Whole life carbon measurement: implementation in the built environment

Draft RICS professional statement

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Acknowledgments

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RICS professional standards and guidance

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Document status defined

RICS produces a range of professional standards, guidance and information documents. These have been defined in the table below. This document is a professional statement.

Publications status

Type of document	Definition	Status
Standard		
International standard	An international high-level principle-based standard developed in collaboration with other relevant bodies.	**Mandatory.**
Professional statement		
RICS professional statement (PS)	A document that provides members with mandatory requirements or a rule that a member or firm is expected to adhere to. This term also encompasses practice statements, Red Book professional standards, global valuation practice statements, regulatory rules, RICS Rules of Conduct and government codes of practice.	**Mandatory.**
Guidance and information		
RICS code of practice	Document approved by RICS, and endorsed by another professional body/ stakeholder, that provides users with recommendations for accepted good practice as followed by conscientious practitioners.	Mandatory or recommended good practice (will be confirmed in the document itself). Usual principles apply in cases of negligence if best practice is not followed.
RICS guidance note (GN)	Document that provides users with recommendations or approach for accepted good practice as followed by competent and conscientious practitioners.	Recommended best practice. Usual principles apply in cases of negligence if best practice is not followed.
RICS information paper (IP)	Practice-based information that provides users with the latest technical information, knowledge or common findings from regulatory reviews.	Information and/or recommended best practice. Usual principles apply in cases of negligence if technical information is known in the market.
RICS insight	Issues-based input that provides users with the latest information. This term encompasses thought leadership papers, market updates, topical items of interest, white papers, futures, reports and news alerts.	Information only.
RICS economic / market report	A document usually based on a survey of members, or a document highlighting economic trends.	Information only.
RICS consumer guide	A document designed solely for use by consumers, providing some limited technical advice.	Information only.
Research	An independent peer-reviewed arm's-length research document designed to inform members, market professionals, end users and other stakeholders.	Information only.

1 Introduction

1.1 Background

Climate change is one of the greatest environmental challenges of our time. Global warming due to anthropogenic or 'human-generated' greenhouse gas (GHG) emissions to the atmosphere, referred to as carbon emissions, (*see* 2.1 for details), may have severe adverse environmental, social and financial effects around the world if temperature levels continue to rise. International treaties and initiatives, the most important being the Paris Agreement adopted in December 2015, have been undertaken aiming to restrict the impact of global warming by mitigating carbon emissions. Reducing carbon emissions also contributes towards limiting resource depletion and pollution.

Sizeable carbon emissions arising from the built environment are attributable not only to the use of built assets – operational emissions (Scopes 1 and 2) – but also to their construction – embodied emissions (Scope 3) (see *Appendix 2: Glossary*). Operational emissions result from energy consumption from the day-to-day running of a property, while embodied emissions are associated with producing, procuring and installing the materials and components that make up a structure. This includes the lifetime emissions from maintenance, repair, replacement and ultimately demolition and disposal.

The built environment industry has so far been addressing mainly operational emissions via reduction targets in building regulations (Part L), planning requirements by local authorities and sustainability assessment rating schemes (BREEAM, LEED, etc.) with the embodied aspect of carbon emissions not being tackled. To fully understand a built project's total carbon impact, it is necessary to assess both the anticipated operational and embodied emissions over the whole life of the asset. Considering operational as well as embodied carbon emissions together over a project's expected life cycle constitutes the whole life approach.

A whole life carbon approach identifies the overall best combined opportunities for reducing lifetime emissions, and also helps to avoid any unintended consequences of focusing on operational emissions alone, e.g. the embodied carbon burden of changing double glazing to triple can be greater than the operational benefit resulting from the additional pane. Therefore, whole life carbon needs to be effectively integrated in the sustainability agenda to achieve a lower carbon future.

Figure 1 illustrates typical breakdowns of whole life carbon emissions for different building types highlighting the relative weight of operational and embodied carbon.

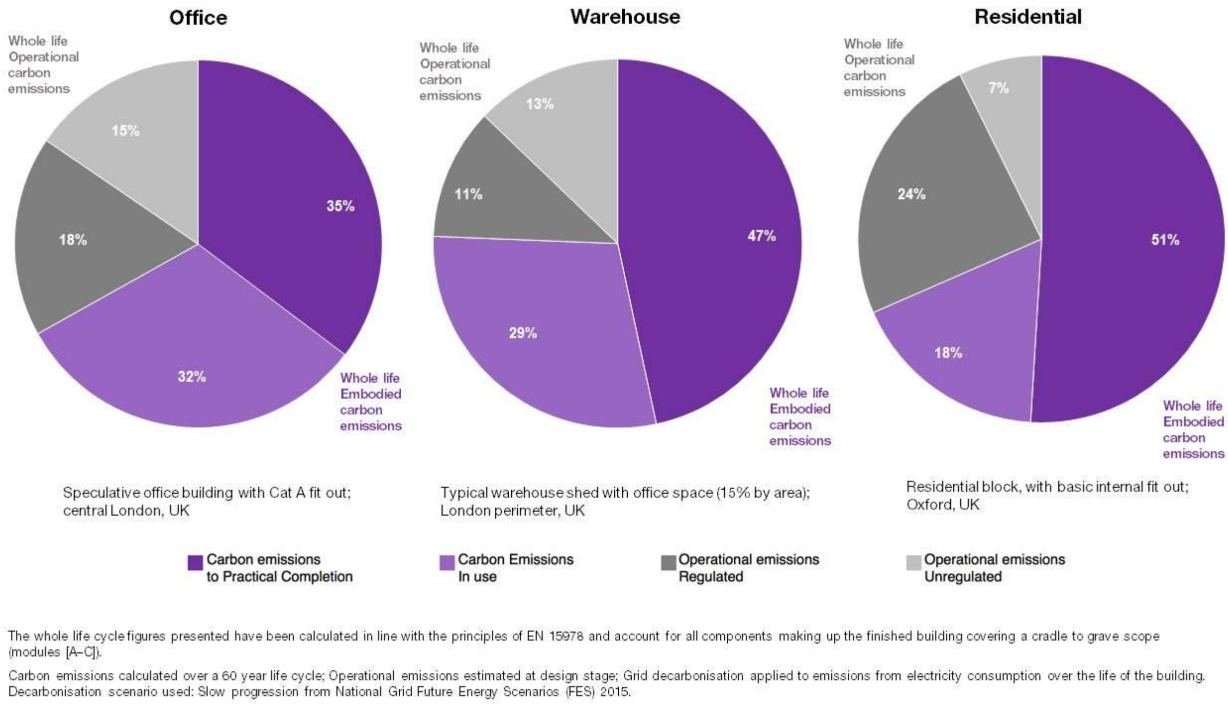


Figure 1: Total whole life carbon emissions breakdown for different building types © Sturgis Carbon Profiling

EN 15978: 2011 is part of the EN 15643 family of standards for the sustainability assessment of buildings and sets out the principles for whole life assessment of the environmental impacts of the built environment, based on life cycle assessment (LCA).

The methodology of EN 15978, however, has lacked a standardised approach to its practical implementation. It has therefore been subject to different interpretations by practitioners and clients: different scopes commissioned according to varying client requirements, varying assumptions made by practitioners and poor quality data selectively and/or inappropriately used.

This has led to the erratic implementation of EN 15978 and subsequently to significant discrepancies in the results of assessments. It has also led to substantial disparities in carbon figures among similar projects. Such variations have undermined the reliability of carbon measurement, discouraging stakeholders from confidently adopting whole life carbon thinking in their projects. More clarity and consistency around the implementation of whole life carbon assessment is therefore needed to boost credibility and uptake across the built environment.

Relevant work in this area has been undertaken (International Energy Agency (2016), Energy-Efficient Building European Initiative (2012), BCO (2012), etc.), including the RICS guidance note *Methodology to calculate embodied carbon* (2014). The latter provide high-level guidance on embodied carbon measurement consistent with the EN 15978 methodology. This professional statement addresses the need for technical details of the numerous aspects influencing whole life carbon calculations for built projects with emphasis on the practical implementation of the EN 15978 principles. It also sets out more detailed calculation and reporting requirements.

1.2 Development process

In response to the challenge of the inconsistent application of EN 15978 principles described, a working group was assembled to address this issue and provide mandatory principles and practical guidance for whole life carbon assessment to be adopted across the industry.

This RICS professional statement is the result of a 16 month InnovateUK co-funded project. This was led and project managed by Sturgis Carbon Profiling, with a working group comprising Arup, Atkins Faithful + Gould, Sustainable Business Partnership, Land Securities, Laing O'Rourke, Cambridge University, and RICS. The project was supported by the UKGBC, Argent, Grosvenor, Legal & General, M&S, Derwent London, HS2 and Higgins. The process to develop this professional statement consisted of the following:

1. Preparation and background knowledge*:* relevant academic and industry literature including standards have been carefully reviewed to establish a solid rationale – *see* References.
2. Analysis of case study assessments*:* five diverse built assets were selected (residential, office, retail, retrofit and infrastructure) in order to be representative of most project types. Each of these case studies has been separately assessed by different consultants (SCP, SBP, F+G). The results were made available to Cambridge University on a confidential basis to perform an impartial comparative analysis of the assessments submitted.
3. Review of findings*:* Cambridge University processed the results, identifying discrepancies in the interpretation and implementation of the standard. The core project team met over a 6-month period to review the inconsistencies identified and come to collectively agreed positions.
4. Consolidation of outputs and compiling of guidelines*:* the draft guidelines have undergone peer review by a specialist panel and the feedback examined and incorporated into the document as appropriate. The technical authors further consulted with LCA and construction experts and also collected, reviewed and cross-referenced where possible empirical carbon data to substantiate any assertions.

1.3 Objectives

The fundamental objective of whole life carbon measurement is the mitigation of carbon impact in the built environment. Better understanding and consistent measurement of the whole life carbon emissions of built projects will in turn enable comparability of results, benchmarking and target setting to achieve carbon reductions.

This professional statement aims to harmonise whole life carbon assessment by providing consistency in the interpretation and implementation of the methodology in EN 15978 – *see* 2 Scope. This is to achieve coherent and comparable results that can be used to benchmark the whole life carbon performance of built assets.

The specific objectives of this professional statement are to:

- provide a consistent and transparent whole life carbon assessment implementation plan and reporting structure for built projects in line with EN 15978
- enable coherence in the outputs of whole life carbon assessments to improve the comparability and usability of results
- make whole life carbon assessments more 'mainstream' by enhancing their accessibility and therefore encourage greater engagement and uptake by the built environment sector
- increase the reliability of whole life carbon assessment by providing a solid source of reference for the industry
- promote long-term thinking past project practical completion, concerning the maintenance, durability and adaptability of building components and the project as a whole; and

- promote circular economic principles by encouraging future repurposing of building components, as well as of the project as a whole, through quantifying the recovery, reuse and/or recycling potential thereof.

1.4 Further impact

Under the overarching objective of facilitating a lower carbon and more resource-efficient model for the built environment, this professional statement is expected to have a number of knock-on effects encouraging actions in this direction.

- Benchmarking: conducting whole life carbon assessments in accordance with the present requirements and guidance will put all studies on the same basis and provide consistency among results enabling meaningful comparisons at different levels: per building element category, per life cycle stage as well as for entire projects throughout their life. Collection of carbon outputs in a structured fashion to populate a database will subsequently facilitate sensible benchmarking that will set the bar for carbon performance in the built environment industry. There are two aspects to benchmarking; comparing a project against itself over time – 'dynamic' – and comparing a project against other similar projects – 'static':
    - – 'Dynamic' benchmarking is where a whole life carbon assessment for the project is carried out at an early design stage thus providing a baseline to compare the results of later assessment iterations, so as to monitor the carbon progress of the project.
    - – 'Static' benchmarking is the collection and analysis of whole life carbon results from the 'as built' stage. This will enable realistic benchmarking based on the actual carbon footprint of construction projects.

- Carbon target setting: Once credible benchmarking is in place, relevant targets, 'static' and/or 'dynamic' can be set for the whole life carbon performance of built assets. Clear and quantifiable whole life carbon targets will aid the pursuit of emissions reductions from a holistic perspective. The incorporation of such targets into sustainable development policies for the built environment, planning requirements, building rating schemes like BREEAM, etc., contractual obligations and legislation/building regulations constitutes the future aspiration to steer the industry.

- Longer-term thinking: early consideration of likely future climate change impacts and the development of appropriate adaptation strategies will promote the resilience of built assets.

The advancements in the quality, scrutiny and availability of carbon data as well as their integration with BIM should further improve the accessibility, accuracy and ease of conducting whole life carbon assessments.

1.5 Standards referred to in this professional statement

Table 1 provides an overview of the key standards referred to this publication, giving their titles in full and regional jurisdiction.

Standard	Full title	Regional jurisdiction
EN 15978: 2011	*Sustainability of construction works – Environmental product declarations – Core rules for the*	European standard

	product category of construction products	
EN 15804: 2012 + A1: 2013	*Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products*	European standard

Table 1: Key European and international standards referred to in this professional statement

2 Scope

This professional statement provides requirements and guidelines for conducting whole life carbon assessments for construction projects in line with EN 15978. It also includes guidance on the interpretation and practical implementation of the EN 15978 methodology. This publication should be read in conjunction with EN 15978 and EN 15804 (see Table 1).

This professional statement can be applied to all types of built assets, including buildings and infrastructure. More detailed guidance on carbon management for infrastructure specifically is given in PAS 2080: 2016. This publication applies to new and existing properties as well as refurbishment, retrofit and fitout projects.

The metric for assessing the climate change impacts of greenhouse gas (GHG) emissions is Global Warming Potential (GWP). This is expressed in units of CO_2 equivalent (CO_2e) over 100 years, commonly referred to as 'carbon emissions'. EN 15978 specifies further indicators for environmental impacts, however, this publication only addresses GWP as it is central to gauging a project's contribution to climate change.

This professional statement provides mandatory requirements and guidance on assessing the carbon emissions arising from built projects throughout their life. It addresses all component categories making up a built asset over all life stages – from extracting raw materials and manufacturing constituent building products through its operation and disposal, and any future potential beyond its end of life. All aspects of whole life carbon assessment covered are explained and put in context. This includes the timing and frequency at which whole life carbon assessments should be undertaken. Practical guidelines for estimating their impacts and organising the results are also provided.

Three core principles constitute the rationale for this publication, in line with its objectives:

1. Consistent whole life carbon measurement:

Whole life carbon assessments need to be reliable and comparable. Therefore, consistency in methodology and the assumptions and data used is required. This professional statement emphasises the practical implementation of the existing and widely accepted environmental performance assessment methodology of EN 15978. This is to facilitate coherence in the calculations even at early design stages where detailed project-specific information might not yet be available.

2. Comprehensive modular structure:

The requirements and guidance cover all components of a built project over its entire life cycle. These features are addressed in a modular fashion, in line with EN 15978. The building components are organised in categories and the project life cycle is broken down into different life stages, so as to address all aspects influencing whole life carbon in a structured way. This also enables flexibility in the scope to be examined without compromising consistency.

3. Integration of whole life carbon assessment into the design process:

For whole life principles to be integrated into the design, procurement and construction processes and beyond, and for project teams to be engaged in a timely fashion, carbon assessments should be carried out at key project stages from concept design to practical completion. Appropriate timing and sequencing of carbon assessments will help identify carbon reduction opportunities and monitor a project's progress in achieving them.

The requirements and guidelines provided can be incorporated in carbon measurement software tools and BIM constituting the wireframe for their carbon calculation procedures.

This professional statement is intended primarily for the UK audience: sustainability consultants, building designers, contractors as well as policy makers, regulators and client bodies, as the numeric assumptions provided throughout are based on UK locations and standard practices. Appropriate geographic adjustments will enable the requirements and guidance to be applied elsewhere as it is aligned with the international methodology of EN 15978.

3 Requirements and guidance for conducting whole life carbon assessments

This section outlines both mandatory requirements and relevant supporting guidance for carrying out whole life carbon assessments. Requirements, i.e. the mandatory principles that must be followed by practitioners, are given in bold type. Where relevant, the specific sub-section of EN 15978 and/or EN 15804 being referred to is provided at the outset.

3.1 General guidance

Whole life carbon assessments should be undertaken in a sequential fashion during the design, production, construction and post-completion stages, starting as early as concept design stage (RIBA Stage 2 or equivalent). Early assessments are recommended to establish a baseline carbon estimate for the project, to integrate whole life carbon into the design process and to identify carbon reduction potential while the capacity to influence decisions is readily available. This is to enable project teams to fully engage and understand the impacts of whole life carbon assessments on the project as a whole. Further assessments at later project stages will allow monitoring of the carbon budget as the project develops.

As a minimum, a whole life carbon assessment must be carried out before the commencement of the technical design (not later than RIBA Stage 3 or equivalent), **representing an 'As designed'** carbon baseline for the project.

At least one other whole life carbon assessment should be conducted for each project after practical completion to represent the 'As built' carbon position. Interim assessments and carbon impact studies should be carried out as appropriate, according to the nature of each project. Whole life carbon savings for a project can only be quantified and claimed when whole life carbon assessments have been carried out at a minimum of two different points in time, in a similar fashion to estimating operational carbon emissions savings between different stages, e.g. DER vs. TER in SAP (see Appendix 2 Glossary).

To provide a holistic view of the GWP, whole life carbon assessments should, where possible, account for all components relating to the project during all life stages.

The minimum scope that must be covered is as follows:

Minimum requirements for whole life carbon assessment	
Building components to be included	1. Substructure 2. Superstructure – see 3.2.2 6. External envelope / facade
Life stages to be included	Product stage [A1–A3] Construction process stage [A4–A5] – see 3.2.4 and Operational energy use [B6]
Assessment timing	At design stage **–** prior to technical design

Table 2: Minimum requirements for whole life carbon assessment

Different levels of detail in the design and specification of the built asset are available at different project stages. The data sources and approaches suggested throughout this publication are prioritised to achieve the highest quality and accuracy possible. However, the stated order of preference is subject to applicability and availability given the project stage at which the assessment is conducted.

Details on what results should be disclosed and guidance on how to structure and present them can be found in section 3.6.

3.2 Determining the object of the whole life carbon assessment

3.2.1 Spatial boundaries

Determining what should be included in a whole life carbon assessment is necessary for consistency purposes. This section explains the requirements concerning the components that need to be accounted for, clarifying and expanding on the detail of EN 15978; section 7.1.

A whole life carbon assessment should consider all building components and works relating to the project, including any external works within the site boundary (see 3.2.2). The site boundary needs to be in line with the definition and intended use of the built asset, including all contiguous land that is associated with the project and supports its operations. A town planning red line can serve as the site boundary, where available. When shared or communal spaces are involved, these should be allocated as appropriate based on reasonable proportions deriving from respective GIAs of the adjoining properties, number of occupants or other metrics of capacity for each built asset, taking into account their respective types of use.

3.2.2 Building physical characteristics

This section outlines the building elements and components to be included in a whole life carbon assessment. It relates to EN 15978; 7.5.

A complete whole life carbon assessment should cover all items listed in the project's Bill of Quantities (BoQ), cost plan or as identified in other design information (drawings, specifications, etc.) that fall under the building element categories specified in Table 2.

Table 2 provides a breakdown of the building element categories that should be covered in the whole life assessment, as applicable for each project. The proposed building components scope is covering and expanding on the relevant scopes specified in *BREEAM Assessor Guidance Note GN08* and in the *Evaluation of Embodied Energy and CO_2e for Building Construction (Annex 57)*.

New build projects assessed are considered to commence their development on a cleared flat site, for consistency purposes. Demolition works are often decoupled from new construction projects and hence the responsibility for any emissions arising from demolition is not necessarily solely attributable to the new build project. Therefore, all carbon emissions associated with facilitating works as listed under '0 Facilitating works' in Table 2, should be reported separately and not aggregated with the rest of the project emissions. However, due to potential opportunities for recovery, reuse and recycling, and for improving the deconstruction and demolition process, pre-demolition assessments should be carried out where possible.

For retrofit projects, the equivalent state to that of 'a cleared flat site' for new build, as described above, is represented by any retained elements. Any removal and/or stripping out of building elements to get the structure to the 'clear flat site' equivalent state should be treated as demolition works and reported separately.

Demolition	Hazardous materials treatment and removal
	Demolition works

0	Facilitating works	0.1 Temporary/Enabling works/Preliminaries
		0.2 Specialist groundworks
1	Substructure	1.1 Foundations incl. excavations
		1.2 Basement retaining walls
		1.3 Lowest floor slab
2	Superstructure	2.1 Frame
		2.2 Upper floors incl. balconies
		2.3 Roof
		2.4 Stairs and ramps
3	Internal finishes	3.1 Wall finishes and internal partitioning and doors
		3.2 Floor finishes
		3.3 Ceiling finishes
4	Fittings, furnishings and equipment (FF&E)	4.1 Building-related*
		4.2 Non building-related**

5	Building services / MEP	5.1 Building-related* – HVAC incl. sanitary
		5.2 Building-related* – Lighting
		5.3 Building-related* – Lifts and escalators
		5.4 Building-related* – Safety, security and communication installations
		5.5 Non building-related** – ICT, cooking, specialist and other loose equipment
6	External envelope / Facade	6.1 External walls incl. opaque cladding
		6.2 Curtain walling, windows and external doors
7	External works	7.1 Roads, paths and paving / Hard landscaping
		7.2 Soft landscaping
		7.3 Fencing, railings and walls
		7.4 External fixtures
		7.5 External services incl. drainage

* Building-related items: Building-integrated technical systems and furniture, fittings and fixtures built into the fabric. Building-related MEP and FF&E typically include the items classified under Shell and core and Category A fit-out.

** Non building-related items: Loose furniture, fittings and other technical equipment like desks, chairs, computers, refrigerators, etc. Such items are usually part of Category B fit-out.

Table 3: Building element categories to be considered (based on the BCIS SFCA)

The building element categories listed in Table 3 are based on the *BCIS Elemental Standard Form of Cost Analysis* (4th edition) but are adjusted to specifically suit the purposes of whole life carbon assessment. This is done by separately reporting element categories that are likely to have high relative importance in carbon terms. Therefore, the items included in each category differ from the BCIS guide in some instances. For example:

- A separate category for façade has been created for the purposes of this professional statement, as the façade can represent a significant proportion of whole life carbon and is hence separated from the rest of the superstructure.
- Temporary works are to be included in Facilitating works (0.1 in Table 3 above) to account for any potential embodied carbon impact associated with them, although they classify as contractor prelims in BCIS.
- Internal partitioning is to be included in internal finishes rather than superstructure as in BCIS.

Any carbon emissions related to non-building-related Fittings, Furnishings and Equipment FF&E and technical equipment such as loose furniture, fittings and fixtures; domestic, commercial and industrial appliances, e.g. entertainment and office electronics, cooking appliances, etc. should be reported separately under categories 4.2 and 5.5 respectively (Table 3), where relevant to the project scope.

Reasonable assumptions should be made for any provisional sums allowances in the cost plan in consultation with the cost consultant and design team.

A minimum of 95% (EN 15804 6.3.5, p.25) of the cost allocated to each building element category (0–7 of Table 3) should be accounted for in the assessment. Items excluded should each account for less than 1% of the total category cost. In case the coverage is lower than recommended, this should be clearly indicated and the actual percentage of coverage stated alongside the carbon calculation results. The subtotal carbon budget of each category should be multiplied by the following adjustment factor to account for the impacts of the items not quantified:

Coverage adjustment factor = (100% / % of cost covered in the given category)

If cost data is unavailable, the same principles apply to the mass or area of elements as appropriate.

3.2.3 Reference study period

This section determines the reference study periods (RSP) to be used for whole life carbon assessments, based on the principles outlined in EN 15978; section 7.3.

The reference study periods that must be used for the purposes of whole life carbon assessment are defined below for the different types of uses of built assets:

- domestic projects: 60 years (BREEAM 2014 New Construction – