hauser, 2011). They have been fundamental at driving innovation regarding sustainability issues within the construction industry. These certification schemes have numerous advantages, one of the most important is the reduction and control of the environmental impact caused by buildings and their materials. Therefore, one of the aims is to encourage the use of materials that have lower impact on the environment, taking account the full life cycle of the materials in question (Ebert, Essig and Hauser, 2011).

The Building Research Establishment Environmental Assessment Method (BREEAM) and The Leadership in Energy and Environmental Design (LEED) are the two most widely recognized environmental assessment methodologies with regard to ecological, economic and social aspects (INBUILT, 2007). They are used globally in the construction industry today and both assessments are involving different issues also called sections (e.g. energy, materials and resources, water efficiency, health and wellbeing etc.) which have a pre-defined weighting factor.

In BREEAM the greatest weight is attached to the section of the Energy efficiency. It accounts for 19% of the total assessment scheme while the section of construction materials relates to 12,5%, making the selection and reuse of materials a significant factor in a building's overall score (see Figure 2 - Appendix1). LEED is divided into six categories. The category of Materials & Resources is at the 4th place with 14 points up to 100 points. Energy & Atmosphere has again the greatest weight (Ebert, Essig and Hauser, 2011).
Each one of these sections is assigned a different number of criteria and each of them has a number of credits or points that can be achieved. By using a single "rating", these certifications encompass a group of issues or broader sustainability aspects which might otherwise be individually dropped or missed when designing a low impact building. (INBUILT, 2000).

The focus of this semester has been the design of a zero emission building in Brøset (Trondhiem), which have been achieved through the use of different approaches. Important environmental objectives have been taken into account in this process, among which the choice of materials has had a big impact on the design. Give the above, the revision included here aimed to analyse the scoring system of the BREEAM certification in terms of the environmental impacts of the building materials. Has the assessment method defined the choice of building materials with the lowest environmental impact during the design process? An attempt to answer the latter, was carried on the basis comparisons and discussion of the positive and negative aspects of the scoring system.

METHOD

Development of the study was carried out on a qualitative method (with both primary and secondary sources) divided in two parts. The information provided is based on a literature review then afterwards discussed.

Given the broad scope of the topic, a first part (Theory – Understanding BREEAM International how it works) includes a review of the building certification scheme providing a comprehensive idea that allows insights on specifics such as scoring of the Materials section and the use of the Green Guide to Specification to assess some of the credits.
Among several schemes available in BRREAM, the BREEAM International (BREEAM Europe Commercial for OFFICE buildings) has been chosen as part of this research for analyzing the scoring of the Material category since it was used in the semester project. Moreover it is being adapted to the Norwegian context and will be soon implemented as BREEAM Nor.

The second part (Analysis and discussion), based on the literature, discusses and compares the positive and negative aspects of the scoring system in terms of the environmental impacts of the building materials.

Conclusions extracted provided a frame for further improvements of the scoring system in BREEAM certification and more specifically improvements that can be done in the Green Guide to Specification in order to provide designers, architects but also students with accessible and accurate guidance on making the best environmental choices when selecting construction materials.

Primary sources
Specific inputs were obtained from the building certification schemes lecture (Dr. Aoife Houlihan Wiberg – essay supervisor) – Environmental assessment tool and methods: comparison of 4 certification schemes. Other useful inputs were also gathered from Paul Woodville's lecture about BREEAM, Inger Andersen's lecture - The road to BREAAM Nor and from useful discussion with professors and researchers of the Master in Sustainable Architecture involved in this field. Information obtained from indexed journals on current research constituted also a primary source of information.

Secondary sources
Text books, together with websites, review articles from journals or compendiums (meetings, workshops, government public information) constitute the secondary sources.

THEORY

Understanding BREEAM International, how it works and the scoring of materials

Description of the scheme

BREEAM was the first certification system to assess the sustainability of buildings published in the United Kingdom (UK). The system was conceived and administrated by the British Building Research Establishment (BRE) and was first used in 1990 to assess the environmental performance of new and existing buildings (BRE, 2008). BREEAM can be regarded as the model for all certificates (included LEED), indeed the contents and assessment methods for most of these are based on this system (Ebert, Essig and Hauser, 2011). Specific versions of BREEAM are available for the UK depending on the building type (BREEAM Offices, BREEAM Retail, BREEAM Ecohomes etc.). Moreover BREEAM assessment schemes can also be used for any specific country or region anywhere in the world (BREEAM International which includes the BREEAM Europe Commercial) (Ebert, Essig and Hauser, 2011).

