Insulation for Environmental Sustainability in BREEAM

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AAR4817 - Use and Operation of Zero Emission Buildings

Summary

This research essay questions if the insulation criteria used in BREEAM actually improves environmental sustainability. This essay consists of mainly three parts. First, it is a studying of BREEAM criteria and weighting. A BREEAM standard covers ten categories of sustainability and material is one of them. Second, this essay focuses on insulation issues, so in this part, the author goes depth into insulation criteria and there are some research findings in BREEAM. Third, it is a case study which indicates how insulation criteria in BREEAM could help reduce the environmental impact in a real project. Finally, the author concludes the advantages and disadvantages of insulation criteria in BREEAM and provides some suggestions for the improvement of BREEAM in the future.

Keywords: *BREEAM (Building Research Establishment's Environmental Assessment Method); Embodied CO_2 eq emissions; Responsible Sourcing; Environmental Sustainability;*

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Glossary

Global Warming (Appendix C)

Embodied CO_2 Emissions The term "embodied CO_2 emissions" is defined as CO_2 emitted at all stages of a product's manufacturing process, from the extraction of raw materials through the distribution process, to the final product provided to the consumer (Kejun et al, 2008). It is noted that "embodied CO_2 emissions" can be referred to in two ways: CO_2 only and CO_2 equivalent (CO_2 eq) which includes CO_2 and other greenhouse gases (GHGs). In this study, we included all GHGs (i.e., CO_2, CH_4, N_2O etc), which means we choose the CO_2 eq emissions, since this is a more common measure than CO_2 emissions only.

Green Guide: The *Green Guide to Specification* is an easy-to-use comprehensive reference website and electronic tool, providing guidance for specifiers, designers and their clients on the relative environmental impacts for a range of different building elemental specifications. The ratings within the Guide are based on Life Cycle Assessment, using the Environmental Profile Methodology (BREEAM, 2009).

Insulation Index: A measure of performance used in BREEAM that seeks to assess the thermal properties of insulation products used in the building relevant to the embodied impact of that insulating material (BREEAM, 2009).

Insulation Index Calculator Tool: A spreadsheet tool used by the BREEAM assessor to determine the Insulation Index and therefore, whether the BREEAM credit is achieved (BREEAM, 2009).

Ecopoint: The Ecopoint used in the Green Guide online is single score that measures the total environmental impact of a product or process as a proportion of overall impact occurring in Europe - 100 Ecopoints is equivalent to the impact of a European Citizen. Green Guide ratings are derived by sub-dividing the range of Ecopoints/m2 achieved by all specifications considered within a building element (BREEAM, 2009).

Weighting: Since people have different views and different levels of understanding of environmental issues, a standardised procedure for assigning relative importance to different environmental impacts is required if there is to be a consistent basis for decision making. This procedure is known as weighting (BREEAM, 2009).

Responsible sourcing: The promotion and support of responsible practices throughout the supply chain demonstrated by actions and behaviour consistent with responsible sourcing principles (BREEAM, 2009).

Supply chain: System of individuals, organizations and resources involved in developing the different elements of a product (BREEAM, 2009).

1. Introduction

The main research topic in this essay is if the insulation criteria in BREEAM help to improve the environmental sustainability of buildings.

The aim of this essay is to assess the criteria and weighting of insulation materials in BREEAM (Building Research Establishment's Environmental Assessment Method). And at the same time, assess the strengths and weakness of BREEAM, and then provide recommendations on how to improve this assessment method. Finally, a case study will be analysed to establish how this method applies in a real project.

The theories in this essay are based on the BREEAM International 2009 version and Green Guide 2008 rating.

1.1 Sustainable buildings

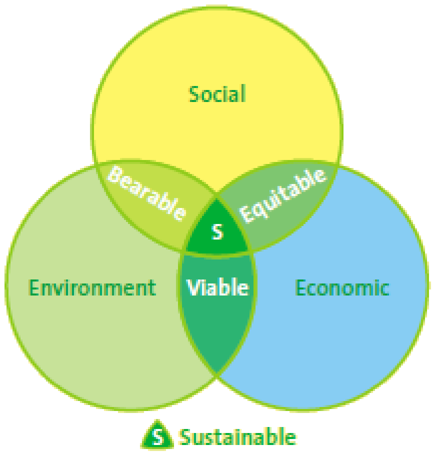

Figure 1: Sustainable development (Isover, 2009)

The Brundtland report (1987) (Figure 1) shows the three main aspects of sustainable development: environment, society and economy. Applying the Brundtland definition to the building sector, sustainable construction could be described as the process of developing built environments that balance economic viability with conserving resources, reducing environmental impacts and taking into account social aspects (Isover, 2009). But the scope of this paper mainly focuses on the environmental issues.

1.2 Building Materials for Environmental Sustainability

Materials are used throughout a building's life time, and they have substantial impacts to the environment during buildings' construction, maintenance, refurbishment and demolition. These impacts include the embodied impact of materials itself, and operational influences after buildings are built. Specifically, the type of materials will directly affect the energy consumption of a building in use which is related to CO_2 emissions which must result in Climate Change, since the U-value of materials decide the heat loss and the heat gain of building elements, which affects the energy demand of a building. That energy consumption will result in the operational CO_2 emissions to the surroundings.

However, the embodied emissions have increasingly outweighed the operational carbon emissions, this is shown in Figure 2. Figure 2 below presents the past and forecast development of the split between embodied and operational carbon emissions. It can be seen that if in the 1970s ignoring embodied carbon could be justified by its low importance compared to operational carbon, 40 years later, the situation is considerably different as new buildings are far more energy-efficient. This increase in the relative importance of embodied carbon is moreover likely to continue as 'zero' (operational) carbon buildings become the norm (2016 for dwellings and 2019 for offices) (Thirison, 2010).

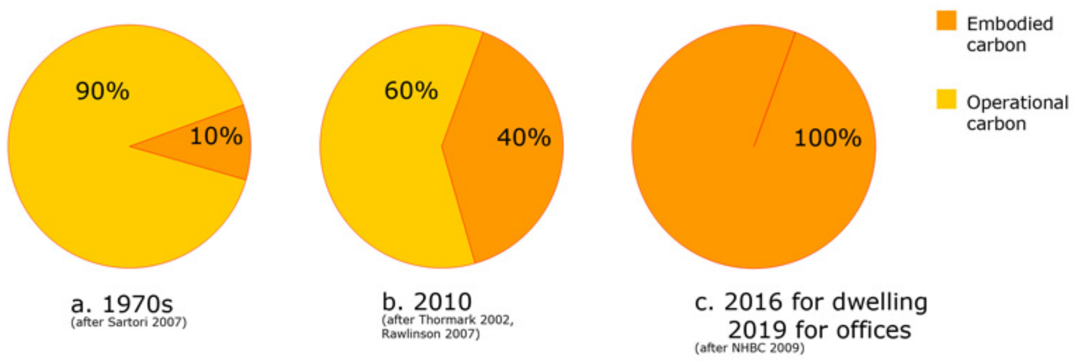

Figure 2: Summarises the past and projected evolution of the split between operating and embodied carbon in buildings (Thirion, 2010)

Further, some materials contain toxic composition which is harmful to the Climate Change.

