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BRE Global Methodology For The Environmental Assessment Of Buildings Using EN 15978:2011

PN 326 Rev 0.0

Contents

Revision of the BRE Global Methodology for the Environmental Assessment of Buildings Using EN 15978:2011

The BRE Global methodology for calculating the environmental performance of buildings using EN 15978 will be revised by the issue of revised editions of amendments. Details will be posted on the BRE Green Book Live website at www.greenbooklive.com.

Technical or other changes which affect the requirements for the calculation of the environmental performance of buildings will result in a new issue. Minor or administrative changes (e.g. corrections of spelling and typographical errors, changes to address and copyright details, update to normative reference details, the addition of notes for clarification, etc.) may be made as amendments.

The revision number will be given in decimal format with the integer part giving the issue and the fractional part giving the number of amendments (e.g. Rev 2.3 indicates that the document is at issue 2 and this is the 3rd amendment to issue 2).

Users of this BRE Global methodology for building evaluation using life cycle assessment should ensure that they possess the latest revision and amendment.

Changes/amendments issued since first publication

This is the first publication of this methodology, Rev 0.0, published in January 2018.

Date	Type	Text/Section affected
01 Jan 2018	Publication	First publication, Rev 0.0

Introduction

In Europe, the environmental performance of a building is evaluated using life cycle assessment (LCA) according to the calculation method prescribed in EN 15978, Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method. Published in 2011 by the European Committee for Standardisation (CEN), EN 15978 is part of a suite of standards and technical reports for the assessment of the sustainability of construction works at both product level and building level. This suite includes:

- EN 15643-1, Sustainability of construction works – Sustainability assessment of buildings – Part 1: General framework
- EN 15643-2, Sustainability of construction works – Assessment of buildings – Part 2: Framework for the assessment of environmental performance
- EN 15804, Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products (EN 15804+A1)
- CEN/TR 15941, Sustainability of construction works – Environmental product declarations – Methodology for the selection and use of generic data
- EN 15942, Sustainability of construction works – Environmental product declarations – Communication formats: business to business

This BRE Global document (PN 326) describes BRE Global's methodology for deriving the environmental performance of buildings using LCA and is complementary to (and complies with) EN 15978:2011. Due to the on-going nature of the work of the CEN Technical Committee (TC 350), and the continuing developments in LCA, it is anticipated that the information contained in this methodology will continue to evolve.

NOTE: Compliance with this methodology does not confer immunity from legal obligations. Users of this methodology should ensure that they possess the latest issue and all amendments.

1 Scope

This methodology has been prepared in compliance with the requirements of EN 15978, Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method. The methodology provides complementary rules for the calculations, and is to be used in conjunction with EN 15978:2011.

The methodology has therefore also been prepared to be in conformity with the relevant ISO standards relating to environmental management using life cycle assessment, ISO 14040:2006 and 14044:2006.

2 Normative References

In addition to EN 15978:2011 and the normative references listed in EN 15978:2011 clause 2, the following referenced and unreferenced documents are indispensable for the application of this document.

- EN 15603:2008, Energy performance of buildings. Overall energy use and definition of energy ratings
- ISO 14040:2006, Environmental management – Life cycle assessment – Principles and framework
- ISO 14044:2006, Environmental management – Life cycle assessment – Requirements and guidelines

NOTE: Throughout this methodology, all undated references to standards refer to the current published version of those standards (including any amendments). Clauses with dated references within the methodology refer only to the cited edition of the particular standard(s). All references to specific clauses and general texts in EN 15978 refer to the cited normative edition, EN 15978:2011.

3 Terms And Definitions

The technical terms and concepts employed in the life cycle assessment of construction works are defined in EN 15978. Terms are not defined where they retain their normal dictionary definition. Below are additional defined terms as used in this methodology.

3.1 Environmental product declaration (EPD / Type III environmental declaration)

Of construction products; an environmental declaration providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information. The predetermined parameters are based on the ISO 14040 series of standards, which is made up of ISO 14040 and ISO 14044. See ISO 21930[1] and EN 15804+A1 for more on EPD.

3.2 Functional unit

Quantified performance used as a reference unit for comparison of buildings or assets based on LCA. Also see *functional equivalent* in EN 15978 clause 3.14.

3.3 Information module

Compilation of data covering a unit process or a combination of unit processes that are part of the life cycle of a building or asset (adapted from the definition contained in EN 15804+A1 clause 3.13).

[1] ISO 21930:2017, Sustainability in buildings and civil engineering works – Core rules for environmental product declarations of construction products and services

4 Abbreviations

Abbreviations in this BRE Global methodology are as used in EN 15978 clause 4.

In addition the abbreviation 'EPD' as used in this methodology is both the singular and plural form for ISO Type III environmental product declarations.

5 Calculation Steps: Methodology

This BRE Global methodology is consistent with and complementary to the process steps defined in EN 15978 clause 5 as being necessary to carry out and complete the calculations needed for the assessment of the environmental performance of buildings. These process steps have been reproduced in Figure 5.1 below.

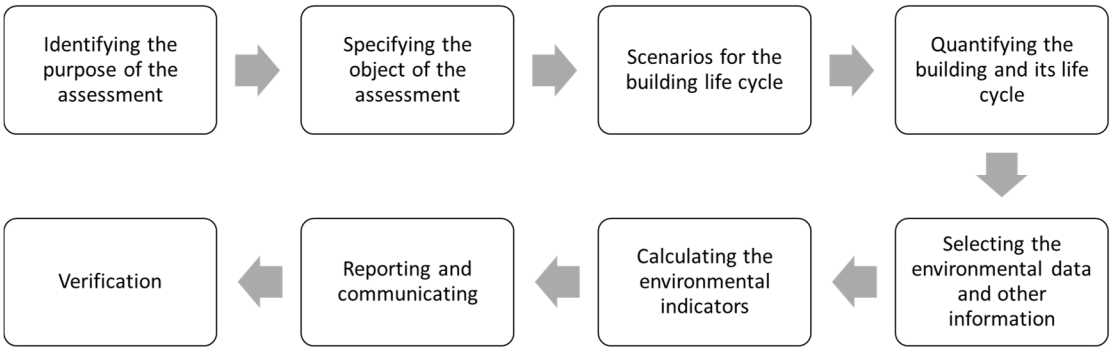

Figure 5.1: Process steps for the assessment of the environmental performance of buildings, adapted from Figure 3 in EN 15978

6 Identifying The Purpose Of The Assessment

As in EN 15978 clause 6.

The scope and the intended use of the study shall be defined, agreed and documented before the study is carried out.

7 Specifying The Object of The Assessment

7.1 General

As in EN 15978 clause 7.1.

In a building LCA study, the object of the assessment is the building and its site. In this methodology the parts of the building including its foundations and external works within the curtilage of the building's site that can be assessed (subject to data availability) are shown in Table 7.1; based on the New Rules of Measurement (NRM) by the RICS[2]. The NRM organises the different aspects of the building into 'Groups' made up of 'elements' which are in turn made up of 'sub-elements'.

NOTE: For new build, demolition works required to clear up the site for the new construction works are outside the scope of the assessment. If included in the LCA study these shall be reported separately. However any preparatory ground works and various other related construction works shall be included in the assessment, as part of the external works. For refurbishment works, demolition works (any activities required to strip off or clear the parts of the building that are no longer required, in order to make way for the refurbishment works) shall be included.

