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BRE Global Environmental Weighting for Construction Products using Selected Parameters from EN 15804

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Executive Summary

Following the introduction of the European Standard for environmental product declaration of construction products, EN 15804, BRE has undertaken a study (a weightings exercise) to identify weightings for a range of environmental issues. A panel of ten experts was set up to assess the relative importance of eleven parameters representative of the overall environmental impacts of construction products, and their responses have been aggregated to create a single set of weightings.

This Report presents a brief description of the methodology used, the statistical techniques employed, an analysis of the statistical robustness of the weightings obtained, and an explanation of how the weightings can be used in communicating the environmental performance of construction products in BRE decision making tools and building level assessment tools.

1 Introduction

BRE has long worked to improve the sustainability of the built environment particularly through the suite of building-level BREEAM (BRE Environmental Assessment Methodology) schemes [1], and has used Life Cycle Assessment (LCA) as a key method to obtain information on the environmental impacts of construction products. Previously, BRE developed its own construction product environmental evaluation methodology [2] that considered a broad range of environmental impact categories. The methodology was designed to produce Type III environmental product declarations (EPD) for construction products, known as BRE Environmental Profiles.

According to the relevant international standard for third party verified environmental declarations (BS ISO 14025) [3], Type III EPD present a list of quantified environmental impacts caused in certain life cycle stages or throughout the life cycle of a particular product to enable comparisons between products fulfilling the same function. For the range of environmental impacts reported in this methodology using LCA studies, a set of weighting factors were produced by an expert panel. These weightings were used to generate an aggregated eco-indicator (BRE Ecopoints score) which was then used amongst other things to produce a benchmarking scale known as BRE Green Guide ratings. These ratings are presented in BRE's Green Guide to Specification [4], a decision support tool for building designers and specifiers.

New European Standards have since emerged aimed at harmonising the approach to LCA in the construction sector following extensive work by CEN TC 350, amongst which is the EN 15804 [5] for EPD of construction products. BRE has therefore developed a Type III environmental labelling scheme for construction products and services in line with the requirements of EN 15804. The resulting EPD, generated from LCA using BRE's EN 15804 product category rules (PCR) [6] or other valid EN 15804-compliant PCR, are used primarily by manufacturers to communicate the environmental characteristics of their products, and by specifiers in decision making (product selection). The EPD provides data for use in building level calculations according to EN 15978 [7] and in building information modelling (BIM).

Similar to the previous BRE methodology published in 2008, an array of LCA derived parameters describing environmental impacts, resource use, waste categories, and output flows are generated using BRE's EN 15804- and ISO 14025-compliant PCR. In addition to reporting these parameters as required by EN 15804, BRE has also now developed a new aggregated eco-indicator. This additional metric combines eleven parameters (which have been selected by BRE as being representative of the overall environmental impact of the construction products assessed) into a single number, known as **BRE EN Ecopoints**. When used, this single number will allow the complex information presented in the EPD to be more easily interpreted.

In order to create the BRE EN Ecopoints metric and to ensure that it reflects the relative importance of the underlying issues within the European context, the different parameters have been weighted relative to one another using an expert panel in a weightings exercise.

2 The Weightings exercise

2.1 The participants

The weightings have been obtained through the use of a panel of experts who have a broad understanding of the relevant underlying issues, and are able to judge their relative importance objectively. The benefits of using an expert panel are that it:

- Minimises bias – which can arise from factors such as recent press coverage and vested interest;
- Removes skewing of results from specialists in a single area, while ensuring all areas are covered by the combined panel membership;
- Ensures the results are robust and acknowledges the expertise needed to understand the complexity of these issues;
- Provides credibility and greater transparency of the process and results.

A list of the 10 experts that participated in the exercise is provided in Appendix 1. These experts were invited to participate on the basis of their wide-ranging environmental and sustainability knowledge and their local and international perspective.

A parallel weightings exercise was also undertaken with the general public, including representatives from the construction industry and stakeholders, using an open-access version of the same survey as had been completed by the expert panel. The aim of this was to provide a means to engage wider industry stakeholders in the weightings process, thereby providing BRE with a better understanding of the wider industry perspective. In addition, if the analysis of the expert panel responses failed or was inconclusive for example, this would provide a backup body of data from which weightings could still be determined.

2.2 The parameters weighted

The 11 parameters considered in this study are presented in Table 1, along with the definitions provided within the weightings exercise (see Appendix 2 for the basis of this selection). The participants were asked to consider each impact relative to the environmental impact caused by all human activity in Western Europe, including impacts associated with imported products.