Criteria

The assessment is performed with a credit point system. The example from the Brøset project presented in the Table 1 illustrates the process: firstly credits in 10 different sections, which the assessment relates to, has to be awarded. Each one of these sections is assigned a different number of criteria and each of them has a maximum number of credits that can be achieved. Then the awarded credits in each of these criteria are added together (Ebert, Essig and Hauser, 2011). The totals are then expressed as percentages of the maximum number of credits achievable in the respective section. These percentages indicate the degree of fulfillment in each section (the Brøset example shows 83,3% fulfillment in the materials section). Pre-defined weighting factors are applied to the section percentage to give weighted performance rates for each individual section. The example shows a result of 10,42% for the materials section due to a weighting factor of 0,125 (12,5%). The sum of all weighted percentages is the overall degree of fulfillment (in the Brøset project 90,38%). The final score (see Table 4 - Appendix 3) or the overall assessment (in the example “outstanding”) derives from this sum but according to the new updated BREEAM scheme (2008) it also depends upon the achievement of minimum levels of fulfillment in individual criteria (Table 2). Only if the minimum scores are met by the criteria the calculated overall assessment level can actually be recognized (Ebert, Essig and Hauser, 2011). This is aimed at avoiding the criticisms of the old BREEAM system as it requires designs to tackle energy issues directly to ensure the highest BREEAM ratings are achieved (INBUILT, 2000).

BREEAM Section	Credits Achieved	Credits Available	% of Credits Achieved	Section Weighting	Section Score
Managment (Man)	7	10	70.0	0.12	8.40%
Health and Wellbeing (Hea)	10	14	71.4	0.15	10.71%
Energy (Ene)	20	21	95.2	0.19	18.10%
Transport (Tra)	8	10	80.0	0.08	6.40%
Water (Wat)	5	6	83.3	0.06	5.00%
Materials (Mat)	10	12	83.3	0.125	10.42%
Waste (Wst)	5	7	71.4	0.075	5.36%
Land Use and Ecology (LE)	6	10	60	0.10	6%
Pollution (Pol)	12	12	100	0.10	10%
Innovation (Inn)	10	10	100	0.10	10%
Final BREEAM score					**90.38%**
BREEAM Rating					**OUTSTANDING**

Table 1: Exemplary results of BREEAM's scoring and rating process for the Master's semester project – Brøset Zero energy building.

BREEAM Issue	PASS	GOOD	VERY GOOD	EXCEL	OUTST
Man 1 - Commissioning				1	2
Man 3 - Construction site impacts				1	2
Man 4 - Building user guide		1	1	1	1
Hea 4 - High frequency lighting	1	1	1	1	1
Ene 1 - Energy efficiency				6	10
Ene 2 - Sub-metering of substantial energy uses			1	1	1
Ene 5 - Low or zero carbon technologies				1	1
Wat 1 - Water consumption			1	1	2
Wat 2 - Water meter				1	1
Wst 3 - Storage of recyclable waste				1	1
LE 4 - Impact on site ecology				2	2

Table 2: Minimum BREEAM levels.

Procedure

A BREEAM assessment involves inspections by a licensed BREEAM assessor. Previously assessment was only undertaken at the design stage, but the new updated version - BREEAM 2008 introduced a new two stage assessment and certification process: design stage and post construction. The aim is to ensure that design stage promises are carried through to the construction phase – a development should achieve the same rating for post construction as well as for design stage (ISLINGTON,2007).

Scoring of Materials section

The section of Materials relates to seven different criteria (Table 3). The assessment looks at each of these criteria and awards credits according to the performance of the building. The scope of this section is to avoid or improve the negative environmental impact of the building materials (BRE,2008).