1.3 Insulation for sustainability

Insulation is a fundamental component to any energy-efficient and sustainable building. The type of insulation and its thickness needs to be considered for the design of sustainable buildings, but what is the most environmental sustainable option?

Some sustainable assessment codes such as Energy Labelling Scheme and Norwegian Passive House Standard mainly focus on energy performance of buildings, but BREEAM which is an environmental assessment method and rating system for buildings sets the standard for best practice in environmental building design, construction and operation.

2. Methodology (Insulation)

Within BREEAM, there are 2 available credits relating to insulation materials specification. In the first case, one credit where evidence provided demonstrates that thermal insulation products used in the building have a low embodied impact relative to their thermal properties. This is determined by the ratings contained The Green Guide to Specification. In the second case, one credit where evidence has been provided to demonstrate that thermal insulation products used in the building has been responsibly sourced.

2.1 First credit – Embodied Impact

The assessment criteria for this credit include (BREEAM, 2009):

1. Any new insulation specified for use within the building elements, including External walls, Ground floor, Roof and Building services must be assessed:

2. The Green Guide rating for the thermal insulation materials must be determined.

3. Where the Insulation Index for the building insulation is the same as or greater than 2.

4. The Insulation Index is calculated using the Insulation Index Calculator Tool in the BREEAM assessor's spreadsheet tool. For each type of thermal insulation used in the relevant building elements, the volume weighted thermal resistance provided by each type of insulation is calculated as follows:

a. (Area of insulation (m^2) * thickness (m)) / Thermal Conductivity (W/ mK) **OR**

b. Total volume of insulation used (m^3) / Thermal conductivity (W/mK)

The volume weighted thermal resistance for each insulation material is then multiplied by the relevant Green Guide point(s) from Table 1:

Green Guide Rating	Points/element
A+	3
A	2
B	1
C	0.5
D	0.25
E	0

Table 1: Green Guide rating points/element (BREEAM, 2009)

To calculate the Insulation Index, the sum of these values is divided by the sum of the volume weighted thermal resistance values.

2.2 Second credit – Responsible Sourcing (BREEAM, 2009)

In BREEAM, the second credit can be achieved if at least 80% of the thermal insulation used in the building elements (external walls, roof, ground floor and building services) is responsibly sourced. Responsible Sourcing material (RSM) could be check on the Green Book Live website. Table 2 shows the key processes and supply chain processes required for common insulation products, it provides some information to users and manufacturers. For example, if it is more than 50% recycled insulation, it would be responsible sourcing.

Material	Key Process	Supply chain processes
Foam Insulation	Insulation manufacture	Principal Polymer production, e.g. Polystyrene, MDI , Phenolic resin or equivalent
Stone wool, glass & cellular glass made using < 50% recycled input	Product manufacture	Any quarried or mined mineral over 20% of input
Wool	Product manufacture	Wool Scouring
Products using > 50% recycled content except those using timber	Product manufacture	Recycled content by default
Timber-based insulation materials including those using recycled timber	Product manufacture	Recycled timber by default, all other timber from one of the recognised timber certification schemes in Table 13.
Other renewable-based insulation materials using agricultural by-products (e.g. straw)	Product manufacture	By-product manufacture by default
Any other product	Product manufacture	1 or 2 main inputs with significant production or extraction impacts should be identified

Table 2: Responsible sourcing criteria for insulation products (BREEAM, 2009)

3. Research and Findings about Insulation Criteria

3.1 Research about Green Guide to Specification

BREEAM uses The Green Guide to Specification to consider the embodied environmental impacts of different specification options and awards credits for using specifications that minimising environmental impact.

3.1.1 Green Guide rating

The impact assessed in BREEAM, not just embodied energy or embodied carbon, but also assesses 13 other impacts and there is a weighting for different environmental issues (Table 3):

Environmental Issue	Weighting (%)
Climate Change	21.6
Water extraction	11.7
Mineral extraction	9.8
Stratospheric ozone depletion	9.1
Human toxicity	8.6
Ecotoxicity to freshwater	8.6
Higher level nuclear waste	8.2
Ecotoxicity to land	8.0
Waste disposal	7.7
Fossil fuel depletion	3.3
Eutrophication	3.0
Photochemical ozone creation	0.20
Acidification	0.05

Table 3: Environmental Issues (See Appendix C) and Weighting (BREEAM)

This data is set out as an **A+** to **E** ranking system, where **A+** represents the best environmental performance / least environmental impact, and **E** the worst environmental performance / most environmental impact (Figure 3) (Anderson, 2009, P.20).

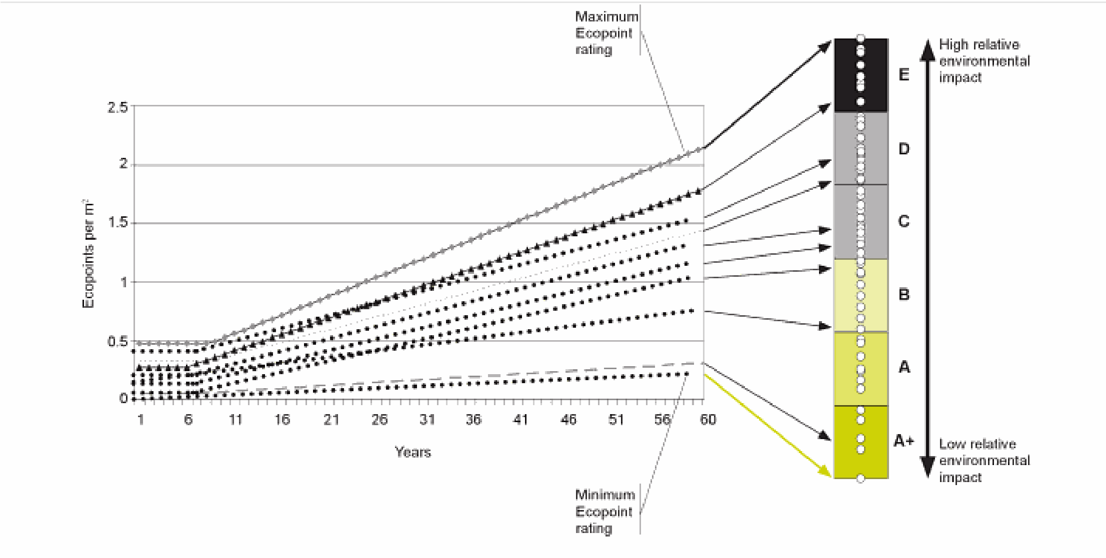

Figure 3: How The Green Guide ratings are determined for both the environmental impact categories and the Summary Rating based on Ecopoints (Anderson, 2009, P.20)

3.1.2 The effects of insulation materials in BREEAM

Figure 4 shows the Green Guide ratings of insulation materials; you will find that almost all insulation materials, for which data is given, get the top rating of A+ or A. The exceptions are cellular glass-density 200kg/m^3, extruded polystyrene, stone wool and strawboard thermal insulation. This is a clear reflection of the fact that the embodied impact of insulation materials is relatively insignificant in BREEAM. However, as building regulations have improved, and low U-values have become more common, the environmental impact of the insulation compared with the impact of the construction element in which it is used has grown (Anderson, 2009).