Table 1. The parameters considered in the weightings exercise

Abiotic depletion potential for fossil resources (fossil fuels)	ADP-F	Fossil fuels provide a valuable source of energy and feedstock for materials such as plastics. Although there are alternatives, these are only able to replace a small proportion of our current use. Fossil fuels are a finite resource and their continued consumption will make them unavailable for use by future generations.
Abiotic depletion potential for non-fossil resources (elements)	ADP-E	This impact category is related to the extraction of virgin abiotic material e.g. extraction of aggregates, metal ores, minerals, earth etc. The extraction of such substances can mean that the natural carrying capacity of the earth is exceeded, and make them unavailable for use by future generations. The category addresses the scarcity of the element under consideration.
Acidification potential of soil and water	AP	Acidic gases such as sulphur dioxide (SO_2) and nitrogen oxides (NO_x) given off in fuel combustion react with water in the soil or in the atmosphere (where it forms "acid rain"). An acid is a chemical that can produce hydrogen ions (H+, also called a 'proton') when it meets water. Hydrogen ions are highly reactive and can cause other substances to change their composition and their physical properties. Acid deposition can therefore damage ecosystems and erode materials.
Depletion potential of the stratospheric ozone layer	ODP	This is also known as ozone depletion potential. The ozone layer is part of the earth's upper atmosphere (the stratosphere), and damage to the ozone layer by chlorinated and brominated chemicals increases the amount of harmful ultraviolet (UV) light reaching the earth's surface. Although the use of chemicals such as chlorofluorocarbons (CFC) and hydrochlorofluorocarbons (HCFC) have been phased out in Europe following the 1987 Montreal Protocol, much of the existing refrigeration equipment and insulation foam still contains CFCs and HCFCs.
Eutrophication potential	EP	Nitrates and phosphates are essential for life but their increased concentrations in water leads to eutrophication (over-'nutrification') which can encourage excessive growth of algae, reducing the oxygen within the water and damaging ecosystems. Sources include fertilisers and nitrogen oxide (NO_x) emissions from the combustion of fossil fuels.
Formation potential of tropospheric ozone	POCP	This is also known as photochemical ozone creation potential. In atmospheres containing nitrogen oxides (NO_x) and volatile organic compounds (VOCs), ozone can be created in the presence of sunlight. Although ozone is critical in the upper atmosphere to protect against ultraviolet (UV) light, in the earth's lower atmosphere (troposphere) it can create smog, and is implicated in impacts as diverse as crop damage and increased incidence of asthma. VOC sources include solvents (e.g. in paints, glues or cleaning materials), and fuels (e.g. diesel and petrol).
Global warming potential (Climate change)	GWP	Climate change refers to the change in global temperature as a result of the greenhouse effect. "Greenhouse gases" such as carbon dioxide (CO_2), which are released by human activity, remain in the earth's atmosphere and prevent the earth losing heat gained from the sun. This raised global temperature is expected to cause climatic disturbance, desertification, rising sea levels and spread of disease. There is considerable scientific consensus that the increase in the emissions of greenhouse gases is therefore having a noticeable effect on the climate.
Net use of fresh water (parameter describing resource use)	FW	Around the world, water is becoming an increasingly scarce resource, due to increased demand and changes in patterns of rainfall. The abstraction of water from rivers, reservoirs and aquifers can cause the depletion, and disruption or pollution of these water sources. This metric therefore recognises the value of water, and the damage that over-extraction from rivers and aquifers can cause.

Table 1. The parameters considered in the weightings exercise

Hazardous waste disposed (parameter describing waste categories)	HWD	Hazardous waste is that defined within existing applicable legislation, e.g. in the European Waste Framework Directive. This metric reports the quantity of hazardous waste generated and disposed in final disposal.
Non-hazardous waste disposed (parameter describing waste categories)	NHWD	This metric reports the quantity of non-hazardous waste generated and disposed in final disposal.
Radioactive waste disposed (high level) (parameter describing waste categories)	RWDHL	Radioactivity can cause serious damage to human health, and as yet, no treatment or permanently secure storage solution exists for higher level radioactive wastes, such as that generated by the nuclear power industry and from decommissioning nuclear power stations. It arises from spent fuel which is highly radioactive (accounting in total for more than 99% of the radioactivity attributed to the nuclear industry) and requires storage for at least 1,000 years before it may be safe.

2.3 The Survey

The weightings exercise for both the expert panel and the general public (non-experts) was conducted using an online survey. Participants were first asked to select their professional sectors from a list provided, and then to rate their knowledge on each of the 11 parameters described in Table 1 above. Figures 1 and 2 show the stakeholders in the survey responses received from all participants.