Materials (section weighting 12.5%)	Credits available	Criteria weighting
Mat 1 - Materials Specification (Major Building Elements)	4	3.85%
Mat 2 - Hard Landscaping and Boundary Protection	1	0.96%
Mat 3 - Re-Use of Façade	1	0.96%
Mat 4 - Re-Use of Structure	1	0.96%
Mat 5 - Responsible Sourcing of Materials	3	2.88%
Mat 6 - Insulation	2	1.92%
Mat 7 - Designing for Robustness	1	0.96%

Table 3: Materials section and criteria of the BREEAM International Europe scheme for office building.

Within the overall section, the greatest weight is attached to the criteria Mat 1 - Materials Specification (Major Building Elements). The aim of this criteria is to recognize and encourage the use of construction materials with a low environmental impact over the full life cycle of the building. The four available credits can be obtained or assessed using two methods (BRE, 2008).

In the first method the BREEAM Green Guide to Specification (available also online) can be used to evaluate the criteria. This is a tool which helps to assess building materials and products according to their environmental impact (using the Life Cycle Assessment tool) (BRE, 2008). To assess the credits a specified portion of major building elements (wall, roof, floor etc.) that achieve an A summary rating in the Green Guide. The results of these evaluations are directly relevant also to two other criteria in the Materials section (Mat 2 Hard Landscaping and Boundary Protection and Mat 6 Insulation) (Ebert, Essig and Hauser, 2011).

As an alternative analysis method to the Green Guide, a life cycle assessment (LCA) can be used to evaluate the criteria. It is permitted to apply existing national LCA methods but some basic conditions must be observed as minimum requirements (Ebert, Essig and Hauser, 2011).

The Green Guide to Specification

Description and structure of the guide

The Green Guide has been developed by the BRE with the aim of providing information and easy-to-use assessment tools for the environmental impact of building materials and major building elements, such as walls, roof or floor (Andersen, Shiers and Sinclair, 2002). The information on building materials and building elements contained in the Green Guide is then used in any further assessment (such as BREEAM) of the overall environmental impact of a whole project (May and Newman, 2008).