Cavity blown glass wool insulation - density 17 kg/m^3	815320036	A+
Cavity blown stone wool insulation density 30 kg/m^3	815320037	A+
Cellular glass insulation - density 100 kg/m^3	915320051	A+
Cellular glass insulation - density 110 kg/m^3	915320052	A
Cellular glass insulation - density 115 kg/m^3	915320053	A
Cellular glass insulation - density 120 kg/m^3	915320054	A
Cellular glass insulation - density 130 kg/m^3	915320055	A
Cellular glass insulation - density 155 kg/m^3	915320056	B
Cellular glass insulation - density 165 kg/m^3	915320057	B
Cellular glass insulation - density 200 kg/m^3	915320058	C
Corkboard insulation - density 120kg/m^3	815320021	A
Dry blown recycled cellulose insulation - density 24kg/m^3	815320035	A+
Expanded polystyrene (EPS) - density 15 kg/m^3	815320022	A+
Expanded polystyrene (EPS) - density 20 kg/m^3	815320023	A+
Expanded polystyrene (EPS) - density 25 kg/m^3	815320024	A+
Expanded polystyrene (EPS) - density 30 kg/m^3	815320025	A+
Extruded polystyrene (XPS) (HFC blown) density 35	815320027	E

Glass wool insulation - density 10 kg/m^3	815320005	A+
Glass wool insulation - density 12 kg/m^3	815320001	A+
Glass wool insulation - density 24 kg/m^3	815320002	A+
Glass wool insulation - density 32 kg/m^3	815320003	A+
Glass wool insulation - density 48 kg/m^3	815320004	A+
Glass wool insulation - density 80 kg/m^3	915320059	A
Rigid urethane (pentane blown) - density 32 kg/m^3	815320017	A
Sheep's wool insulation - density 25 kg/m3	1115320021	A+
Stone wool insulation - density 100 kg/m^3	815320011	A
Stone wool insulation - density 128 kg/m^3	815320012	B
Stone wool insulation - density 140 kg/m^3	815320013	B
Stone wool insulation - density 160 kg/m^3	815320014	C
Stone wool insulation - density 33 kg/m^3	815320007	A+
Stone wool insulation - density 45 kg/m^3	815320008	A+
Stone wool insulation - density 60 kg/m^3	815320009	A+
Stone wool insulation - density 80 kg/m^3	815320010	A
Straw bale used as insulation	815320029	A
Strawboard thermal insulation (420kg/m^3)	815320034	C
Wet blown recycled cellulose insulation -density 45 kg/m^3	815320039	A+

Figure 4: Summary rating of insulation materials (BRE, 2011)

It also illustrates that it is important to consider the density of the insulation material, as more dense insulation may have a low embodied impact per kilogram, but not per m^3 or m^2. As we can see in Figure 5, the embodied CO_2 eq emissions of EPS varies with different densities, assuming that the thickness of EPS is 0.1m. This shows that the impact maybe very different when compared on a per kg basis. For example, EPS-density 30 kg/m^3 have a lower embodied impact per kg comparing to EPS-density 15 kg/m^3. Therefore, when choosing insulation materials, high density insulation materials are preferential.

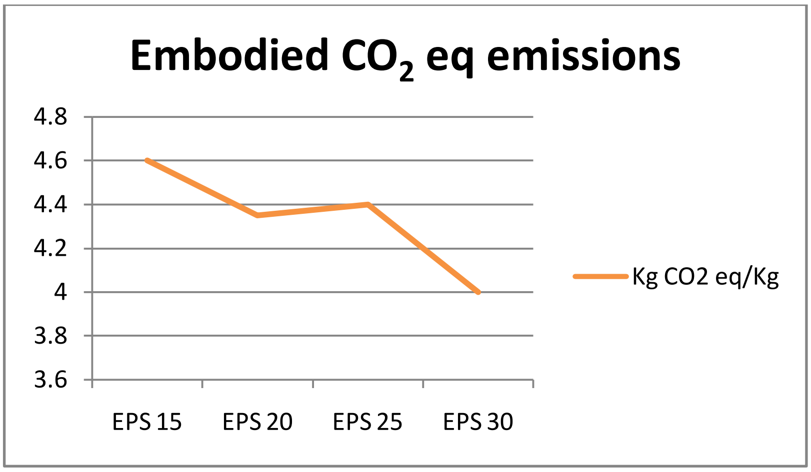

Figure 5: Embodied CO_2 eq emissions of different EPS (Author's work)

Additionally, within construction elements, BRE assesses impact based on a typical "generic" insulation, except where the insulation provides a significant additional function. For example, a beam and expanded polystyrene block floor where the insulation also provides a structural function, or where the insulation is incorporated into the construction offsite, for example, in a composite insulated cladding panel. In these instances, the specific insulation is listed in the element description and its specific impact is assessed for the element where this occurs. The insulation should be assumed to be A+ to calculate the BREEAM insulation credit (Anderson, 2009).

3.1.3 Limitations of The Green Guide rating

If an insulation material is not listed in the Green Guide Online, assessors could use the Green Guide Calculator to generate Green Guide rating for a special product. Unfortunately, the Green Guide Calculator is not yet available for public use, so the author could not log in and check the special insulations which are not included in Online Green Guide rating.

3.1.4 Disadvantages of rating system

It should also be noted that when the impacts for insulation are combined with the impacts for all other materials in a building component such as a wall or a roof, the different ratings of insulation products become largely less effect as they are masked by the impacts of the other materials in the construction. On the one hand, it is perfectly possible for a wall insulated with extruded polystyrene to get an overall A rating, even if the insulation itself does not. On the other hand, it is equally possible for a wall insulated with an A rated insulation material to get an overall B or C rating. It is the rating for the whole construction that counts as far as the Green Guide data is concerned (Hall, 2006).

3.2 Comments about Responsible Sourcing

In a project, if insulation materials are certified as responsible sourcing, the second credit can be achieved in BREEAM.

The certification of responsible sourcing material could promote the sustainable development of the insulation market. Especially, this certification strongly forces the manufactures to produce responsible insulation materials in terms of environmental, social and economic aspect. But it is not transparent, unclear and not user-friendly.

However, this certification also has its own disadvantages. Firstly, the authoritativeness of the certification system needs to be made evident because it is not transparent. It is not clear if it comprehensively includes all aspects of responsible sourcing material? Secondly, the results of this certification are very subjective. For example, the product process of insulation is inconsistent, and this makes it difficult for assessors to decide whether the insulation is responsibly sourced or not. Moreover, different assessors will have different opinions, so there need to be a standardised procedure. Thirdly, the development of this certification system is slow; there are still some insulation materials such as EPS (Expanded polystyrene) insulation which have not been certified to data. This is unfair to those designers or users who decide to use EPS as insulation material in their buildings if they cannot achieve credit as a result.

Based on the above disadvantages, the author provides some suggestions about the use of responsible sourcing in BREEAM. It is would be much clearer if BREEAM included some of the following issues which could be directly checked by designers and users during the early design stage. For example, these issues could include:

- Embodied energy (energy consumed within its processing and transport)
- Raw material extraction
- Low toxicity levels
- Related health issues in manufacture, installation and for occupants
- Use of ozone depletion chemicals
- Ability to be recycled

4 Other Disadvantages

Apart from disadvantages already outlined in relation to the insulation criteria, the scheme also has some other problems.