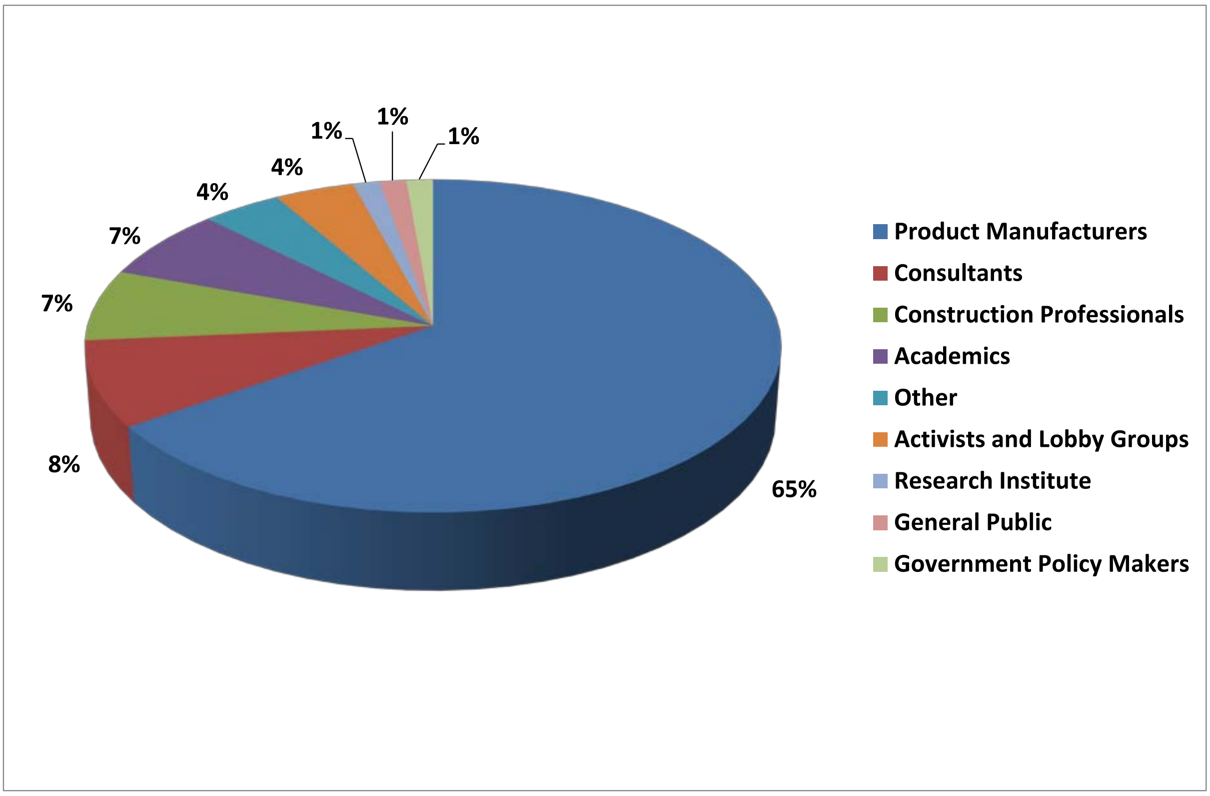


Figure 1. Stakeholders represented in the survey responses received

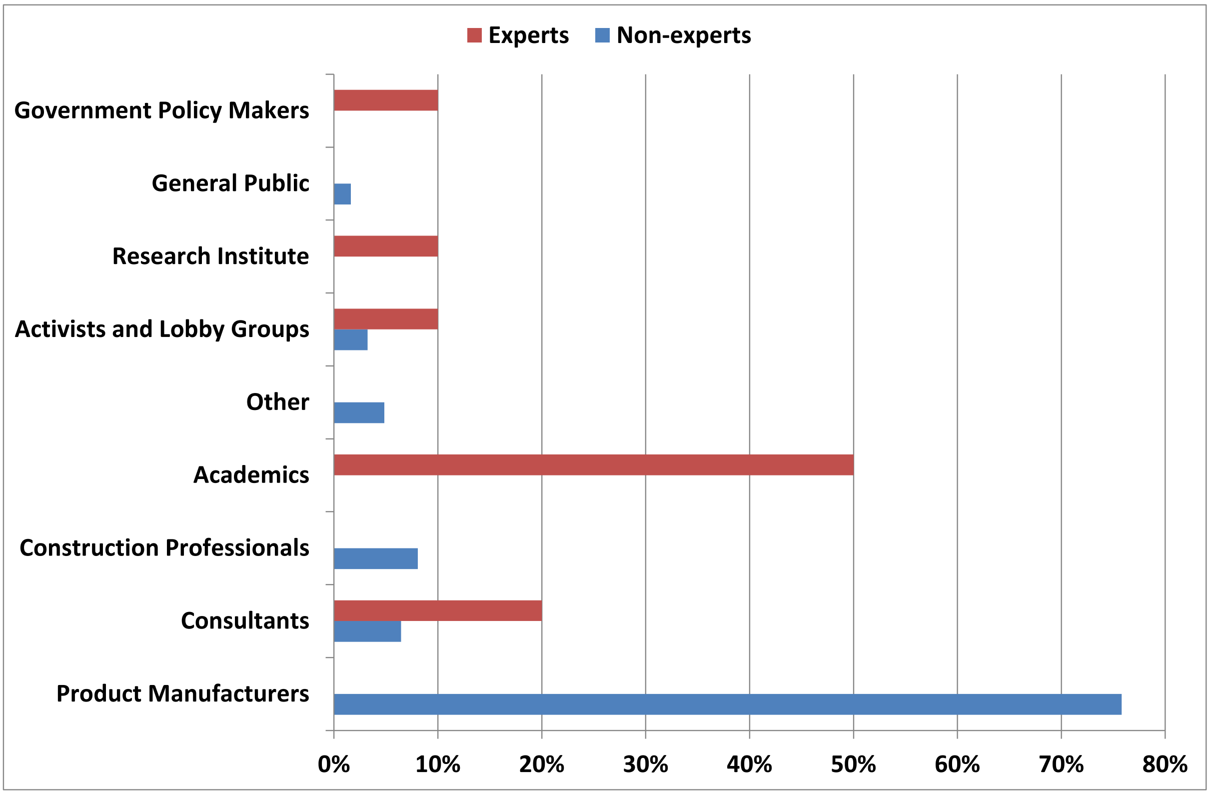


Figure 2. Distribution of participants: Experts and Non-experts

The weightings were then obtained using a method called *paired comparison* in which each parameter was valued relative to every other parameter in pairs. The pairs were presented in random order and the comparisons were on a 9-point scale. Extracts of the online survey are presented in Appendix 3.

3 Analysis and Results

The application of weights to the 11 parameters provides a mechanism for indicating how the impacts of each issue compares to any other. The generation of the weights and the subsequent prioritisation of the issues in terms of their impact required the assessment of the parameters using an appropriate technique for assessing multiple criteria. Multi-criteria decision-making (MCDM) methods provide several techniques for this sort of assessment.

The discipline of MCDM provides decision makers with standardised methodologies with which to make decisions that are complex in nature, based as they are on many criteria. There are a number of techniques available, one of the most popular of which is analytic hierarchy process (AHP). AHP uses fuzzy logic to make sense of value judgements, providing an established and standardised approach to the derivation of a set of weights. The analysis is both open and explicit, providing transparency of process.

3.1 The Analysis

84 responses were received in total, of which only 60 were valid. Invalid responses are those where the same rating for all comparisons have been given by the respondent or there was insufficient information provided, i.e. partial completions or blank submissions.

The 60 valid responses were provided by 9 expert responses and 51 non-expert (stakeholders from the general public that completed the open-access survey) responses.

Expertise
Respondents were asked to indicate their level of knowledge on each issue under consideration, on a five-point scale where 1 = no knowledge and 5 = expert knowledge. Responses are presented in Figures 3 and 4. As expected, all of the experts had some knowledge of all of the issues. Seven out of the nine reported reasonable expert knowledge of eight of the eleven issues under consideration. In contrast, the level of knowledge of the issues amongst the 51 stakeholders was more variable. Stakeholders reported higher level of knowledge of global warming and very little knowledge of radioactive waste disposed. For each issue under consideration, between one and ten stakeholders reported having no knowledge of the area.