Table 7.1: Building elements ***that can be assessed***

	From RICS NRM		
	Level 1 Group	**Level 2 Element (Building aspect)**	**Level 3 Sub-elements**
1	Substructure	Substructure	Foundations (standard, specialists) Basements (incl. excavation and retaining walls)
2	Superstructure	Frame	Frames (steel, concrete, timber, others) Beams / Columns support systems
		Upper floors	Floors Balconies
		Roof	Roof elements (structure, coverings, specialist roof systems, drainages) Rooflights, skylights and openings
		Stairs and ramps	Stairs, ramps (structures and finishes) Balustrades, handrails Ladders, chutes and slides
		External walls	External walls (above and below ground level) Curtain walls
		Windows and external doors	External windows External doors

[2] Royal Institution of Chartered Surveyors, RICS, www.rics.org

	From RICS NRM		
	Level 1 Group	**Level 2 Element (Building aspect)**	**Level 3 Sub-elements**
		Internal walls and partitions	Walls and partitions Balustrades and handrails Movable room dividers Cubicles
		Internal doors	Internal doors
3	Internal finishes	Wall finishes	Wall finishes
		Floor finishes	Floor finishes Raised access floors
		Ceiling finishes	Ceilings, including false and suspended ceilings
4	Fittings, furnishes and equipment	Fittings, furnishes and equipment	General, domestic kitchen and special purpose Signs / Notices
5	Services	Sanitary installations	Appliances and ancillaries
		Services equipment	Equipment
		Disposal installations	Drainage network (above ground) Refuse disposal
		Water installations	Supply and distribution network and fittings
		Heat source	Equipment and related fittings
		Space heating and air conditioning	Equipment and related fittings
		Ventilation	Ventilation network and fittings
		Electrical installations	Equipment and fittings
		Fuel installations	Equipment and fittings
		Lift and conveyor installations	Equipment and fittings
		Fire and lightning protection	Systems
		Communication, security and control systems	Systems
		Specialist installations	Equipment and fittings

	From RICS NRM		
	Level 1 Group	**Level 2 Element (Building aspect)**	**Level 3 Sub-elements**
		Builder's work In connection with services	
6	Prefabricated buildings and building units	Complete buildings	Modular buildings
		Building units	Modular room units
		Pods	Bathroom, toilet and shower pods
7	Work to existing buildings	Minor demolition and alteration works	
		Repairs to existing services	
		Damp-proof courses, etc.	
		Façade retention	
		Cleaning existing surfaces	
		Renovation works	Masonry, concrete, metal, timber and plastic repairs
8	External works	Site preparation works	Site clearance Preparatory groundworks
		Roads, paths, pavings and surfaces	Roads, paths and pavings Special surfacings and pavings
		Soft landscaping, planting and irrigation systems	Seeding and turfing External planting Irrigation systems
		Fencing, railings and walls	Fencing and railings Walls and screens Retaining walls Barriers and guardrails
		External fixtures	Site / street furniture and equipment Ornamental features
		External drainage	Surface and foul water drainage Ancillary drainage systems External chemical, toxic and industrial liquid waste drainage
		External services	

	From RICS NRM		
	Level 1 Group	**Level 2 Element (Building aspect)**	**Level 3 Sub-elements**
		Minor building works and ancillary buildings	

7.2 Functional equivalent

As in EN 15978 clause 7.2.

It includes the various aspects that are related to the technical characteristics and functionalities of the building under assessment, and provides a minimum description of the building suitable for making comparative assertions. Below are two examples of a functional equivalent definition for a building, covering the core aspects:

Example 1 (Commercial):

- Building type: an office building with 2000 m^2 net floor area.
- Relevant technical and functional requirements: climate controlled to maintain a temperature range of 20°C to 25°C, lighting level and air flow to meet minimum UK Building Regulations etc.
- Pattern of use: 100 workers, 9:00 am to 5:00 pm, 5 days per week, 48 weeks per year.
- Required service life: 60 years.

Example 2 (Education):

- Building type: a school building with 2000 m^2 net floor area.
- Relevant technical and functional requirements: Resistance to the passage of sound as described in UK Building Regulations Parts E1, E2, E3 and E4, control climate controlled to maintain a temperature range of 20°C to 25°C, etc.
- Pattern of use: 250 pupils, 9:00 am to 3:00 pm, 5 days per week, 39 weeks per year.
- Required service life: 60 years.

The significance of the required service life is detailed further in clause 7.3 of this BRE Global methodology, and the Table 7.2 below shows examples of building types referred to in this methodology.

Table 7.2: Building types

Sector	Building types
Residential	Long term stay (e.g. dwellings)
	Short term stay (e.g. hotels)
Commercial	Offices
	Industrial
	Retail
Education	Education

Sector	Building types
Non-standard building types	Bespoke

7.3 Reference study period

As in EN 15978 clause 7.3.

For comparative assessments and benchmarking, the same reference study period (RSP, *period over which time-dependent characteristics of the object of assessment are analysed*, EN 15978 clause 3.25) shall be applied. The default RSP in a building LCA study is the required service life of the building ($ReqSL$), see EN 15978 clause 7.3, and the required service life is an important aspect in determining functional equivalence of buildings. In this methodology, $RSP = ReqSL = \mathbf{60}\ \boldsymbol{years}$ is to be used as default.

However, for an assessment covering a specific scope, a suitable and applicable $ReqSL$ for the different building types as designed can be used, and this should be clearly reported in the LCA project documentation. This implies that in some studies the RSP and the $ReqSL$ may differ due to reasons including the aim of the assessment or regulatory requirements, and there are implications of this difference on the outcomes of such building assessments. In the building life cycle stages (see Figure 7.1 below), the quantified impacts for the product stage (modules A1, A2 and A3), the construction stage (modules A4 and A5), the end-of-life stage (modules C1, C2, C3 and C4), and any benefits and loads resulting from net flow of materials and exported energy (module D) from these three life cycle stages (product, construction and end-of-life) are all independent of the RSP of the building. But this is not the same for the quantified impacts of the use stage (modules B1 to B7) and for the benefits and loads (module D) that come from modules B1 to B7; as these are dependent on the RSP of the assessment. These impacts are therefore first quantified for the $ReqSL$ of the building, and then adjusted using an adjustment factor (f_a) obtained from the mathematical relationship between the RSP and the $ReqSL$ of the building as shown below:

Adjustment factor $\quad f_a = \frac{RSP}{ReqSL}$

Further details of the application of this adjustment factor are given in the Appendix A, clause A.2.7.2 of this BRE Global methodology.

7.4 System boundary

7.4.1 General

As in EN 15978 clause 7.4.1.

The object of the assessment is the building and its site, and the study system boundary is set according to the building life cycle stages illustrated in Figure 7.1 below. These life cycle stages correspond to the modular structure for presenting environmental data for construction products described in EN 15804+A1.

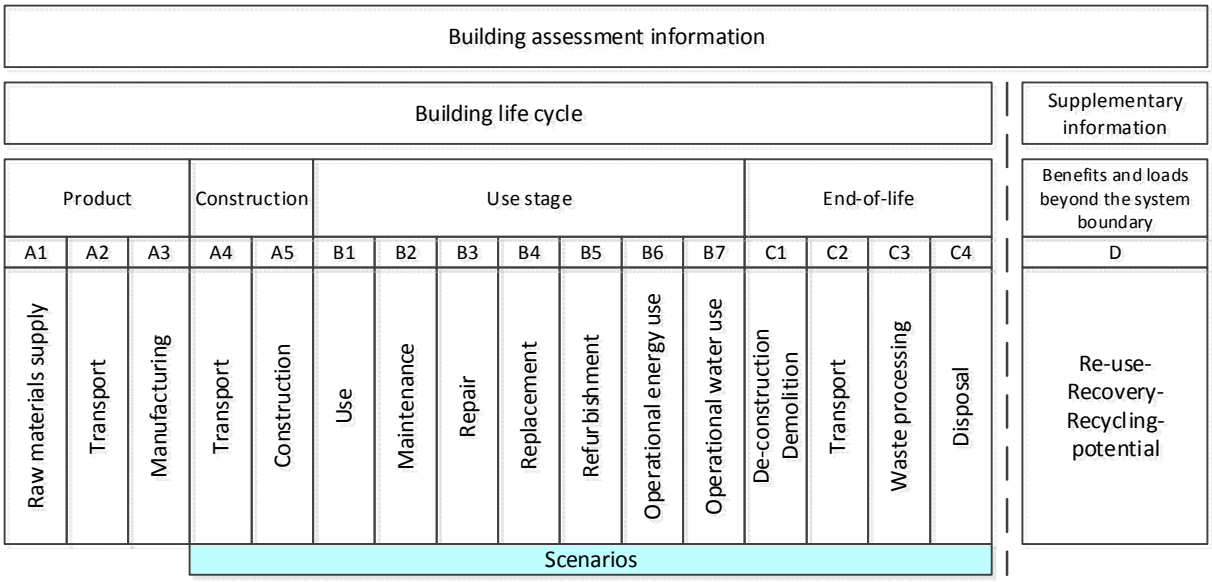

Figure 7.1: Building life cycle, adapted from Figure 6 in EN 15978

For a new build project, the system boundary in the assessment shall include the life cycle stages as shown in Figure 7.1. The construction, use, and end-of-life stages of the life cycle are modelled based on scenarios (appropriate assumptions) depending on the information available.