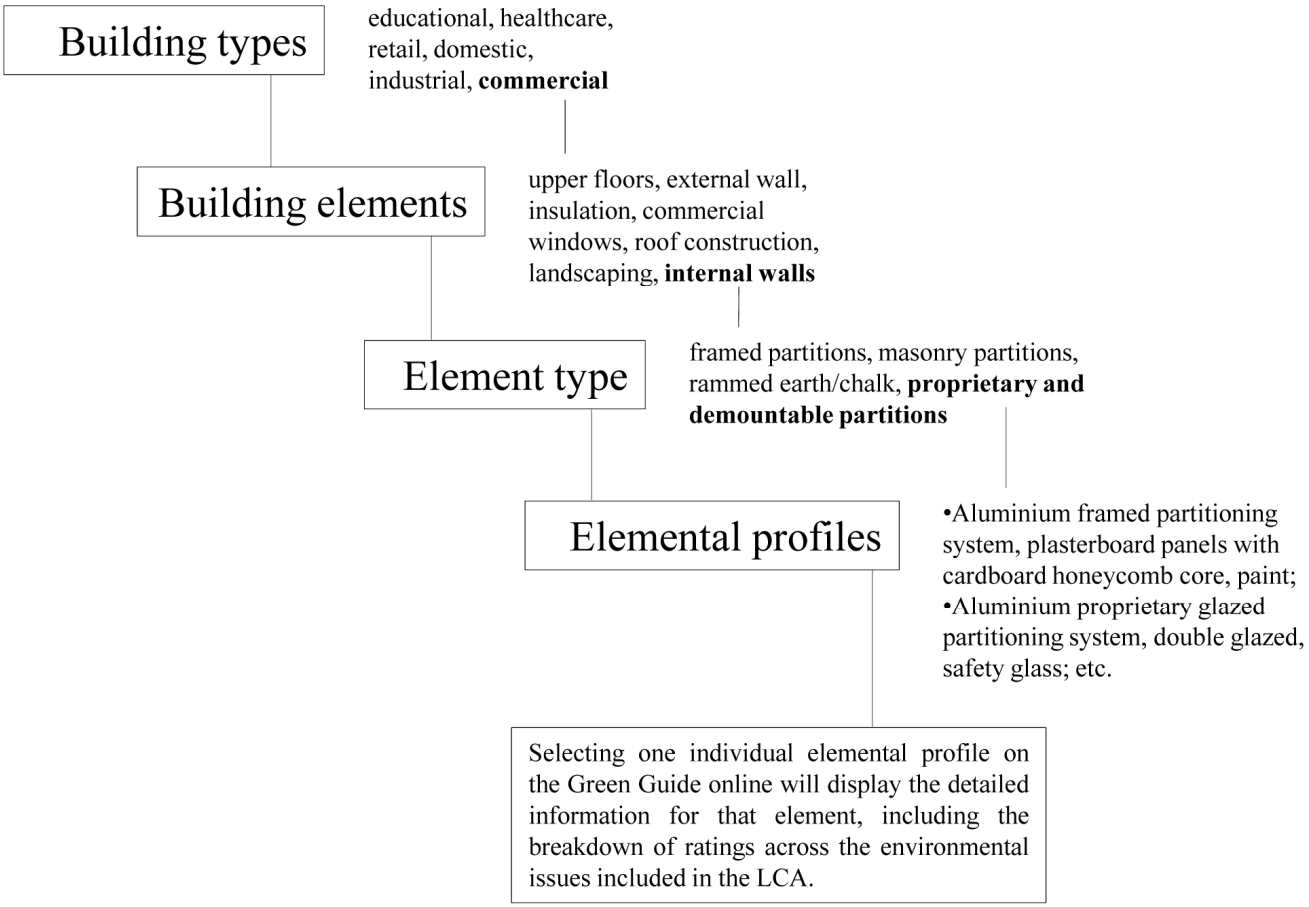

Figure 1: Example of the structure of the Green Guide (see also Figure 3 Appendix 2).

Criteria

The Guide presents information on building materials (i.e. elemental profiles) by a rating system, A+ to E (where A+ represents the best environmental performance / least environmental impact, and E the worst environmental performance / most environmental impact). These environmental ratings are based on Life Cycle Assessment ("LCA") methodology (May and Newman, 2008). The system used by the BRE organises this LCA data into 13 environmental impact categories:

- climate change
- water extraction
- mineral resource extraction
- stratospheric ozone depletion
- human toxicity
- ecotoxicity to freshwater
- ecotoxicity to land
- nuclear waste
- waste disposal
- fossil fuel depletion
- eutrophication
- photochemical ozone creation
- acidification.

The rating is generated by creating the environmental impact score for a specification by first aggregating the data for each of the materials described, then converting this aggregated data into a single environmental score by applying weighting factors to each of the 13 impact categories. Finally, within each element group the environmental impact score of each specification (or elemental profile) is arranged from best to worst (May and Newman, 2008).

ANALYSIS AND DISCUSSION

Nowadays there is increasingly public interest and debate regarding environmental impact of building materials. Even though over the last decade significant achievements has been reached in order to reduce these impact, it is vital to keep on improving the standard (May, 2008). In particular a way to guarantee traceability of materials should be developed (Esin, 2006). A step toward this direction has been made in BREEAM. Indeed in the updated version from 2008 the weighting system is corrected to give greater importance to the materials section. The section accounts to 12,5% of the total assessment scheme making it a more significant factor for a building's overall score (see Figure 2 – Appendix 1). However, in BREEAM 2008 the introduction of mandatory minimum requirements can be seen as a limit when trying to emphasize the importance of the choice of low impact materials. The BREEAM rating scale (see Table 4 - Appendix 3) derives from the sum of the weighted percentages but it also depends upon the achievement of minimum levels (Table 2). They have been set at all ratings (from pass to outstanding) but just for some criteria among which there are no mandatory levels for the section of Materials. As a result, a building can be assessed as excellent even though none of the credits in the Materials section has been achieved (see Table 5 - Appendix 4) which can be interpreted as no major relevance is given to the choice of low impact materials during the design process. It can be pointed out that introducing at least one mandatory criteria also in the Materials section (e.g. Mat 1 - Materials Specification with the greatest weight) to all ratings, starting from the pass, would lead to a more careful selection of the material used in a building since the early design stage. As a consequence only if the minimum score from the Material section together with others mentioned in the Table 2 are met, the calculated overall assessment level can actually be recognized.
As a matter of fact in the case of BREEAM Nor which will be soon implemented in the Norway, the criteria Mat 1 (Materials Specification) will be set as a mandatory minimum requirement for all ratings – from pass to outstanding.