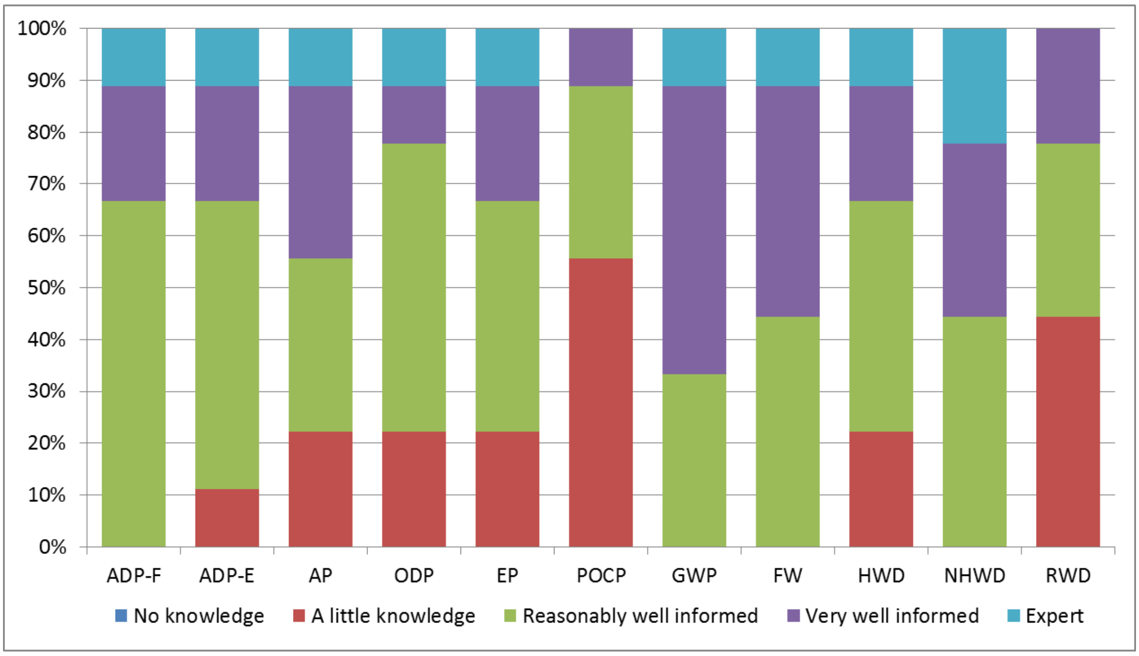


Figure 3. Self-reported levels of expertise in the expert group

Self-reported assessments of expertise are not as robust as independent assessments. Experience suggests that experts may somewhat under report their levels of expertise while those considered not to be experts would be more likely to over report their level of expertise. However, the reporting presented in Figures 3 and 4 gave an indication of where there are potential gaps in understanding of the issues and allowed for some sensitivity analysis on the generated weights.

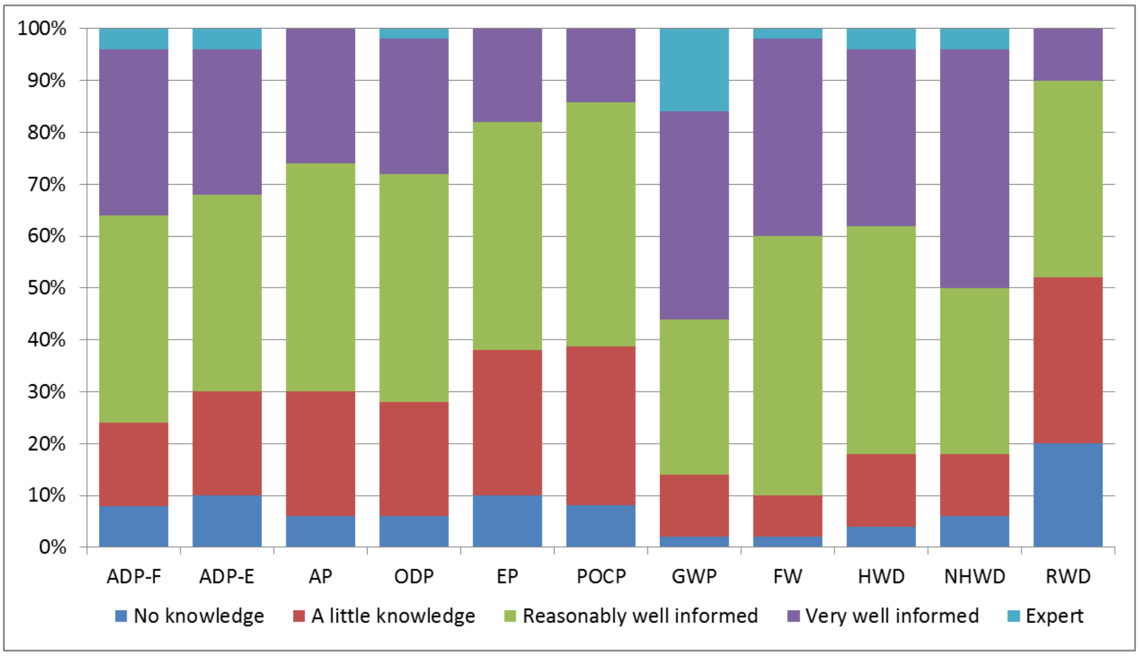


Figure 4. Self-reported levels of expertise in the stakeholder group

3.1.1 Reliability – Inter-rater reliability

Reliability analysis was used to investigate inter-rater reliability, otherwise known as the level of agreement between the expert responses. Inter-rater reliability demonstrates the degree of concordance, i.e. how much consensus there is among a group of raters/judges. The expectation is that there will be some differences in opinion but that on the whole responses will be consistent. The analysis is therefore checking for consistency of response as opposed to absolute agreement between the experts.

The intraclass correlation coefficient, (calculated for a 2-way random effects model), for the average expert measures was 0.774 with a 95% confidence interval of 0.672 to 0.854. This value rose to 0.808 with a 95% confidence interval of 0.721 to 0.826 with the removal of responses from Expert 10. The results implied that despite some differences in scoring, there was a good degree of homogeneity between the expert judgements, i.e. that their ratings were on the whole consistent.