Firstly, insulation materials are also related to the credits which we could get from the energy part. That is up to fifteen credits can be achieved where evidence provided to demonstrate an improvement in the energy efficiency of the building's fabric and services and thus achieves lower building operational related CO_2 emissions. This is because insulation materials could help improve the energy efficiency of the building, which could reduce the CO_2 emissions during the operational process. Therefore, the operational CO_2 emissions is influenced by insulation materials, the author thinks that the credits which are included in the energy part should be reorganised and contained in insulation category. For example, 10 credits could be achieved in energy part and 5 credits could be achieved in insulation part.

Secondly, the large number of credits (up to 15 credits) is available in BREEAM for reducing operational CO_2 emissions, but it only one credit for insulation specification. The author thinks that the number of credits for embodied impact of insulation needs to be increased and the credits for the operational CO_2 emissions need to be decreased, because the embodied CO_2 eq emissions have outweighed the operational CO2 emissions.

It is concluded that the insulation criteria in BREEAM still need to be clearly defined and developed.

5. Case study

This chapter contains three parts. The first part is the introduction of the case study together with parameters and limitations. The second part shows how the First Credit in BREEAM can be achieved. The third part explains how to get the Second Credit in BREEAM.

5.1 Case description and Limitations

For this case study Brøset Climate Centre—Filter Project will be analysed. The case study is a zero emission design project located in Trondheim, Norway. One of the design tasks in this project was to design an environmental- friendly climate centre. The project is taken from author's design work in Zero Emission Design Course (Msc. in Sustainable Architecture), see Figure 6.

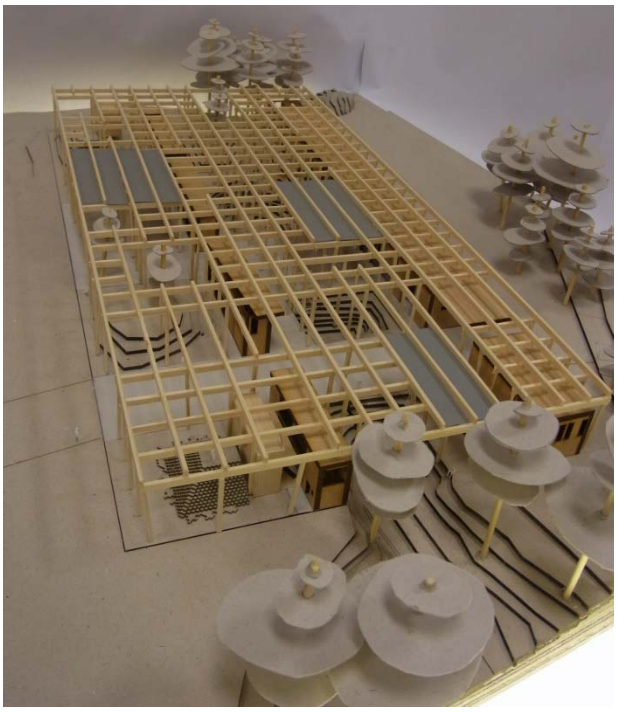

Figure 6: Project Model

Parameters:

Here are the total insulation areas of different building components,

External Walls: 1656.2m^2

Roof: 860.3m^2

Ground floor: 884.54m^2 (Detail drawing see Appendix A)

Limitations: Since the case study is a student project, time is limited and the building services were not designed. So, the calculation of this case study does not include the insulation area of building services.

5.2 First Credit in BREEAM

The analysis of this case study bases on the insulation criteria in BREEAM, which has been shown in chapter 2.

According to the research findings in Chapter 3, the author decided to choose corkboard insulation (density 120kg/m^3), expanded polystyrene (EPS) - density 30 kg/m^3 and cellular glass insulation (density 130 kg/m^3) as alternative materials. All of them have high densities and achieve above A rating (Table 4). The detail contents of these three insulation materials see Appendix B.

Insulation	Thermal conductivity	Green Guide rating*
Corkboard	0.04[a]	A
EPS	0.036[b]	A+
Cellular glass	0.044[c]	A

Table 4: Thermal conductivity and Green Guide rating of insulation

*Functional unit
1m² of insulation with sufficient thickness to provide a thermal resistance value of 3 m²K/W, equivalent to approximately 100mm of insulation with a conductivity (k value) of 0.033 W/mK To include any repair, refurbishment or replacement over the 60-year study period (Anderson, 2009).

The embodied CO_2 eq emissions of different insulations are illustrated in Figure 7. We can see that corkboard achieves negative CO_2 emissions, this is because there carbon is stored through the tree grows. Also, the EPS has much less embodied CO_2 eq emissions to the environment compared to cellular glass. It seems that corkboard is the best choice from the embodied CO_2 point, but it is also expensive. So if considering the cost of the project, EPS is a much better choice here.

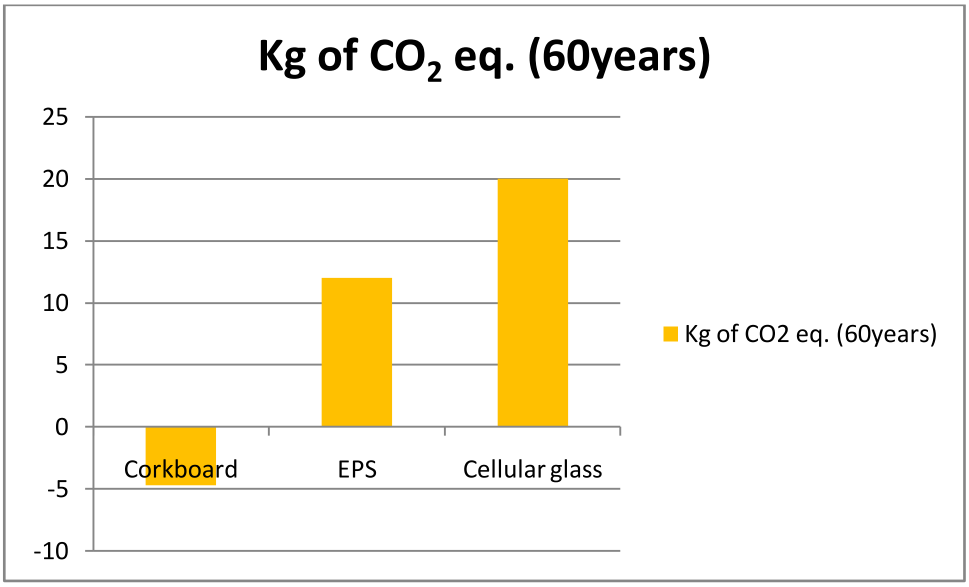

Figure 7: Embodied CO_2 eq emissions

a http://www.acm.amorim.com/client/skins/english/page.asp?id=5
b (Hegger, 2006, P.136)
c http://www.unitedperlite.net/cel_glass.htm

In order to achieve the same thermal performance (the U-value of insulation of walls is 0.13, roof and ground floor is 0.1), the different insulation need to be set in different thickness (See Figure 8). Among them, EPS could achieve a high thermal property with least thickness.