As in Norway, specific versions of BREEAM are also available in some others European countries such as Netherlands, Spain and Sweden where some sections (mainly health - well being and energy) are adapted for local conditions (Sebake, 2009). For the assessment of building materials (criteria Mat 1 - Materials Specification) the use of Green Guide is limited to United Kingdom. These ratings are representative of UK-supplied construction products and materials (BRE,2008). As a consequence the other versions, in particular in Netherlands and Norway, are using alternative nationally recognized life cycle assessment (LCA) tools to evaluate this specific criteria. In one

hand, this implies advances in the improvement of tools for the assessment of the environmental performance of specific building materials which is currently needed and has to be developed even further (May and Newman, 2008). On the other hand however, globalization trends over the last decade has increased the demand for standardization also within assessment tools (Sebake, 2009). Therefore, the usage of different methods (The Green Guide and an alternative LCA) to assess the same criteria is definitely limiting when comparing building materials evaluated within different BREEAM versions.

The environmental assessment of building materials represents a key point of our understanding of how buildings, people and nature interact, either in positive or negative ways (Esin, 2006). Thus the assessment must be as simple as possible in order to be achievable and understandable and must have integrity, rigour in science, data and transparency (May and Newman, 2008). The latter constitute an important issue and perhaps the starting point, as without complete transparency of data, none of the ratings or assumptions can be understood or questioned, and no actual learning on environmental impacts of materials is possible (May, 2008). In the last few years a lot has been done to make the Green Guide an accurate, achievable and helpful guidance tool, enabling designers to make more environmentally friendly choices. Indeed in June 2008 BRE Global launched the basic Green Guide online as a free to view service for the common components (BRE, 2008). The guide is easy to use and constantly updated with data available at this present time (i.e. new elemental profiles are frequently added, some of them are revised or superseded). However when analyzing the Green Guide online it has been noticed that there is a lack of clearness of data which makes difficult to understand the ratings (i.e. the real impact) of the profiles and to determine what has been included in the analysis. Some information can also be found in the book Green Guide to Specification but it is not clear how the methodology has been applied to each specific profile. Further more in the Green Guide online significant amount of specifications are not listed. The online Green Guide Calculator has been introduced as a solution which enables to generate an instant rating for an elemental profile based on the components currently used (BRE, 2008). This enhanced service includes the transparency of some data, however it is not yet available for public use. As a consequence, students and designers that are not licensed BREEAM assessor but at the same time are interested in understanding the environmental attributes of the materials are not able to use the calculator and learn more about the assessment methodology. Moreover when searching for examples to be mentioned in this paper, information on the number of buildings certified in each specific category and what ratings they have achieved were hard to find.

CONCLUSION

The choice of low impact materials is a fundamental design step. Therefore a building certification scheme as BRREAM must emphasize the importance of an environmental assessment. Introducing at least one mandatory criteria in the Materials section, and apply it to all ratings can be an optimal solution that would lead to a more careful selection of the material used in a building.

Becomes evident that one of the most important requirements for a proper and effective environmental assessment of building materials is the transparency of data and assumptions in all areas. Even though BREEAM has a well developed scientific basis for the research behind some credits, like the one in Materials section, it's important that all the information are accessible and reliable in order to understand the methodology behind. Since the Green Guide is not yet fully accessible (also due to some non-free services) was of no help when trying to understand what is the environmental impact of a certain material.

Further research can be done on the adaptability of the Green Guide to make the assessment of building materials comparable within the same building certification scheme.