Table 2. Intraclass Correlation Coefficients

		Intraclass correlation[b]	95% Confidence Interval		F Test with True Value 0			
			Lower Bound	Upper Bound	Value	df1	df2	Sig
Expert	Single Measures	.345[a]	.244	.469	5.213	54	378	.000
	Average Measures	.808[c]	.721	.876	5.213	54	378	.000
Stakeholder	Single Measures	.115[a]	.079	.173	7.464	54	2700	.000
	Average Measures	.869[c]	.815	.914	7.464	54	2700	.000

Two-way mixed effects model where people effects are random and measures effects are fixed
a. The estimator is the same, whether the interaction effect is present or not
b. Type C intraclass correlation coefficients using a consistency definition. The between measure variance is excluded from the denominator variance
c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

A similar exercise undertaken on the stakeholder group revealed that their ratings were also largely consistent, yielding an intraclass correlation coefficient of 0.896 with a 95% confidence interval of 0.815 to 0.914. The fact that the vast majority (76%) of stakeholders are product manufacturers may account for this group having greater consensus than the expert group.

3.1.2 Analytic hierarchy process (derivation of weights)

The weights were derived using analytic hierarchy process (AHP) for the experts and separately for stakeholders. The formula used to calculate the weightings are provided in Appendix 4. The process involved constructing a matrix which expressed the relative values of the parameters. The scale used in the matrix, Table 3, allowed for judgements where if attribute A is absolutely more important than attribute B and is rated 9, then B must be rated absolutely less important than A and is valued at 1/9. The scale was mapped onto all parameter comparisons and Eigenvectors were used to calculate the relative weights.

Table 3. Common AHP scale [8]

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more important	Experience and judgement slightly favour one over the other
5	Much more important	Experience and judgement strongly favour one over the other
7	Very much more important	Experience and judgement very strongly favour one over the other. Its importance is demonstrated in practice
9	Absolutely more important	The evidence favouring one over the other is of the highest possible validity

A consistency ratio calculation was made for each respondent and was used to measure the consistency of judgements relative to random judgements. Whereas inter-rater reliability looked at agreement between raters, AHP looked at internal consistency within the person rating. If the consistency ratio is below 0.1, judgements are said to be consistent.

This AHP assumed that the individuals who took part in the exercise are ‘informed’ on the topics upon which they are commenting. It was not possible to make that assumption about the stakeholder group. Therefore, the cut off consistency ratio for this group was set at 0.3. AHP allows for this when circumstances dictate, although it is noted that while ratings with a consistency ratio greater than 0.1 may be accepted they may also be less trustworthy [8]. Those respondents that were not considered to have internal consistency were screened out and the remaining respondent weightings were used for group based judgements. This resulted in a final working data set of 45 stakeholders.

3.1.3 Sensitivity

The weights generated for the expert group and for the stakeholder (non-expert) group showed some differences in opinions in how the 11 parameters should be prioritised, see Figure 5 below.

Between the experts and the stakeholders there was an apparent difference in the weightings allocated to those issues considered to have the greatest and the smallest impacts. This difference in views may be due to the composition of the groups, as over three quarters of the stakeholder group were product manufacturers.

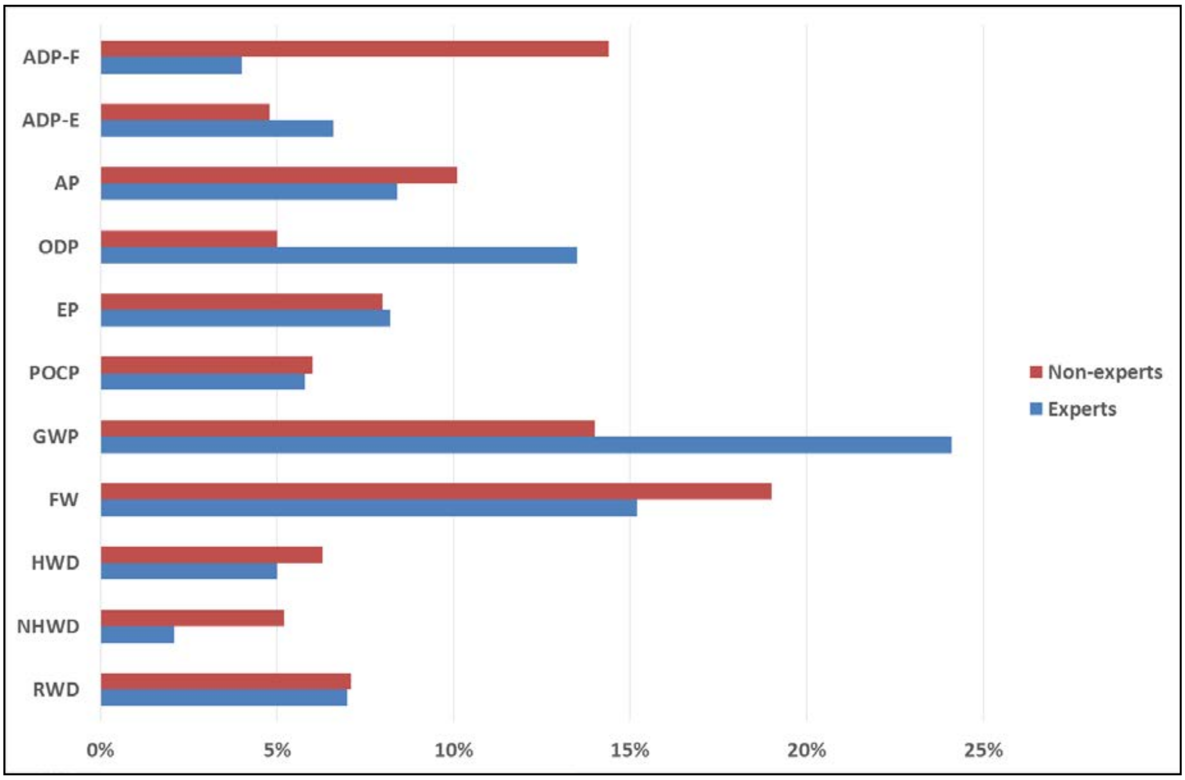


Figure 5. Comparing expert and non-expert responses

Alternative group constructs were assessed to gauge the sensitivity of the weights. Alternative groups considered include but are not limited to:

- All experts
- Subset of experts with the highest inter-rater reliability
- Subset of experts that rated themselves as being reasonably well informed for at least 8 parameters
- All stakeholders
- Subset of stakeholders with the highest inter-rater reliability
- Subset of stakeholders that rated themselves as being reasonably well informed for at least eight parameters
- Subset of stakeholders who are product manufacturers
- Subset of stakeholders who are not product manufacturers

While each group yielded different sets of priorities, there were some commonalities observed across the board. Non-hazardous waste disposal was consistently considered to be least important and global warming was almost always considered to be most important.