Demolition works (site clearance) for the new construction are outside of the system boundary. If assessed in the study these shall be reported separately. However, any preparatory ground works and various other related construction works are within the system boundary, as part of the external works in the construction stage. For refurbishment works, any demolition activities required to strip off or clear the parts of the building that are no longer required, in order to make way for the refurbishment works, are within the system boundary as part of the construction stage.

For an existing building, the system boundary shall include only the remaining life cycle stages beginning at the stage where the assessment is conducted, i.e. the remaining service life of the building.

The following sub-sections describe in detail the application of the different life cycle stages according to EN 15978 in this BRE Global methodology. **The modelling requirements described below are subject to the availability of suitable data, unavoidable deviations and omissions therefore shall be clearly documented** for clarity, transparency and practical applicability of the outcomes of such assessments.

7.4.2 The Product stage (modules A1 to A3)

As in EN 15978 clause 7.4.2.

The product stage covers the cradle to gate processes for all the materials and services required for the building, derived according to EN 15804+A1.

7.4.3 The Construction stage (modules A4 and A5)

As in EN 15978 clause 7.4.3, summarised in Table 7.3 below.

Table 7.3: Construction stage

Module	Modelling requirements
A4	Transport of the amount of construction materials and products required for the building from manufacturing plant (gate) to the building construction site, including any intermediate storage and distribution, as well as any related losses due to transportation. Module A4 includes transport of construction equipment mobilised for the building construction works, but excludes the transport of persons/personnel to the building construction site.
A5	The construction of the building, i.e. installation of the materials and products (energy, water), ancillary installation materials (e.g. screws/nails/glue, etc.), plus disposal of any amount wasted (e.g. based on a representative installation wastage rate) plus A1 – A3 for the quantity of the construction products wasted during installation (that needs to be remanufactured to fulfil the installation of the correct quantity of the products) plus the delivery (A4) of this replacement quantity to site. Also includes any storage requirements for the products on site before installation, where applicable. Module A5 also includes any required ground works and landscaping and all construction-related activities onsite e.g. all transport within the site and temporary works on and offsite.

7.4.4 The Use stage (modules B1 to B7)

As in EN 15978 clause 7.4.4.

This stage covers the use of the building to meet the specified functional and technical performance over the $ReqSL$, i.e. until deconstruction or demolition at its end-of-life. The assessment of modules B1 to B7 includes both the fabric and operation (including integrated technical systems) of the building. The boundaries are defined as shown in Table 7.4.

In practice it may be difficult to separate use stage activities into the different modules B2 to B5, therefore the scenarios modelled in the building assessment will always need to be clearly described in the supporting LCA project documentation.

Table 7.4: Use stage

Module	Modelling requirements
B1	**Use** – any emissions to the environment during the normal use of the building over the reference study period (RSP). Such emissions includes release of substances from the building façade, coated surfaces, floor finishes, etc.

Module	Modelling requirements
B2	**Maintenance** – activities carried out to maintain the required functional and technical performance of a building component. Examples of maintenance include cleaning of floor coverings or replacement of rubber seals in a window unit according to a manufacturer-specified maintenance regime. B2 covers both preventative and regular maintenance: ***planned*** cleaning, servicing, replacement or mending of worn, damaged or degraded ***parts of the building components*** during the RSP. If the RSP of the building under assessment is longer than the reference service life of the component RSL_P (see component or product RSL as defined in EN 15804+A1 clause 3.25), this should reflect the first service life and the additional service life required to fulfil the building function in the study period. Modelling example: for a planned replacement of worn out rubber seals in a window unit as part of the maintenance schedule, the modules A1 – A3 and A4 for the replacement rubber seals, the disposal of the rubber seals being replaced (modules C1 – C4), and installation module A5 in order to cover the replacement process including energy, water and ancillary materials used (e.g. glue), other wastes generated and disposed, and any emissions.
B3	**Repair** – works carried out to repair a building component and therefore return it to its required functional and technical performance state, e.g. the replacement of a broken glass pane in a window unit constitutes repair of the window unit. B3 covers corrective, responsive or reactive repair of components of the building during the RSP, and includes an assumption of how many such repair situations will arise during the study period. Modelling example: for repairing a window unit by replacing an accidentally broken glass pane, this covers the modules A1 – A3 and A4 for the new glass pane, the disposal of the pieces (if any) of the broken glass pane being replaced (modules C1 – C4), and module A5 in order to cover the replacement process including energy, water and ancillary materials used (e.g. glue), other wastes generated and disposed, and any emissions.
B4	**Replacement** – replacement of damaged components which cannot be repaired, or which have come to their manufacturer-specified end of life during the building's RSP. B4 also covers the replacement of a complete component at the end of its reference service life RSL_P, if this is shorter than the RSP of the building under assessment. Examples of complete components in the building include window units, partition walls, roofing, etc. Modelling example: for the replacement of a complete window unit, this covers the A1 – A3, A4 and A5 of a new replacement window unit, the processes for deconstructing (removing) the damaged window unit, managing the waste and disposing of the waste (i.e. the entire end of life C1 – C4 for the damaged window unit). **Note: the replacement of complete components of the building due to damage shall be reported here, in module B4; while the replacement of complete components as part of a scheduled programme of refurbishment for the building shall be reported in module, B5 (refurbishment).**

Module	Modelling requirements
B5	**Refurbishment** – major work carried out either to renew or repurpose the building or aspects of the building, e.g. installing partition walls to change the layout of the top floor of a building to change its use from a commercial space to apartments. The refurbishment of existing components as part of a planned or scheduled programme of maintenance, repair and or replacement of a significant part of, or the entire building in which the component is installed; or the installation of an entirely new component in the refurbished section of the building as part of the refurbishment processes. B5 is therefore actually either B2, B3 or B4 (as described above) for existing components, or A1 – A3, A4 and A5 for new components, whichever is appropriate to the scenario being modelled in the assessment. In principle, the replacement of a component as part of a scheduled programme of refurbishment of the building is reported here, in module B5.
B6	**Operational energy use** – Energy used in the normal operation of the building during the RSP, to meet various functions required in the use of the building; applicable to building integrated technical systems for activities and processes according to EN 15603:2008: for heating ventilation and cooling (HVAC), lighting, cold and hot water supply, pumps and automation, etc. Energy used for other technical systems according to EN 15603:2008 such as internal transport (lifts, escalators), safety and security installations and communication shall also be modelled as part of the operational energy demand in the LCA study for module B6 but the results obtained shall be reported separately. See Energy Performance of Buildings Directive. Module B6 excludes energy use of non-building related appliances. If these are included in the assessment of the operational energy demand they shall be reported and communicated separately. Where energy is generated within the building's site there is a specific hierarchy of the use of this energy in fulfilling first the building-related energy demand, before non-building related demand. The amount of any exported energy is reported in module B6 using the output flow indicator 'Exported Energy' in MJ per energy carrier (see Table 5 in EN 15978 clause 11.1.4), while the benefits or loads of the energy exported shall be reported in module D. See Figure 8 in EN 15978 clause 7.4.4.7.
B7	**Operational water use** – Water used in the normal operation of the building during the RSP; applicable to building integrated water consuming processes for drinking, hot water and HVAC, sanitation, irrigation of associated areas of the building and for integrated systems like fountains and swimming pools. Module B7 excludes water used in maintenance, repair, replacement and refurbishment activities. Module B6 also excludes water use of non-building related appliances. If these are included in the assessment of the operational water demand they shall be reported and communicated separately.