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APPENDICES

Appendix 1 – Figure 2

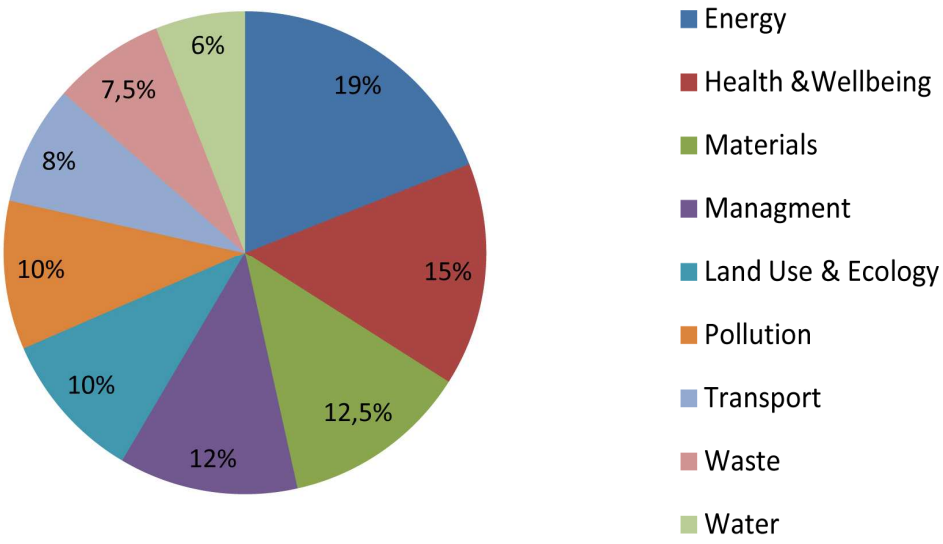
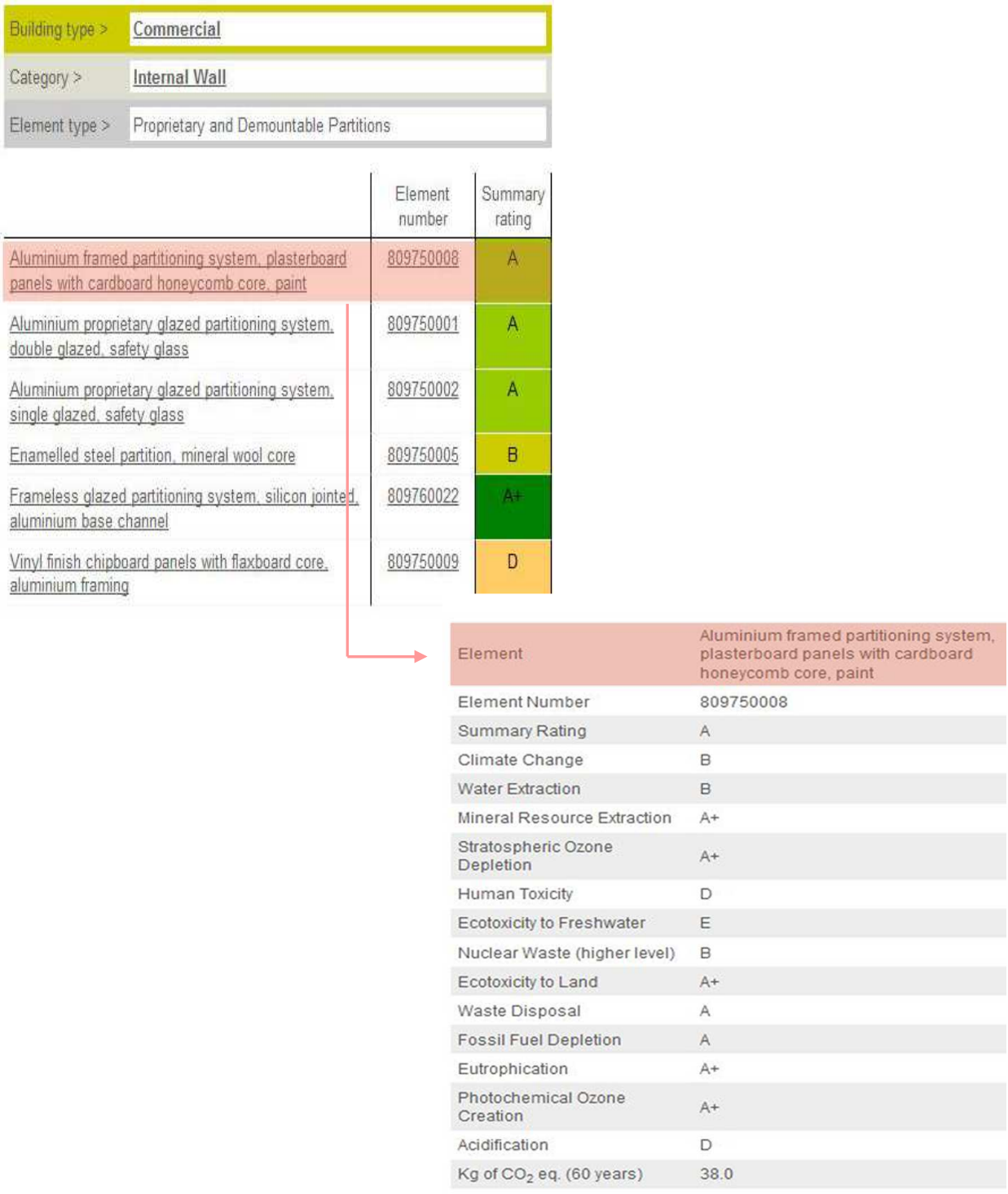