Sensitivity analysis of the expert groups showed that the top and bottom three issues considered to have the greatest and least impacts respectfully, were often the same, even if the order might change. Sensitivity analysis of the stakeholder groups showed greater variation in how priorities were set.

3.2 The Results

The weightings exercise showed that the expert perceptions of the impact of the issues measured by the 11 parameters is reasonably consistent across different breakdowns. There is a general hierarchy across the issues, which implies that global warming, net use of fresh water and depletion potential of the stratospheric ozone layer are most important and that hazardous waste disposed, abiotic depletion potential for fossil fuel resources and non-hazardous waste disposed are least important on average. The final results of the weightings exercise are as shown in Table 4.

Table 4. Final weightings results of the 2015 exercise based on the results of the expert group

Ranking	Parameter		Weighting (%)
1	Global warming potential (Climate change)	GWP	24.1
2	Net use of fresh water (parameter describing resource use)	FW	15.2
3	Depletion potential of the stratospheric ozone layer	ODP	13.5
4	Acidification potential of soil and water	AP	8.4
5	Eutrophication potential	EP	8.2
6	Radioactive waste disposed* (parameter describing waste categories)	RWD	7.0
7	Abiotic depletion potential for non-fossil resources (elements)	ADP-E	6.6
8	Formation potential of tropospheric ozone	POCP	5.8
9	Hazardous waste disposed (parameter describing waste categories)	HWD	5.0
10	Abiotic depletion potential for fossil resources (fossil fuels)	ADP-F	4.0
11	Non-hazardous waste disposed (parameter describing waste categories)	NHWD	2.1

* This was referred to as high level radioactive waste disposed in the survey, but is applied to radioactive waste disposed, as this is the parameter to be reported in EN 15804, for consistency

4 How the weightings can be used

The weightings enable the generation of BRE EN Ecopoints which can be used (by construction product manufacturers) in product differentiation and sustainability reporting and (by all other stakeholders) in product selection and comparison – subject to specific conditions for the use of LCA study results in product comparison. To obtain the BRE EN Ecopoints, as used in the BRE methodology, the characterised data obtained from an EN 15804 compliant LCA study for the 11 parameters weighted are referenced to the impact for each issue for one European citizen per year using appropriate European normalisation factors, and the normalised impact values so obtained are multiplied by the weighting factors shown in Table 4 developed for the respective 11 parameters. The results are then summed to give a single score.

When used in an appropriate comparative assessment of construction products or buildings, higher BRE EN Ecopoints scores indicate higher environmental impacts. Currently, BRE EN Ecopoints scores are used in BRE's IMPACT specification and database for building level assessments.

In a BRE generated EN EPD, the corresponding BRE EN Ecopoints score can be added as additional information – as this does not form a standard part of the EPD communication as required by EN 15804.

5 Conclusions

BRE has successfully carried out a weightings exercise to determine the relative importance of a selected number of issues using their respective parameters from the EN 15804 standard. The results of the weightings exercise show that the topmost issues of concern continue to be in terms of the carbon footprint and the water footprint, conveyed through the global warming potential (climate change) parameter and the net use of fresh water parameter respectively. These two issues were the same leading issues in the previous BRE weightings exercise published in the BRE 2008 methodology, indicating that while knowledge and understanding has progressed over the years, the overall perception of the issues of importance has not changed significantly.

However, it is to be noted that the data and findings from this research are time- and information-dependent, and are therefore subject to varying degrees of change in future exercises.

Appendices

Appendix 1 – The Expert Panel members

Table Appendix 1. Expert Panel members

Paul Leinster – Chief Executive, Environment Agency
Ian Boyd – Chief Scientist, Department for Environment, Food & Rural Affairs (DEFRA)
Ioannis Ioannou – Professor of Strategy and Entrepreneurship, London Business School
Martin Nesbit – Senior Fellow and Head of Environmental Governance Team, IEEP
James Cadman – Lead Consultant, Action Sustainability
Ariel Brunner – Head of EU Policy, BirdLife Europe
Stephen Smith – Professor of Bioresource Systems, Imperial College London
Margaret Bates – Professor of Sustainable Wastes Management, University of Northampton
Mark Goedkoop – CEO of PRé Consultants
Nick Voulvoulis – Reader in Environmental Technology, Imperial College London

Appendix 2 – Selection of Parameters

The following table is a summary of the justification in the selection of the 11 parameters included in the weightings exercise. The conditions applied were that the parameters selected:

- could be calculated reliably;
- would use commonly available LCA databases;
- use an internationally agreed standardised / accepted methodology for calculating impacts;
- are directly or inversely linked to environmental impacts;
- in combination, provide a broad coverage of the issues, without introducing bias by double counting benefits and burdens.

Table Appendix 2. Selection of Parameters

Parameter	Finding	Include?
Parameters describing environmental impacts		
Global warming potential (Climate change), GWP	Well established effect not addressed by another parameter	Yes
Depletion potential of the stratospheric ozone layer, ODP	Well established effect not addressed by another parameter	Yes
Acidification potential of soil and water, AP	Well established effect not addressed by another parameter	Yes
Eutrophication potential, EP	Well established effect not addressed by another parameter	Yes
Formation potential of tropospheric ozone, POCP	Well established effect not addressed by another parameter	Yes
Abiotic depletion potential for non-fossil resources (elements), ADP-E	New approach to assessing non-renewable resource consumption	Yes
Abiotic depletion potential for fossil resources (fossil fuels), ADP-F	New approach to assessing non-renewable resource consumption	Yes