In the UK for example, operational energy use of a building can be derived using Standard Assessment Procedure (SAP) for energy ratings for dwellings.

Both operational energy and operational water use covers the RSP of the building being assessed, beginning from handover of the building to the user.

7.4.5 The End of life stage (modules C1 to C4)

As in EN 15978 clause 7.4.5.

The building end-of-life is when the building is decommissioned and is not intended to have any future use. The boundaries are defined as shown in Table 7.5.

Table 7.5: End-of-life stage

Module	Modelling requirements
C1	Deconstruction (dismantling/demolition) of the end-of-life building. Includes on- and related offsite activities
C2	Transporting the demolition wastes to sorting/recycling or to end-of-life disposal site
C3	Sorting, collection, processing of the demolition wastes for the different routes (reuse, recycling, energy recovery, final disposal) at a waste processing facility
C4	Final disposal of the demolition wastes at a disposal site, including any required pre-treatment and the management of the disposal facility

At the building's end-of-life, all the demolition wastes are considered to be 'waste' until they reach the end-of-waste state. The end-of-waste state is reached when any such material complies with the following criteria (see EN 15978 clause 7.4.5.4):

- It is (commonly) used for specific purposes
- There is an existing market or demand for it
- Its use fulfils technical requirements for the specific purpose, as well as applicable standards and legislation
- Its use will not lead to overall adverse effects by introducing pollutants to the environment

The boundary for this is either module C3, i.e. following sorting and waste processing, or module C2 if the material can be obtained directly from the deconstruction/demolition process.

The benefits and loads from the use of end-of-waste state materials in another system (i.e. beyond the building assessment boundary) are reported in module D, see 7.4.6 below. Note that materials for energy recovery are materials that have reached the end-of-waste state and are used in an energy recovery process with an energy efficiency rate (of the process) higher than 60%.

The potential benefits from utilising energy arising from a waste disposal process in module C4, e.g. incineration of waste and landfill gas can also be presented in module D, using current average substitution processes. See EN 15978 clause 7.4.5.4.

7.4.6 The Benefits and loads beyond the system boundary (D)

As in EN 15978 clause 7.4.6.

Module D covers the net benefits and loads arising from the reuse, recycling and energy recovery from materials/components leaving the system boundary, having been generated as waste and having reached the end-of-waste state from the construction stage (modules A4 – A5), the use stage (modules B1 – B7) including exported energy, and the end-of-life stage (modules C1 – C4).

In addition to being a net impact calculation, module D shall also be based on average existing technology and current practice (see EN 15978 clause 7.4.6). The principle of module D is presented in EN 15804+A1, and illustrated in detail in BRE Global's PCR for construction products evaluation, PN 514[3], Figure 6.1 in clause 6.3.4. A detailed example is provided in Appendix A of this BRE Global methodology.

7.5 The Building Model

7.5.1 Purpose and information needed

As in EN 15978 clause 7.5.1.

For comparative building assessments the goal and scope definition of the LCA study should take into account the suitability of available data to enable the quantification of the mass and energy flows (known as the building model) of the buildings under assessment. The building model must reflect the level of detail available, dependent on the stage at which the assessment is carried out, e.g. RIBA[4] stage 2 (Concept Design) or stage 4 (Technical Design). This should also be clearly stated in the LCA report generated.

For example in an assessment to be carried out before the construction of a new build project for the purpose of providing quantified environmental data on the whole life, i.e. at the conclusion of stage 4:

- Data on the product stage shall reflect as accurately as possible the specification contained in the finished Technical Design.
- Data for the construction scenarios shall be informed by the anticipated construction products and materials sources as well as construction programme details and best available or recommended construction techniques
- Data for the use scenarios shall reflect manufacturer-recommended product performance, assumptions on user behaviour and realistic end-of-life assumptions, in combination with data used in product and construction scenarios
- Data on the end-of-life scenarios should reflect the reality of how the respective construction products and materials are treated at their end-of-life

[3] PN 514 Rev 1.0, BRE Global Product Category Rules (PCR) for Type III EPD of Construction Products to EN 15804+A1, www.greenbooklive.com
[4] Royal Institute of British Architects, RIBA, www.architecture.com

7.5.2 Describing the physical characteristics of the building

As in EN 15978 clause 7.5.2.

Also see example illustrated in Figure A.1 in EN 15978 Annex A.

8 Scenarios For Defining The Building Life Cycle

8.1 General

As in EN 15978 clause 8.1.

Realistic and representative scenarios, covering both assumptions (based on relevant technical information) and known or actual information shall support the calculation of the information modules (shown in Figure 7.1 above) and the assessment of the environmental performance of a building in the construction, use and end-of-life stages.

The use stage in particular shall reflect the service life of the building and respective information related to the building in conjunction with suitably representative product data as may be found in EPD.

8.2 Requirements for scenarios

As in EN 15978 clause 8.2.

The key requirement is clarity and transparency – of data characteristics (actual or estimates) and sources, assumptions, limitations, etc.

8.3 Time-related characteristics and associated scenarios

As in EN 15978 clause 8.3.

8.4 Scenarios for the different life cycle stages

As in EN 15978 clauses 8.4 to 8.8.

For modules A1 to A3, wherever possible, the product stage environmental data shall come from EN 15804 EPD, in the absence of which other EPD and LCA study sources may be used with appropriate value judgements.

For modules A4 and A5, if transport and construction stage environmental data from EPD are being used in the LCA study then the scenario used in the EPD must be applicable to the scenario defined for the building under assessment, otherwise the applicable modelling data will have to be developed in the LCA study.

The assessment of information modules in the use stage (modules B1 to B7) are dependent on and shall therefore clearly reflect the defined functional performance characteristics of the building (i.e. the 'functional equivalent' defined for the LCA study).

All scenarios shall be according to the modelling requirements described in 7.4 above, using the specified study system boundaries.

As stated in clause 7.4.6 in this BRE Global methodology, module D reports the net environmental benefits based on net output flows (derived essentially from the difference between materials entering the system boundary in module A1 and materials leaving the system boundary in modules A5 and C3). An example of net output flow and module D calculation for a building component that is leaving the building in module C3 having reached its end of waste state is provided in Appendix A of this BRE Global methodology.

For all scenarios developed and modelled in the LCA study, clear justification for various data sources along with any additional assumptions made shall be documented, for transparency.

9 Quantifying The Building And Its Life Cycle

9.1 General

As in EN 15978 clause 9.1.

9.2 Specification of net amount

As in EN 15978 clause 9.2. The net amounts are the actual quantities of the products or components that constitute the building under assessment.

9.3 Accounting for the gross amount

As in EN 15978 clause 9.3.

Where applicable during the building LCA assessment, gross amounts shall be accounted for by assessing the additional quantities due to losses, e.g. losses and damages during transport to site, storage on site, and in construction processes (installation wastages such as due to design requirements, supply conditions or just installation processes), subject to availability of data. This follows the modularity principle by evaluating and reporting environmental impacts where they occur, i.e. in their respective modules, e.g. module A5 shall include the production and transport of additional quantities of construction products to replace material wastage during construction, as well as the disposal of the wasted material.