Figure 2: Sections and weighting in BREEAM International. Energy has the greatest weight – 19%, materials accounts for 12,5%.

Appendix 2 – Figure 3



Building type >	Commercial
Category >	Internal Wall
Element type >	Proprietary and Demountable Partitions

	Element number	Summary rating
Aluminium framed partitioning system, plasterboard panels with cardboard honeycomb core, paint	809750008	A
Aluminium proprietary glazed partitioning system, double glazed, safety glass	809750001	A
Aluminium proprietary glazed partitioning system, single glazed, safety glass	809750002	A
Enamelled steel partition, mineral wool core	809750005	B
Frameless glazed partitioning system, silicon jointed, aluminium base channel	809760022	A+
Vinyl finish chipboard panels with flaxboard core, aluminium framing	809750009	D

Element	Aluminium framed partitioning system, plasterboard panels with cardboard honeycomb core, paint
Element Number	809750008
Summary Rating	A
Climate Change	B
Water Extraction	B
Mineral Resource Extraction	A+
Stratospheric Ozone Depletion	A+
Human Toxicity	D
Ecotoxicity to Freshwater	E
Nuclear Waste (higher level)	B
Ecotoxicity to Land	A+
Waste Disposal	A
Fossil Fuel Depletion	A
Eutrophication	A+
Photochemical Ozone Creation	A+
Acidification	D
Kg of CO_2 eq. (60 years)	38.0

Figure 3: Example of the selection of one individual elemental profile on the Green Guide online and the detailed information including the breakdown of ratings across the environmental issues included in the LCA (BRE, 2008).

Appendix 3 – Table 4

BREEAM Rating	% score
UNCLASSIFIED	<30
PASS	≥30
GOOD	≥45
VERY GOOD	≥55
EXCELLENT	≥70
OUTSTANDING	≥85

Table 4: BREEAM rating benchmarks.

Appendix 4 – Table 5

BREEAM Section	**Credits Achieved**	**Credits Available**	**% of Credits Achieved**	**Section Weighting**	**Section Score**
Managment (Man)	7	10	70.0	0.12	8.40%
Health and Wellbeing (Hea)	10	14	71.4	0.15	10.71%
Energy (Ene)	20	21	95.2	0.19	18.10%
Transport (Tra)	8	10	80.0	0.08	6.40%
Water (Wat)	5	6	83.3	0.06	5.00%
Materials (Mat)	0	12	0.0	0.125	0.00%
Waste (Wst)	5	7	71.4	0.075	5.36%
Land Use and Ecology (LE)	6	10	60	0.10	6%
Pollution (Pol)	12	12	100	0.10	10%
Innovation (Inn)	10	10	100	0.10	10%
Final BREEAM score					**79.97%**
BREEAM Rating					**EXCELLENT**

Table 5: Results of BREEAM's scoring and rating process when no credits in the Materials section has been achieved.