Table Appendix 2. Selection of Parameters

Parameter	Finding	Include?
Parameters describing resource use		
Use of renewable primary energy excluding renewable primary energy resources used as raw materials, PERE	Captured in other impact parameters. Upstream data sets may not categorise primary energy mixes in this way	No
Use of renewable primary energy resources used as raw materials, PERM	Linked to fossil fuel combustion. Upstream data sets may not categorise primary energy mixes in this way	No
Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials), PERT	Captured elsewhere – see ADP-F. Upstream data sets may not categorise primary energy mix in this way	No
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials, PENRE	Captured elsewhere – see ADP-F & GWP. Upstream data sets may not categorise primary energy mix in this way	No
Use of non-renewable primary energy resources used as raw materials, PENRM	Captured elsewhere – see ADP-F. Upstream data sets may not categorise primary energy mix in this way	No
Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials), PENRT	Captured elsewhere – see ADP-F. Upstream data sets may not categorise primary energy mix in this way	No
Use of secondary material, SM	Captured elsewhere. Not always proportional to % in product, benefits may also outweigh loads and vice versa	No
Use of renewable secondary fuels, RSF	Captured elsewhere. Benefits may also outweigh loads and vice versa	No
Use of non-renewable secondary fuels, NRSF	Captured elsewhere. Benefits may also outweigh loads and vice versa	No
Net use of fresh water, FW	A very important parameter, with increasing national, and international focus	Yes
Parameters describing waste categories		
Hazardous waste disposed, HWD	Very important	Yes
Non-hazardous waste disposed, NHWD	Very important	Yes
Radioactive waste disposed (Total), TRWD	Characterisation factors potentially highly variable	No
Radioactive waste disposed (high level), RWDHL	Very important, not captured elsewhere. A BRE parameter	Yes
Parameters describing other output flows		
Components for re-use, CRU	Captured elsewhere, can help with interpretation of EPD and specific product assessment and modelling in building scenarios, but not linked to environmental impacts	No
Materials for recycling, MFR	Captured elsewhere, can help with interpretation of EPD and specific product assessment and modelling in building scenarios, but not linked to environmental impacts	No
Materials for energy recovery, MER	Captured elsewhere, can help with interpretation of EPD and specific product assessment and modelling in building scenarios, but not linked to environmental impacts	No
Exported energy, EE	Captured elsewhere, can help with interpretation of EPD and specific product assessment and modelling in building scenarios, but not linked to environmental impacts	No

Appendix 3 – Extracts from the online survey

BRE Weightings Exercise - Environmental Parameter Definitions

What are the selected environmental parameters measuring?

Brief descriptions of the 11 environmental metrics (impact categories) are given below, to show what is being measured in each case.

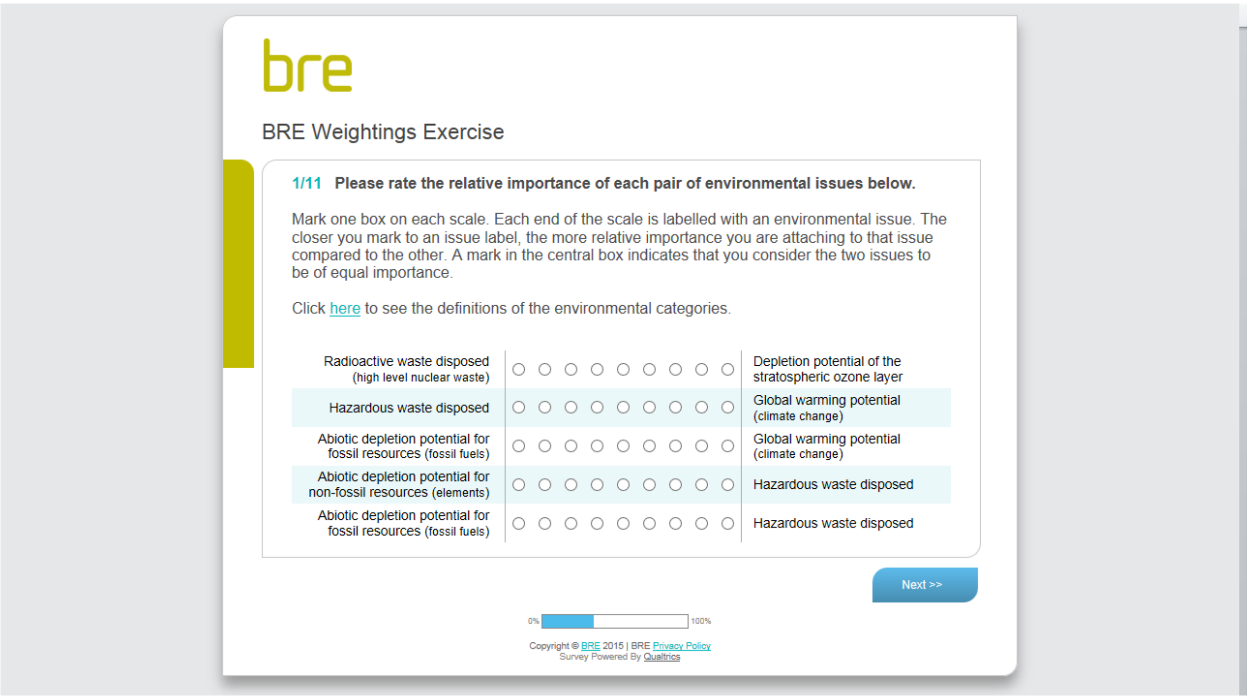
- **Abiotic depletion potential for fossil resources (fossil fuels)**
  Fossil fuels provide a valuable source of energy and feedstock for materials such as plastics. Although there are alternatives, these are only able to replace a small proportion of our current use. Fossil fuels are a finite resource and their continued consumption will make them unavailable for use by future generations.

- **Abiotic depletion potential for non-fossil resources (elements)**
  This impact category is related to the extraction of virgin abiotic material e.g. extraction of aggregates, metal ores, minerals, earth etc. The extraction of such substances can mean that the natural carrying capacity of the earth is exceeded, and make them unavailable for use by future generations. The category addresses the scarcity of the element under consideration.