Some products or components are replaced during the lifetime of a building or during the RSP used in the assessment. This is particularly applicable when assessing the use stage module B4, and the following relationship between the estimated / reference service life of the component (RSL_P) and the RSP of the building is used to derive the number of replacements ($N_{replace}$) for that component:

Number of Replacements $\quad N_{replace} = \frac{RSP}{RSL_P} - 1$

NOTE: there are no partial replacements in a building assessment. The value obtained for $N_{replace}$ from the equation above shall be *rounded up* to the next whole number and used in the building assessment, i.e. a derived $N_{replace}$ of 2.2 = 3 replacements while 2.6 = 3 replacements. EN 15978 clause 9.3.3 includes examples and considerations in the

application of number of replacements in assessments, including the likelihood of replacement occurring or being necessary in the context of the building being assessed. Further details and examples are provided in Appendix A of this BRE Global methodology.

9.4 Type of data for the assessment

As in EN 15978 clause 9.4.

In terms of the material inputs and outputs, the assessment shall be carried out using the most representative quantified data for the building being assessed and the stage or time of the assessment. The criteria for the exclusion of material inputs and outputs are to be applied as stated in clause 6.3.5 of EN 15804+A1.

The inventory process gathers all the material data that are associated with the building under assessment. For many buildings, a large number of construction materials are used in very small quantities and it is unrealistic to gather data on all of these.

However, it is important that significant environmental effects are not omitted by ignoring low mass flows of construction products. Analysis may later reveal that these materials do not significantly affect the overall result but it is important that data is provided to enable this conclusion to be drawn. To achieve this, the following conventions are applied:

In case of insufficient data or data gaps for a building component, the cut-off criteria shall be 1% of the total mass input of the building element category. The total of neglected material flows per information module shall be a maximum of 5% of energy usage and mass. The exception is if they have any of the following in which case they have to be included:

- Significant effects of or energy use in their manufacture, their use, or disposal
- Are classed as hazardous waste

Table 1 in EN 15978 clause 9.4.1 shows the type of data that can be used for the quantification of the amounts in different stages of the assessment. Therefore, for new build projects, following the completion of detail design[5], a bill of quantities provides detailed mass values for building LCA assessments. Other sources of material quantities include building information models and estimations from the consultants' drawings/sketches.

For existing buildings actual material quantities are available from as-built drawings and contractor records from measurements taken during the construction stage.

All assumptions are to be clearly stated, and justified where necessary, in the study report generated.

9.5 Quantification specific to operational energy use

As in EN 15978 clause 9.5, and Table 7.4 in this document.

NOTE: the benefits resulting from exported energy, where applicable, are reported in information module D.

9.6 Quantification specific to operational water use

As in EN 15978 clause 9.6, and Table 7.4 in this document.

[5] RIBA stages of work, Work Stage E: Detail Design, www.architecture.com

10 Selection of environmental data and other information

10.1 General

As in EN 15978 clause 10.1.

Specifically, EN 15804 EPD for a construction product / material / component is intended to provide the quantified information on the environmental impacts and aspects relevant to a building assessment using the EN 15978 calculation methodology. However, care should be taken to only use EPD data that is appropriate for the building materials used in the building and, where the EPD provides data beyond the gate stage of the product lifecycle, on data based on specific scenarios applicable to the building assessment. Where an EPD is not available, or is available but is not suitable, data can also be obtained from generic material databases and peer-reviewed LCA studies, including the use of suitable proxies.

The input and output materials attributed to imported finished materials and products are, wherever possible, based upon analyses appropriate to the country of origin and include the energy of transportation. Where data for the country of origin are not available, the input and output data are based upon the most comparable product (internationally or domestically produced) with an addition made for the transportation from the country of origin.

All details and assumptions on data sources shall be clearly stated in the report compiled for the building LCA study.

10.2 Scenarios for the building

As in EN 15978 clause 10.2.

Realistic and representative scenarios shall be based on relevant technical performance information and shall support the calculation of the information modules as shown in Figure 7.1 for the assessment of the environmental performance of a building in construction, use and end-of-life stages, as well as in module D. The scenarios shall be developed relevant to the building under assessment.

10.3 Data quality

As in EN 15978 clause 10.3.

10.4 Consistency

As in EN 15978 clause 10.4.

11 Calculating The Environmental Indicators

11.1 Environmental impacts, aspects and related indicators

As in EN 15978 clause 11.1.

The quantified environmental impacts of the building shall be declared and reported using the category indicators (parameters) and units shown in Table 11.1 below.

Table 11.1: Parameters for describing environmental impacts

Impact Category	Parameter (Category Indicator)	Unit
Global Warming (Climate Change)	Global warming potential, GWP	kg CO_2 eq.
Ozone Depletion	Depletion potential of the stratospheric ozone layer, ODP	kg CFC 11 eq.
Acidification for Soil and Water	Acidification potential of land (soil) and water, AP	kg SO_2 eq.
Eutrophication	Eutrophication potential, EP	kg $(PO_4)^{3-}$ eq.
Photochemical Ozone Creation	Formation potential of tropospheric ozone photochemical oxidants, POCP	kg C_2H_4 eq.
Depletion of Abiotic Resources – elements	Abiotic resource depletion potential for elements (non-fossil resources), ADP-elements	kg Sb eq.
Depletion of Abiotic Resources – fossil fuels	Abiotic resource depletion potential of fossil fuels, ADP-fossil fuels	MJ, net calorific value

In addition to the environmental impact category indicators, the following environmental indicators describing resource use, waste and other output flows, which are derived from data from the life cycle inventory process but not assigned to the impact category indicators listed in Table 11.1, shall be reported in the building assessment as shown in Table 11.2 below.

Table 11.2: Other parameters (combined for ease of presentation)

	Parameter	Unit
Resource Use	Use of renewable primary energy excluding renewable primary energy resources used as raw materials, PERE	MJ, net calorific value
	Use of renewable primary energy resources used as raw materials, PERM	MJ, net calorific value
	Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials, PENRE	MJ, net calorific value
	Use of non-renewable primary energy resources used as raw materials, PENRM	MJ, net calorific value

	Parameter	Unit
	Use of secondary material, SM	kg
	Use of renewable secondary fuels, RSF	MJ, net calorific value
	Use of non-renewable secondary fuels, NRSF	MJ, net calorific value
	Net use of fresh water, FW	m^3
Waste to disposal	Hazardous waste disposed, HWD	kg
	Non-hazardous waste disposed, NHWD	kg
	Radioactive waste disposed, RWD	kg
Other output flows	Components for reuse, CRU	kg
	Materials for recycling, MFR	kg
	Materials for energy recovery, MER	kg
	Exported energy, EE	MJ for each energy carrier

For additional guidance, see NOTES in EN 15978 clause 11.1.

11.2 Calculation methods

As in EN 15978 clause 11.2.

A matrix calculation is provided in EN 15978 clause 11.2 for deriving the total values by environmental parameter (category indicator in Tables 11.1 and 11.2 above) per life cycle module (Figure 7.1) by multiplying the amounts for all the products and services in the stage by their respective environmental parameter values.

Appendix A of this BRE Global methodology provides detailed formulae along with examples.

12 Reporting the results of a building assessment

12.1 General information on the assessment

As in EN 15978 clause 12.1.

All environmental parameter results shall be reported to a maximum of 3 significant figures.

To ensure transparency of the results of the building assessment, the results documentation shall include as a minimum the information itemised in EN 15978 clause 12.1

12.2 General information on the object of the assessment

As in EN 15978 clause 12.2.

The functional equivalence, described using the appropriate functional unit which has been used in the assessment, along with the reference study period and other relevant building information (see EN 15978 clause 12.2) shall be provided as general information on the building that has been assessed.

12.3 Statement of boundaries and scenarios used in the assessment

As in EN 15978 clause 12.3.

12.4 Data sources

As in EN 15978 clause 12.4.