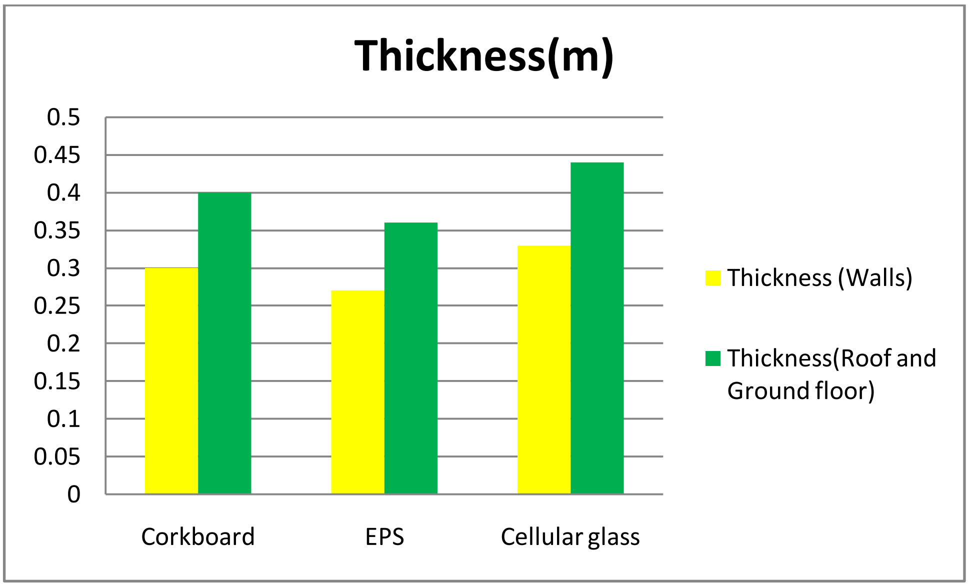

Figure 8: Thickness of different insulation (Author's work)

Result:

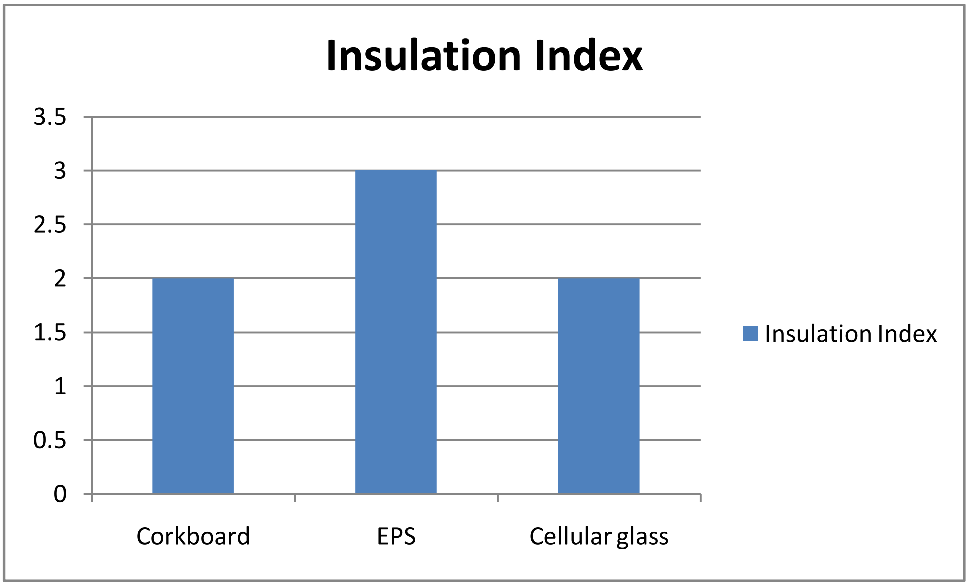

Figure 9: Insulation Index (Author's work)

Figure 9 illustrates that the Insulation Index of three insulation materials could get the first credit, which is greater than 2. However, the insulation index of EPS is 3, which is the highest one among the three materials.

Therefore, it can be concluded that EPS is preferential among the three insulation materials in terms of embodied CO_2 eq emissions, thickness and Insulation Index.

5.3 Second Credit in BREEAM

According to Table 2, corkboard is a renewable insulation material, and is definite as responsible sourcing. Cellular glass and EPS, it is difficult for the author to draw a conclusion, because it is according to product manufacturer information for which there is no certification. It can be concluded this criteria need to be developed further. However, according to Green Guide 2008 rating (See Appendix B), all three insulation materials should be responsible sourcing. So, in order to get the second credit, any one of three insulation materials could be chosen in this project.

In conclusion, for this project, EPS is a preferential among the three insulation materials according to the insulation criteria in BREEAM.

6. Conclusion and Suggestion to BREEAM

6.1 Conclusion

The author concludes that the insulation criteria in BREEAM indeed help designers and material manufacturers to improve the environmental sustainability of buildings.

On the one hand, the first credit of insulation criteria provides an analysis system to designers to help them choose insulation materials with a low embodied impact. The second credit informs designers and manufacturers which insulation materials are responsible sourcing.

On the other hand, BREEAM scheme also encourages the environmental sustainability of the market for insulation materials. Based on this framework, material manufactures can make an informed decision on which materials have lower environmental impact and are responsibly sourced.

The case study in this essay also proves that insulation criteria in BREEAM can help designers choose environmental friendly insulation material. The author finally concludes that EPS is a preferential among the three insulation materials in order to achieve the two credits in BREEAM.

6.2 Suggestions

It is concluded that BREEAM is a credible environmental assessment system for insulation materials. The strengths of BREEAM are apparent, but there are still some weaknesses which could be improved.

Firstly, the material category in BREEAM accounts for about 10.9 percentages of the overall scores (BREEAM). Compared to other criteria, the percentage of materials needs to be increased since they take an important role in the building environment.

Secondly, the thermal performance of building elements are closely related to the performance of insulation material, so the 15 credits which have been accounted for reducing operation CO_2 emissions in the energy part should be reorganised and considered in the insulation criteria. For example, 10 credits could be achieved in energy part and 5 credits could be achieved in insulation part.

Thirdly, the credits for embodied impact of insulation need to be increased and the credits for the operational CO_2 emissions need to be decreased, because the embodied CO_2 emissions have outweighed the operational CO_2 emissions.

Finally, it is concluded that insulation criteria in BREEAM can be transparent and user friendly if BREEAM could direct set some following issues such as embodied energy, low toxicity levels, and ability to be recycled instead of the certification for responsible sourcing insulation. This method will not limit designers' decision only because one insulation material is not certified by BREEAM, which could expand the diversities in BREEAM.

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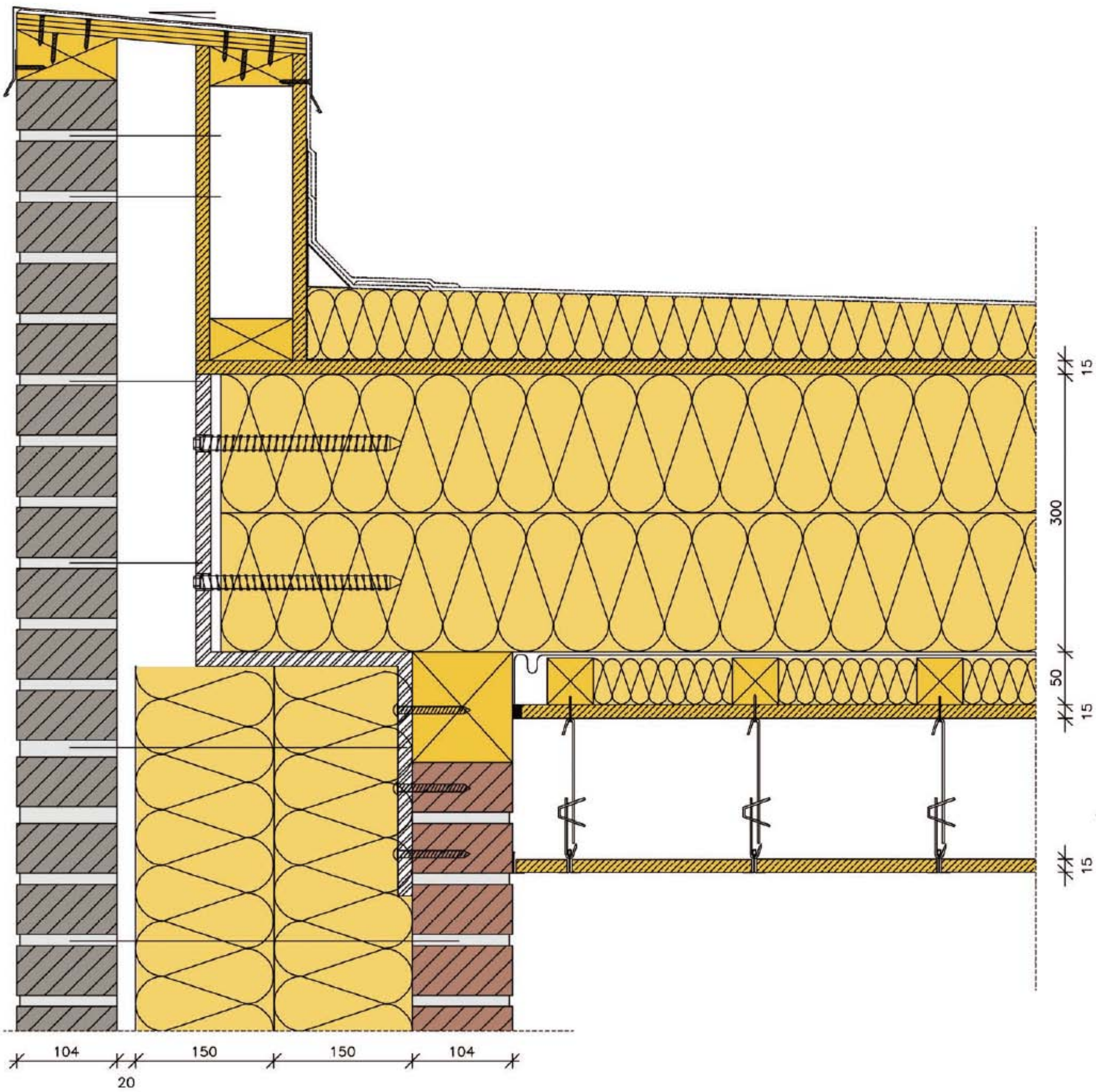
Attachments

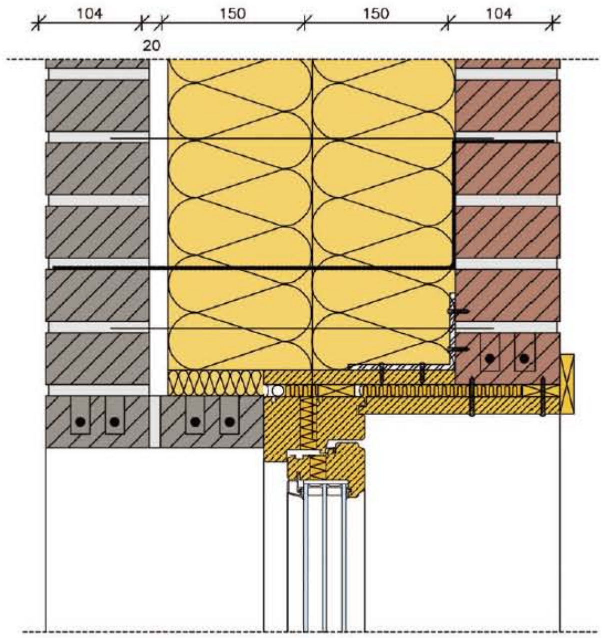
Appendix A

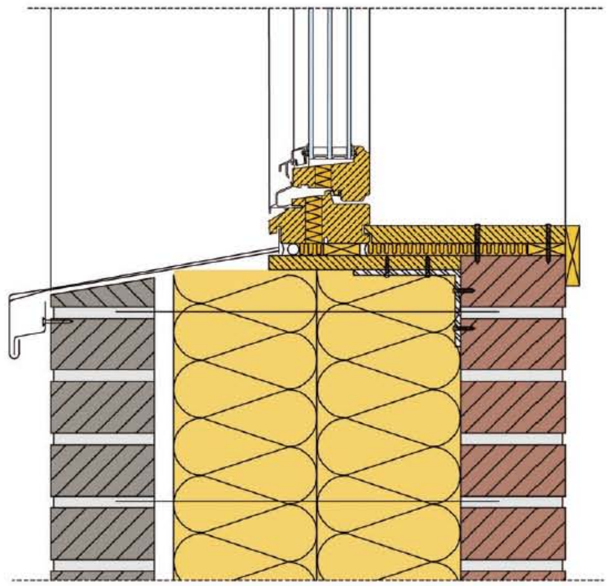
Detail Drawing

Roof

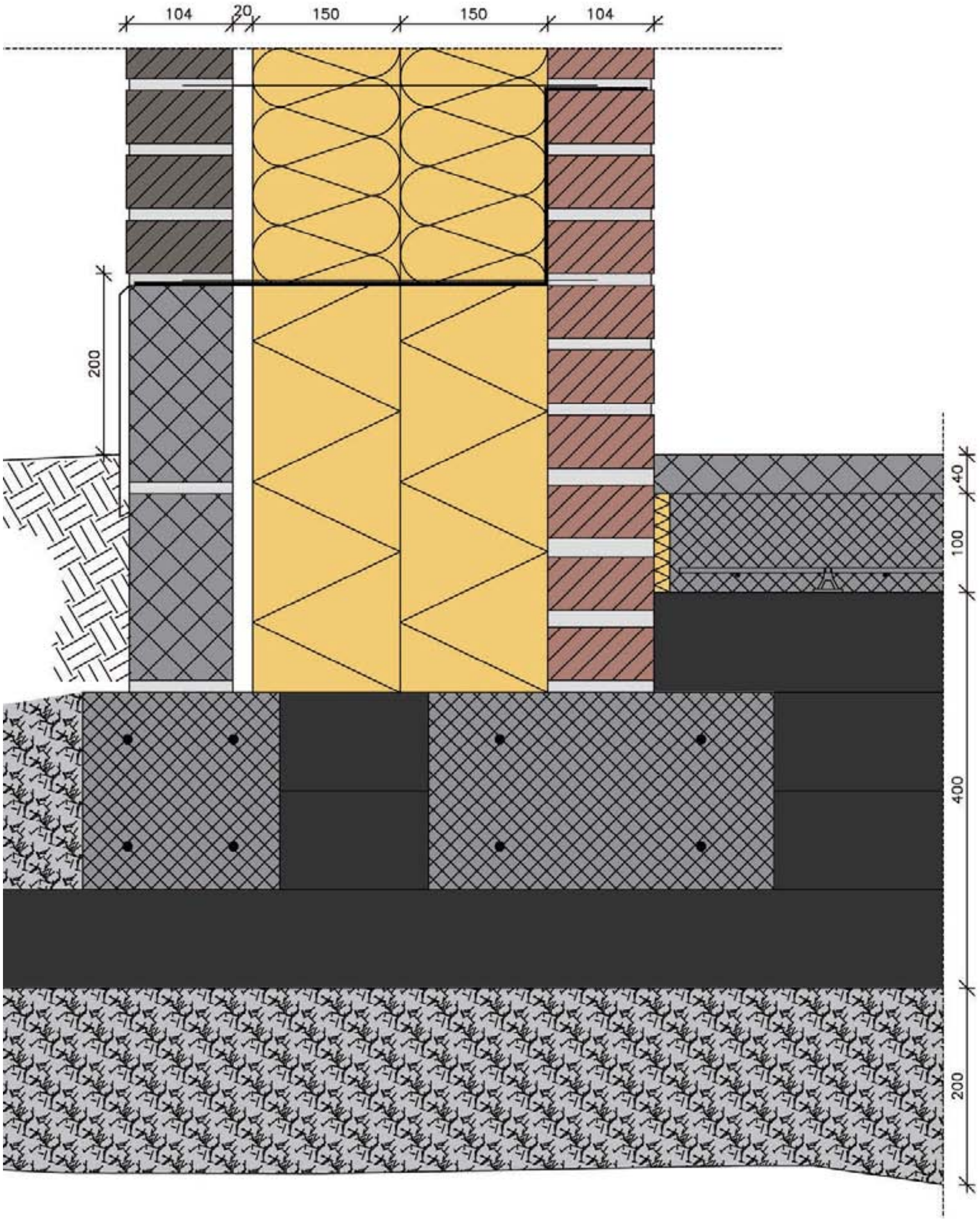


External wall





Foundation



Appendix B

Insulation from Green Guide 2008 rating

Green Guide 2008 ratings

Building type >	Commercial
Category >	Insulation
Element type >	Insulation

Element	Expanded polystyrene (EPS) - density 30 kg/m³
Element Number	815320025
Summary Rating	A+
Climate Change	B
Water Extraction	A+
Mineral Resource Extraction	A+
Stratospheric Ozone Depletion	A
Human Toxicity	A+
Ecotoxicity to Freshwater	A+
Nuclear Waste (higher level)	A+
Ecotoxicity to Land	E
Waste Disposal	A+
Fossil Fuel Depletion	B
Eutrophication	A+
Photochemical Ozone Creation	E
Acidification	B
Kg of CO_2 eq. (60 years)	12.0

Green Guide 2008 ratings

Building type >	Commercial
Category >	Insulation
Element type >	Insulation

Element	Cellular glass insulation - density 130 kg/m³
Element Number	915320055
Summary Rating	A
Climate Change	B
Water Extraction	A+
Mineral Resource Extraction	A
Stratospheric Ozone Depletion	A
Human Toxicity	A
Ecotoxicity to Freshwater	A+
Nuclear Waste (higher level)	A+
Ecotoxicity to Land	E
Waste Disposal	A+
Fossil Fuel Depletion	B
Eutrophication	A+
Photochemical Ozone Creation	A
Acidification	A
Kg of CO_2 eq. (60 years)	20.0

Green Guide 2008 ratings

Building type >	Commercial
Category >	Insulation
Element type >	Insulation

Element	Corkboard insulation - density 120kg/m³
Element Number	815320021
Summary Rating	A
Climate Change	A
Water Extraction	A
Mineral Resource Extraction	A+
Stratospheric Ozone Depletion	A
Human Toxicity	C
Ecotoxicity to Freshwater	A
Nuclear Waste (higher level)	B
Ecotoxicity to Land	E
Waste Disposal	A+
Fossil Fuel Depletion	B
Eutrophication	A+
Photochemical Ozone Creation	B
Acidification	C
Kg of CO_2 eq. (60 years)	-4.7

Appendix C

Environmental issues (BRE, 2001)

Climate Change

Climate change: kg CO_2 eq. (100 yr)

Climate change refers to the change in global temperature caused via the greenhouse effect by the release of "greenhouse gases" such as carbon dioxide by human activity. There is now scientific consensus that the increase in these emissions is having a noticeable effect on climate. Raised global temperature is expected to cause climatic disturbance, desertification, rising sea levels and spread of disease.

The Environmental Profiles characterisation model is based on factors developed by the UN's Intergovernmental Panel on Climate Change (IPCC). Factors are expressed as Global Warming Potential over the time horizon of 100 years (GWP100), measured in the reference unit, kg CO_2 equivalent.

Water Extraction

Water extraction: m^3 water extracted

Around the world, water is becoming an increasingly scarce resource, due to increased demand, and changes in patterns of rainfall. To recognise the value of water as a resource, and the damage that over-extraction from rivers and aquifers can cause, this category established by BRE, includes all water extraction, except:

- Seawater
- Water extracted for cooling or power generation and then returned to the same source with no change in water quality (water lost through evaporation would be included in the category)

- Water stored in holding lakes on site for recirculation ('top-up' water from other sources would be included)
- Rainwater collected for storage on site

This category is measured using m^3 of water extracted

Mineral Resource Extraction

Mineral resource extraction: tonne of minerals extracted

This impact category is related to the consumption of all virgin mineral material, e.g. the extraction of aggregates, metal ores and minerals. The consumption of such substances can mean that they are unavailable for use by future generations. This indicator is intended to relate purely to resource use, with no coverage of other environmental impacts which might be associated with mining or quarrying, or the relative scarcity of resources. The indicator is based on the Total Material Requirement (TMR) indicators used by the European Union and developed by the Wuppertal Institute, based on earlier work for the World Resources Institute. However the indicators covering fossil fuel, biomass (mainly agricultural product) and soil erosion (only covered for agriculture, not forestry) are not included. Further details can be obtained in the Eurostat working papers.

The indicator calculates the total resource use associated with any use of any non-energy, abiotic materials within the EU, wherever the resource use occurs. For example, for steel use, it traces back to tonnes of iron ore extraction wherever this occurs. The TMR indicator includes material that is extracted as a result of economic activities, but not used as input for production or consumption activities, for example mining overburden. Excavated and dredged material is also included. For normalisation purposes the Eurostat data provides relevant figures covering imports of materials as well as resource use within Europe.

The category is measured in tonnes of mineral extracted.

Stratospheric Ozone Depletion

Stratospheric ozone depletion: kg CFC-11 eq.

Ozone-depleting gases cause damage to stratospheric ozone or the "ozone layer". CFCs, Halons and HCFCs are the major causes of ozone depletion. Damage to the ozone layer reduces its ability to prevent ultraviolet (UV) light entering the earth's atmosphere, increasing the amount of carcinogenic UVB light hitting the earth's surface.

Human Toxicity

Human toxicity: kg 1,4 dichlorobenzene (1,4-DB) eq. *

The emission of some substances (such as heavy metals) can have impacts on human health. Assessments of toxicity are based on tolerable concentrations in air, water, air quality guidelines, tolerable daily intake and acceptable daily intake for human toxicity. Impacts to air and water have been combined in the ratings tables. Characterisation factors, expressed as Human Toxicity Potentials (HTP), are calculated using USES-LCA, as with Ecotoxicity, which describes fate, exposure and effects of toxic substances for an infinite time horizon. For each toxic substance HTPs are expressed using the reference unit, kg 1,4-dichlorobenzene (1,4-DB) equivalent.

Indoor air quality and its effect on human health are not covered by this category.

Toxicity: It should be noted that issues relating to toxicity generate much debate. Designers are advised to carefully review the material supplier's guidance, to note any relevant regulations, codes and standards appropriate to different industries and materials and to consider the context and application within which the materials are to be used. The results in the Green Guide do consider some toxic effects, but these should in no way be considered comprehensive for any of the material alternatives considered. Many of the chemicals used in society have not undergone a risk assessment and assessment techniques are still developing.*

Ecotoxicity

Ecotoxicity to freshwater and land: kg 1,4 dichlorobenzene (1,4-DB) eq.

Environmental toxicity is measured as two separate impact categories which examine freshwater and land respectively. The emission of some substances, such as heavy metals, can have impacts on the ecosystem. Assessment of toxicity has been based on maximum tolerable concentrations in water for ecosystems. **Ecotoxicity Potentials** are calculated with the USES-LCA, which is based on EUSES, the EU's toxicity model. This provides a method for describing fate, exposure and the effects of toxic substances on the environment. Characterisation factors are expressed using the reference unit, kg 1,4-dichlorobenzene equivalent (1,4-DB), and are measured separately for impacts of toxic substances on:

- Fresh-water aquatic ecosystems
- Terrestrial ecosystems

Toxicity: It should be noted that issues relating to toxicity generate much debate. Designers are advised to carefully review the material supplier's guidance, to note any relevant regulations, codes and standards appropriate to different industries and materials and to consider the context and application within which the materials are to be used. The results in the Green Guide do consider some toxic effects, but these should in no way be considered comprehensive for any of the material alternatives considered. Many of the chemicals used in society have not undergone a risk assessment and assessment techniques are still developing.*

Higher Level Nuclear Waste

Nuclear waste: mm^3 high level waste

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. Such wastes need to be stored for periods of 10,000 years or more before their radioactivity reaches safe levels. The World Nuclear Association states that higher level nuclear waste

(high and intermediate level waste) accounts for a very low percentage of nuclear waste, around 10% by volume, but 99% of its radioactivity. Other characterisation methods, such as the Swiss Ecopoints, use the volume of highly active radioactive waste as a category.
The characterisation factor for the category is measured in mm^3 of spent fuel, high and intermediate level radioactive waste. All of these waste:

- are highly radioactive, accounting in total for more than 99% of the radioactivity attributed to the nuclear industry;
- have no agreed form of permanent disposal anywhere in the world;
- require storage for at least 10,000 years before they may be safe.

Waste Disposal

Waste disposal: tonne solid waste

This category represents the environmental issues associated with the loss of resource implied by the final disposal of waste. BRE uses an absolute measure based on the mass of any waste that is disposed of in landfill or incinerated. The characterisation factor is based on the mass of solid waste. Key points for this characterisation factor are:

- it reflects the loss of resource resulting from waste disposal (in contrast to recycling or reuse);
- it does not include any other impacts associated with landfill or incineration – emissions from decomposition, burning and associated transport and other machinery are included in the relevant categories;
- the mass of waste is used as a proxy for the loss of resource;
- it includes waste sent to incineration and landfill or any other form of final disposal (e.g. dumping on land or in the sea);
- it does not differentiate between hazardous, non-hazardous, inert or organic wastes;

- different impacts from hazardous, non-hazardous etc will be included within the waste treatment models (landfill, incineration and composting) for these wastes;

Where heat recovery, energy recovery or other material recovery (e.g. recovery/recycling of ash, metal residues etc) are undertaken as part of incineration or landfill, then value is used to calculate the loss of resource.

Fossil Fuel Depletion

Fossil fuel depletion: tonnes of oil eq. (toe)

This impact category indicator is related to the use of 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.

BRE uses an absolute measure based on the energy content of the fossil fuel. This does not take into account the relative scarcity of different fossil fuels, but in fact these only vary by 17% between coals (the most common) and gas (the most scarce). The characterisation factor is measured in tonnes of oil equivalent (toe). 41.87 GJ = 1 toe.

Eutrophication

Eutrophication: kg phosphate (PO_4) eq.

Nitrates and phosphates are essential for life, but increased concentrations in water can encourage excessive growth of algae and reduce the oxygen within the water. Eutrophication can therefore be classified as the over-enrichment of water courses. Its occurrence can lead to damage of ecosystems, increasing mortality of aquatic fauna and flora and to loss of species dependent on low-nutrient environments. Emissions of ammonia, nitrates, nitrogen oxides and phosphorous to air or water all have an impact on eutrophication. Eutrophication potential is based on the work of Heijungs, and is expressed using the reference unit, kg PO_4 equivalents.

Direct and indirect impacts of fertilisers are included in the method. The direct impacts are from production of the fertilisers and the indirect ones are calculated using the IPCC method to estimate emissions to water causing Eutrophication.

Photochemical Ozone Creation

Photochemical ozone creation: kg ethene (C_2H_4) eq.

In atmospheres containing nitrogen oxides (NO_x, a common pollutant) and volatile organic compounds (VOCs), ozone can be created in the presence of sunlight. Although ozone is critical in the high atmosphere to protect against ultraviolet (UV) light, low level ozone is implicated in impacts as diverse as crop damage and increased incidence of asthma and other respiratory complaints. Photochemical ozone creation potential (also known as summer smog) for emission of substances to air is calculated with the United Nations Economic Commission for Europe (UNECE) trajectory model (including fate) and expressed using the reference unit, kg ethene (C_2H_4) equivalent.

Acidification

Acidification: kg sulphur dioxide (SO_2) eq.

Acidic gases such as sulphur dioxide (SO_2) react with water in the atmosphere to form “acid rain”, a process known as acid deposition. When this rain falls, often a considerable distance from the original source of the gas, it causes ecosystem impairment of varying degree, depending upon the nature of the landscape ecosystems. Gases that cause acid deposition include ammonia, nitrogen oxides and sulphur oxides.

Acidification potential is expressed using the reference unit, kg SO_2 equivalent. The model does not take account of regional differences in terms of which areas are more or less susceptible to acidification. It accounts only for acidification caused by SO_2 and NO_x. This includes acidification due to fertiliser use, according to the method developed by the Intergovernmental

Panel on Climate Change (IPCC). CML have based the characterisation factor on the RAINS model developed by the University of Amsterdam.