- **Acidification potential of soil and water**
  Acidic gases such as sulphur dioxide (SO_2) and nitrogen oxides (NO_X) given off in fuel combustion react with water in the soil or in the atmosphere (where it forms "acid rain"). An acid is a chemical that can produce hydrogen ions (H+, also called a 'proton') when it meets water. Hydrogen ions are highly reactive and can cause other substances to change their composition and their physical properties. Acid deposition can therefore damage ecosystems and erode materials.

- **Depletion potential of the stratospheric ozone layer**
  This is also known as ozone depletion potential. The ozone layer is part of the earth's upper atmosphere (the stratosphere), and damage to the ozone layer by chlorinated and brominated chemicals increases the amount of harmful ultraviolet (UV) light reaching the earth's surface. Although the use of chemicals such as chlorofluorocarbons (CFC) and hydrochlorofluorocarbons (HCFC) have been phased out in Europe following the 1987 Montreal Protocol, much of the existing refrigeration equipment and insulation foam still contains CFCs and HCFCs.

- **Eutrophication potential**



BRE Weightings Exercise

1/11 Please rate the relative importance of each pair of environmental issues below.

Mark one box on each scale. Each end of the scale is labelled with an environmental issue. The closer you mark to an issue label, the more relative importance you are attaching to that issue compared to the other. A mark in the central box indicates that you consider the two issues to be of equal importance.

Click here to see the definitions of the environmental categories.

Radioactive waste disposed (high level nuclear waste)	○ ○ ○ ○ ○ ○ ○ ○ ○	Depletion potential of the stratospheric ozone layer
Hazardous waste disposed	○ ○ ○ ○ ○ ○ ○ ○ ○	Global warming potential (climate change)
Abiotic depletion potential for fossil resources (fossil fuels)	○ ○ ○ ○ ○ ○ ○ ○ ○	Global warming potential (climate change)
Abiotic depletion potential for non-fossil resources (elements)	○ ○ ○ ○ ○ ○ ○ ○ ○	Hazardous waste disposed
Abiotic depletion potential for fossil resources (fossil fuels)	○ ○ ○ ○ ○ ○ ○ ○ ○	Hazardous waste disposed

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Appendix 4 – AHP Formula [8] [9]

Calculation of the eigenvector was achieved using the eigenvector method. A pair-wise comparison (judgement) matrix, for an individual respondent (the k[th] decision maker) is given by $A^{[k]}$ and the corresponding priority vectors (weights) are given by $\omega^{[k]}$, where:

$$A^{[k]} = \left(a_{ij}^{[k]}\right) \forall\, i, j\ \in \{1, n\}$$

$$\omega^{[k]} = (\omega_1^{[k]}, \omega_2^{[k]}, \dots, \omega_n^{[k]}), where\ \omega_i^{[k]} > 0\ and \sum\nolimits_{i=1}^{n} \omega_i^{[k]} = 1$$

To calculate the priority vector ($\omega^{[k]}$) the n[th] root method is used as illustrated below:

$$\omega_i^{[k]} = \frac{x_i^{[k]}}{\sum_{i=1}^{n} x_i^{[k]}}\ where\ x_i^{[k]} = \sqrt[n]{\prod_{j=1}^{n} a_{ij}}$$

$$\omega^{[k]} = (\omega_1^{[k]}, \omega_2^{[k]}, \dots, \omega_n^{[k]})$$

The steps above calculate priority vectors (weightings) for each individual, these are tested for consistency using the Consistency Index (CI) and Consistency Ratio (CR), where:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

$$CR = \frac{CI}{RI}$$

Derived values of RI for values of n are provided in a look up table, this has been reproduced in the table below.

Table Appendix 4 Saaty index of consistency for random judgements [8]

n	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51

The weighted geometric mean method (WGMM) is used to aggregate individual priorities and create group matrices, given below:

$$A^{[G]} = \left(a_{ij}^{[G]}\right), where\ a_{ij}^{[G]} = \prod_{k=1}^{r} \left(a_{ij}^{[k]}\right)^{\beta k}, i, j \in \{1, n\}$$

The groups aggregated priority vector is given by $\omega^{[G]} = \left(\omega_i^{[G]}\right), i \in \{1, n\}$, where:

$$\omega_i^{[G]} = \prod_{k=1}^{r} \left(\omega_i^{[k]}\right)^{\beta k}, and\ \omega_i^{[k]} = \left(\prod_{j=1}^{n} a_{ij}^{[k]}\right)^{\frac{1}{n}} \forall\ i \in \{1, n\}$$

This method will be used to produce group matrices and priority vectors for groups e.g. experts, stakeholders, stakeholders with high level of knowledge, etc.

References

[1] http://www.breeam.org/

[2] BRE. BRE Methodology for Environmental profiles of Construction Products: Product Category Rules for Type III environmental product declaration of construction products. SD 6050. Watford, BRE, 2007. http://www.bre.co.uk/filelibrary/greenguide/PDF/Methodology_for_Environmental_Profiles_2008_SD6050.pdf

[3] BSI. Environmental labels and declarations – Type III Environmental declarations – Principles and procedures. BS ISO 14025:2010. London, BSI, 2010.

[4] Anderson J, Shiers D and Steele K. The Green Guide to Specification. BRE BR 501. Bracknell, IHS BRE Press, and Oxford, Wiley-Blackwell, 2009, 4th edn.

[5] BSI. Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products. BS EN 15804:2012+A1:2013. London, BSI, 2013.

[6] BRE Global Product Category Rules for Type III environmental product declaration of construction products to EN15804. PN514. Watford, BRE, 2014. http://www.bre.co.uk/enepd/

[7] BSI. Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method. BS EN 15978:2011. London, BSI, 2012.

[8] Coyle G. The Analytic Hierarchy Process (AHP). 2004. Retrieved from: http://www.booksites.net/download/coyle/student_files/AHP_Technique.pdf.

[9] Ssebuggwawo D, Hoppenbrouwers S and Proper E. Group Decision Making in Collaborative Modeling: Aggregating Individual Preferences with AHP. 2009. Retrieved from: http://www.win.tue.nl/eis2010/lib/exe/fetch.php?media=2009:z-ssebuggwawo.pdf .