12.5 List of indicators used for assessment and expression of results

As in EN 15978 clause 12.5.

The results shall be presented separately for all building life cycle stages and for module D, see Table 12.1 below.

The product stage modules A1 – A3 may be provided as an aggregated total, depending on the sources of the data for the individual materials; this is because EN 15804+A1 permits this aggregation at the product level. For the remaining life cycle stages, it is possible to have indicators and modules not assessed. Where this occurs these shall be reported as INA (for indicator not assessed) or MNA (for module not assessed), and the reasons for these omissions shall be clearly provided.

NOTE: where a comparative assessment is being carried out, e.g. for use in a building rating scheme or for benchmarking, there may be minimum requirements for the indicators and modules assessed, which, along with functional equivalence and data source restrictions will ensure that comparison between the buildings assessed is on a like-for-like basis.

Further, within each life cycle stage the results may be summed, provided the values have been determined for each module within that stage. In other words, if any module within a life cycle stage has not been assessed, the results for this stage must be expressed separately per module.

Table 12.1: Example table of results

Indicator	Unit	Life cycle stages				Supplementary
		Product stage	Construction stage	Use stage	End of life stage	Benefits and loads beyond the system boundary
		A1 – A3	A4 – A5	B1 – B7	C1 – C4	D
e.g. GWP	kg CO_2 eq.	xx	xx	xx	xx	xx

12.6 Communication of assessment results

As in EN 15978 clause 12.6.

13 Verification of the results of a building assessment

As in EN 15978 clause 13.

Verification is not a mandatory requirement in building assessment using LCA. If carried out, verification provides a formal independent confirmation of the validity of the results obtained from the assessment.

There are assessments in which verification not only adds value to the output, but may also be a requirement, e.g. where the purpose of the assessment is for building sustainability certification.

Appendix A – Calculating the impacts

The equations in this Appendix are a linear interpretation of the matrix routine described in EN 15978 clause 11.2.

The examples within this Appendix are based on an illustrative simplified building, composed of blocks, steel, insulation and cladding. The illustrative material quantities and environmental data for GWP are shown in Table A.1 below.

Table A.1: Example material quantities and GWP unit data for a building under assessment

		Blocks	Steel	Insulation	Cladding
Quantity, net	Q_M (kg)	10	5	2	3
GWP (kg CO_2 eq.) unit data for the respective information modules	A1	8	12	11	9
	A2	2	4	3	1
	A3	16	18	17	15
	A4	2	2	2	2
	A5	3	3	3	3
	B1	0	0	0	0
	B2	0	0	0	2
	B3	0	0	0	0
	B4	0	0	0	32
	B5	0	0	0	0
	B6	0	0	0	0
	B7	0	0	0	0
	C1	1	1	1	1
	C2	2	2	2	2
	C3	5	7	6	4
	C4	13	15	14	12

NOTE: in order to conduct a building LCA study it is a pre-requisite that the environmental impacts data (unit data) for all the individual materials has already been provided/collated from compatible generic or manufacturer/product-specific EN 15804 EPD or from suitable LCA study reports and publicly available datasets.

A.1 Material Quantities

In a building LCA study, where the net material quantities Q_M have not been provided in mass units these can typically be obtained from any of the following possible given units:

From linear metre (m): $Q_M = mass\ per\ m \times number\ of\ m$

From area (m^2): $Q_M = mass\ per\ m^2 \times number\ of\ m^2$

From volume (m^3): $Q_M = mass\ per\ m^3 \times number\ of\ m^3$

From piece/unit: $Q_M = mass\ per\ piece \times number\ of\ pieces$

A.2 Module and Stage Calculations per Category Indicator

A.2.1 General

Using the material quantities Q_M, and where

P = the specified construction material

$Q_M P$ = quantity of the specified construction material

CI = category indicator, e.g. GWP, EP, etc.

Mod = information module, e.g. A1, A2, A3, etc.

$CI_{Mod} P\ unit\ data$ = category indicator unit data for P in respective information module

$Stage$ = Life cycle stage, e.g. Product stage (A1-A3), Construction stage (A4-A5), etc.

The category indicator result for each material in an information module is obtained from Eqn. 1 as follows:

$$CI_{Mod} P = CI_{Mod} P\ unit\ data \times Q_M P \qquad \text{Eqn. 1}$$

The total of that category indicator for the information module is then obtained by summing up the results for the different materials in that module according to the Eqn. 2 below:

$$\sum CI_{Mod} = CI_{Mod} P1 + CI_{Mod} P2 + CI_{Mod} P3 + \cdots + CI_{Mod} Pn \qquad \text{Eqn. 2}$$

And, where there are results for every information module in the respective life cycle stage, the total of the category indicators for all the modules in the stage are summed up to obtain a total value for that category indicator for the stage according to Eqn. 3 below:

$$\sum CI_{Stage} = \sum CI_{Mod1} + \sum CI_{Mod2} + \cdots + \sum CI_{Mod\ n} \qquad \text{Eqn. 3}$$

Examples of general calculations:

In order to derive the GWP category indicator results for the building's product stage modules A1-A3 the Eqns 1, 2 and 3 above are applied as follows:

1. The GWP result in individual information modules per material used in the building is obtained using Eqn. 1, as shown in the following example below for blocks:

$$GWP_{A1}Blocks = GWP_{A1}Blocks\ unit\ data \times Q_M Blocks = 8 \times 10 = 80\ kg\ CO_2eq.$$

2. The total category indicator GWP for information modules A1, A2 and A3 are then derived for all the materials in the building under assessment using Eqn. 2 as follows:

$$\sum GWP_{A1} = GWP_{A1}Blocks + GWP_{A1}Steel + GWP_{A1}Insulation + GWP_{A1}Cladding$$
$$= 80 + 60 + 22 + 27 = 189\ kg\ CO_2eq.$$
$$\sum GWP_{A2} = GWP_{A2}Blocks + GWP_{A2}Steel + GWP_{A2}Insulation + GWP_{A2}Cladding$$
$$= 20 + 20 + 6 + 3 = 49\ kg\ CO_2eq.$$
$$\sum GWP_{A3} = GWP_{A3}Blocks + GWP_{A3}Steel + GWP_{A3}Insulation + GWP_{A3}Cladding$$
$$= 160 + 90 + 34 + 45 = 329\ kg\ CO_2eq.$$

3. And the total GWP results for the product stage modules A1 to A3 for the building under assessment is derived using Eqn. 3 as follows:

$$\sum GWP_{A1-A3} = \sum GWP_{A1} + \sum GWP_{A2} + \sum GWP_{A3}$$
$$= 189 + 49 + 329 = 567\ kg\ CO_2eq.$$

In addition to the Eqns. 1, 2 and 3 above, the following sections provide instructions and additional equations applicable to the different modules and life cycle stages in a building LCA study.

A.2.2 Modules A1-A3 aggregated

For construction materials where the data for the product stage have been aggregated, i.e. where the materials unit data for modules A1-A3 have been provided as aggregated values (this is permitted in EN 15804+A1), using the net Q_M values the Eqn. 1 for deriving the category indicator result for each material is adapted from 'modular' to 'stage' calculation as shown in Eqn. 4 below:

$$CI_{A1-3}P = CI_{A1-3}P\ unit\ data \times Q_M P \qquad \text{Eqn. 4}$$

The total of that category indicator for the modules A1-A3 (aggregated) is then obtained by summing up the results for the different materials according to the Eqn. 5 below:

$$\sum CI_{A1-3} = CI_{A1-3}P1 + CI_{A1-3}P2 + CI_{A1-3}P3 + \cdots + CI_{A1-3}Pn \qquad \text{Eqn. 5}$$

A.2.3 Modules A4 and A5

For transport to site (module A4), the category indicators shall be derived for impacts for transporting the quantity required in the building under assessment as well as for any additional quantities to account for transport losses e.g. due to damage, where applicable.

Where the material's unit data for module A4 has already taken into account the loss %, the net Q_M value is used (rather than a gross Q_M value) in Eqns. 1 and 2.

But if the losses during the transport stage have not been accounted for in the unit data, the gross quantity is derived as shown in Eqn. 6 below:

$$Gross\ Q_M P_{A4} = (Net\ quantity) + (Net\ quantity \times \%\ loss) \quad \text{Eqn. 6}$$

The gross Q_M obtained from Eqn. 6 is then used in Eqns. 1 and 2 to obtain the category indicator results for module A4.

Example of module A4:

In order to deliver the 8 kg of blocks to the construction site there is a transportation loss of 2.5%. Therefore, where the loss % is not already included in the unit data for module A4, to derive the GWP category indicator for the blocks in module A4 the gross quantity is used:

$$Gross\ Q_M Blocks_{A4} = 10 + (10 \times 2.5\%) = 10.25\ kg\ CO_2eq.$$
$$GWP_{A4}Blocks = GWP_{A4}Blocks\ unit\ data \times Gross\ Q_M Blocks_{A4}$$
$$= 2 \times 10.25 = 20.5\ kg\ CO_2eq.$$

Subject to data availability, module A4 shall also include the transport of the various construction equipment to the construction site, using Eqn. 2 above, i.e.:

$$\sum CI_{A4} = \sum CI_{A4}P + \sum CI_{A4}Equipment \quad \text{Eqn. 7}$$

For construction (module A5), the category indicators shall be computed for installing the respective materials in the building under assessment, plus the impacts for manufacturing and delivering any material lost through the installation process if applicable, and the disposal of the wasted material.

Where the material's unit data for module A5 is based on an appropriate scenario for the building under assessment, it should therefore already have taken into account the loss %, the provision of this additional material and the disposal of this installation loss (material wasted), in which case the category indicator is derived from Eqns. 1 and 2 using the net Q_M value.

But if the losses during the construction stage have not been accounted for in the unit data, a $Q_M \times \%\ loss$ value is introduced as shown in Eqn. 8 below:

$$CI_{A5}P = (CI_{A5}P\ unit\ data \times Q_M P) + (CI_{A1-A3}P \times \%\ loss) + (CI_{A4}P \times \%\ loss) + (CI_{C4}P\ unit\ data \times Q_M P \times \%\ loss) \quad \text{Eqn. 8}$$

Example of module A5:

In order to install 8 kg of blocks in the construction stage there is an installation wastage (loss) of 5%. Therefore, where the loss % is not already included in the unit data, to derive the GWP category indicator for the blocks in module A5, using Eqn. 8:

$$GWP_{A5}Blocks = (GWP_{A5}Blocks\ unit\ data \times Q_M Blocks) + (GWP_{A1-A3}Blocks \times \%\ loss) + (GWP_{A4}Blocks \times \%\ loss) + (GWP_{C4}Blocks\ unit\ data \times Q_M Blocks \times \%\ loss)$$

$$= (3 \times 10) + ((80 + 20 + 160) \times 5\%) + (20.5 \times 5\%) + (13 \times 10 \times 5\%)$$

$$= 30 + 13 + 1.025 + 6.5 = 50.5\ kg\ CO_2eq.$$

The category indicator results for the construction stage (modules A4-A5) can then be calculated using Eqn. 3 for stage calculations.

A.2.4 Modules B1 to B7

For the use of the material in the building under assessment (module B1), the category indicators shall be derived using the net Q_M values in Eqns. 1 and 2.

For the use modules B2 to B5, where a material's unit data for B2 to B5 is based on an appropriate scenario for the building under assessment, the category indicators are derived from Eqns. 1 and 2 using the net Q_M value and the given unit data category indicator.

Example of module B4 (where the given unit data is appropriate to the scenario):

The GWP category indicator for replacing the cladding material at the end of its service life is derived using Eqn. 1:

$$GWP_{B4}Cladding = GWP_{B4}Cladding\ unit\ data \times Q_M Cladding = 32 \times 3 = 96\ kg\ CO_2eq.$$

But where the material's unit data have not been derived using scenarios applicable to the building under assessment, then the category indicators for modules B2 to B5 will have to be derived in the study as these modules are directly related to the context of the building, i.e. the functional equivalence and defined applicable scenarios. The derivation of the indicators for these modules will require the data from the preceding modules A1-A3, A4 and A5 for the materials in the LCA study, as well as end of life (module C4) unit data for the materials.

Based on the respective applicable scenarios, e.g. for repair of damaged components or part or complete replacements, the category indicators shall then also cover the additional quantities (manufacture and transport to site) resulting from losses during the respective activity and any end of life disposal or management required as a result. The frequency of occurrence or cycle, the building study period RSP and the materials' reference service life RSL_P shall also all be taken into account when deriving the category indicators for modules B2 to B5.

For module B2, in order to derive the category indicator for a manufacturer recommended process such as maintenance cleaning, the Eqn. 1 for deriving the category indicator result for each material is adapted as shown in Eqn. 9 below:

$$CI_{B2}P = Freq_{maint} \times RSP \times (CI_{maint}P\ unit\ data \times Q_M P) \qquad \text{Eqn. 9}$$

Where

$Freq_{maint}$ = frequency of maintenance activity (number per year)

CI_{maint}= applicable unit data for specific maintenance operation, sourced

RSP = study period in LCA study, e.g 60 years.

The total of the category indicators for the module B2 is then obtained by summing up the results for the different materials in that module according to the Eqn. 2.

Example of module B2:

In order to derive the GWP category indicator for the maintenance cleaning of the cladding in the building under assessment, where the recommended cleaning is once every year for a study period of 60 years, where the GWP for cleaning the cladding unit has been obtained from a suitable data source or proxy as 2.5 kg CO_2eq.:

$$GWP_{B2}Cladding = Freq_{maint} \times RSP \times (GWP_{maint}Cladding\ unit\ data \times Q_M Cladding)$$
$$= 1 \times 60 \times (2.5 \times 3) = 450\ kg\ CO_2eq.$$

For module B3, in order to derive the category indicators for a planned repair or replacement of a worn out material, the Eqn. 1 for deriving the category indicator result for each material is adapted as shown in Eqn. 10 below:

$$CI_{B3}P = Freq_{repair} \times RSP \times (CI_{repair}P\ unit\ data \times Q_M P) \qquad \text{Eqn. 10}$$

Where

$Freq_{repair}$ = frequency of repair activity (number per year)

CI_{repair}= applicable unit data for specific repair operation, sourced

The total of the category indicators for the module B3 is then obtained by summing up the results for the different materials in that module according to the Eqn. 2.

For modules B4 and B5, in order to derive the category indicators for replacing a material at the end of its RSL_P (module B4) or as part of a scheduled programme of refurbishment of parts of the building (module B5) the Eqns. 11 and 12 respectively below are used:

$$CI_{B4}P = N_{replace} \times \sum(CI_{A1-3}P + CI_{A4}P + CI_{A5}P + CI_{C4}P) \quad \text{Eqn. 11}$$

$$CI_{B5}P = N_{refurb} \times \sum(CI_{A1-3}P + CI_{A4}P + CI_{A5}P + CI_{C4}P) \quad \text{Eqn. 12}$$

Where

$N_{replace}$ = number of replacements during the RSP

= $\frac{RSP}{RSL_P} - 1$, *rounded up* to the next whole number

N_{refurb} = number of refurbishments during the RSP, based on the defined scenario

The total of the category indicators for the modules B4 or B5 is then obtained by summing up the results for the different materials in that module according to the Eqn. 2.

Example of module B4:

In order to derive the GWP category indicator for the replacement of a cladding unit in the cladding in the building under assessment, where there is a transportation loss during A4 of 2.5%, and an installation wastage during A5 of 5%, and the RSL_P of the cladding is 25 years, using Eqn. 11:

$$GWP_{B4}Cladding = N_{replace} \times \sum(GWP_{A1-3}Cladding + GWP_{A4}Cladding + GWP_{A5}Cladding + GWP_{C4}Cladding)$$

Where:

$N_{replace} = \frac{60}{25} - 1 = 1.4, this\ is\ rounded\ up\ to\ 2$

$GWP_{A1-3}Cladding = (9 \times 3) + (1 \times 3) + (15 \times 3) = 75\ kg\ CO_2eq.$

$GWP_{A4}Cladding = 2 \times \big(3 + (3 \times 2.5\%)\big) = 6.15\ kg\ CO_2eq.$

$GWP_{A5}Cladding = (3 \times 3) + (75 \times 5\%) + (6.15 \times 5\%) + (12 \times 3 \times 5\%) = 14.85\ kg\ CO_2eq.$

$GWP_{C4}Cladding = 12 \times 3 = 36\ kg\ CO_2eq.$

$$GWP_{B4}Cladding = 2 \times \sum(75 + 6.15 + 14.85 + 36) = 264\ kg\ CO_2eq.$$

For the energy and water use of the material in the building under assessment (modules B6 and B7 respectively), the category indicators shall be derived using the net Q_M values in Eqns. 1 and 2.

The category indicator results for the use stage (modules B1-B7) can then be calculated using Eqn. 3 for stage calculations.

A.2.5 Modules C1 to C4

The end of life modules C1, C2, C3 and C4 refer to the fate of materials following dismantling or demolition of the building under assessment at the end of life. Where a material's unit data for modules C1 to C4 is based on an appropriate scenario for the building under assessment, the category indicators shall be derived using the net Q_M values in Eqns. 1 and 2 (as this is the quantity of the material that is actually installed in the building).Where the scenarios for the unit data are different from the required scenarios for the building under assessment, the category indicators will have to be derived by applying unit data for comparable materials in applicable scenarios using the net Q_M values in Eqns. 1 and 2.

A.2.6 Module D

Module D is outside of the life cycle of the building under assessment, and is used to express environmental benefits or loads from a future use of end of life materials from the building. This future use is either through reuse, recovery or recycling, including in energy generation) and is provided as supplementary information which is beyond the building life cycle.

Where a material's unit data is based on an appropriate scenario for the building under assessment, the category indicators are derived from Eqns. 1 and 2 using the net Q_M value and the given unit data category indicator.

NOTE: where a material's unit data has not been derived using scenarios applicable to the building under assessment, then the category indicators for module D for this material will have to be derived in the study, requiring expert judgment in determining the net secondary material flows and therefore the avoided impacts (burdens or loads) for the respective materials.

Therefore, where

P = the specified construction material in the building under assessment

$Q_M P_{in}$ = the quantity of the material used in the building

$Q_M P_{in} Secondary\ content$ = the quantity of secondary material in $Q_M P_{in}$

$Q_M P_{out}$ = the quantity of the material leaving the building having reached its end of waste state

The net secondary material flow $\Delta Q_M P$ is derived using Eqn. 13 below:

$$\Delta Q_M P = Q_M P_{out} - Q_M P_{in} Secondary\ content \qquad \text{Eqn. 13}$$

$Q_M P_{in} Future$ = the quantity of virgin material P that can be replaced by the secondary material P obtained from the building under assessment, i.e. $\Delta Q_M P$

The category indicator (i.e. avoided impact) for material P reported in module D is derived from Eqn. 14 below:

$$CI_D P = -(CI_{A1-A3} P \times \Delta Q_M P_{in} Future) \qquad \text{Eqn. 14}$$

In a scenario where the recovered material is capable of replacing virgin material on a 1:1 basis $\Delta Q_M P = Q_M P_{in}$Future.

Example of module D:

At the building's end of life, after demolition/deconstruction and other related waste processing activities, 8 kg of bricks will be recovered.

As 10 kg of bricks were initially installed in the building under assessment, and assuming the recovered bricks are capable of replacing virgin bricks on a 1:1 basis in a new or in another building (i.e. the future use), then the net output flow and module D calculations that can be reported for the 10 kg of bricks initially installed in the building are as follows:

Step 1: If the 8 kg of end of waste bricks are available to replace 8 kg of virgin bricks in a subsequent system (e.g. another building), then the benefit of avoiding 8 kg of virgin bricks production for that subsequent system are presented in module D for this material in the building under assessment, by reporting the avoided impacts as negative values. The GWP category indicator for the bricks in module D will be derived as follows:

$$GWP_D Bricks = -(GWP_{A1-A3} Bricks \times \Delta Q_M Bricks_{in} Future)$$
$$= -(26 \times 8) = -208\ kg\ CO_2 eq.$$

Step 2: If the 10 kg of bricks initially had a 50% secondary material content, i.e. based on recycled material input in its product stage (A1-A3), then $\Delta Q_M Bricks = 8 - 5 = 3\ kg$, and

$$GWP_D Bricks = -(26 \times 3) = -78\ kg\ CO_2 eq.$$

This avoids double counting, as the benefits of the initial use of secondary material (5 kg) have been accounted for in the environmental impact contribution of bricks to the building under assessment.

Step 3: Now, if the 3 kg of end of waste bricks available actually required a further processing step to make them suitable for a 1:1 replacement of virgin bricks, resulting in a further loss of 0.5 kg disposed as waste, meaning only 2.5 kg from the end of waste bricks ends up in the future building, i.e. $\Delta Q_M Bricks_{in} Future = 2.5\ kg$, and the GWP category indicator for the bricks in module D will be derived as follows:

$$GWP_D Bricks = -(26 \times 2.5\ kg) + (GWP_{additional\ processing}) + (GWP_{C4} Bricks \times 0.5\ kg)$$

Step 4: If, however, the bricks had 90% recycled content (and not 50% as stated in step 2 above), then $\Delta Q_M Bricks = 8 - 9 = -1\ kg$. This implies a negative flow of secondary bricks, and therefore a positive value for $GWP_D Bricks$ (a load rather than a benefit). In a situation such as this, where there is a load (burden) rather than a benefit in a future recovery scenario, it is not likely that a module D calculation will be included for that material in the building under assessment.

A.2.7 Additional aspects of note

A.2.7.1 Allocation of site wide data

Modules A5 (construction) and C1 (deconstruction / demolition) are intricately linked with the overall construction practice –planned or actual – in the building under assessment, for which research shows that there are currently data gaps. There is therefore typically no availability of useable unit data in practice, meaning these modules may have to be derived either from general overhead assumptions or as a fraction of values available as a total at the building level.

This therefore involves either a mass based allocation per unit of material from a total value per m^2 of the building under assessment, or a value allocation – depending on data available for the LCA study. Such allocation shall be clearly documented and justified in the report compiled for the building LCA study.

A.2.7.2 Adjustments to Module B results

(Following clause 7.3 of this BRE Global methodology).

When the building's $RSP \neq ReqSL$ of the building, the category indicator results for the use stage modules B1 to B7 are first derived for the $ReqSL$ of the building, and then adjusted using an adjustment factor (f_a) obtained from the mathematical relationship between the RSP and the $ReqSL$ of the building as shown below:

Adjustment factor $f_a = \frac{RSP}{ReqSL}$ Eqn. 15

Therefore,

1. If $RSP = ReqSL, then\ f_a = 1$

   i.e. no adjustment. This is the default value
2. If $RSP < ReqSL$,
   The reported impact = $f_a \times Quantified\ impact.$
3. If $RSP > ReqSL$,
   The reported impact = $(f_a \times Quantified\ impact) + additional\ scenarios$

   Where $additional\ scenarios$ are the scenarios for refurbishment (module B5) to extend the service life of the building to cover the study period or for end of life

modules (C1 to C4) and construction including product stages modules (A1 to A3 and A4 to A5) of an equivalent new building.

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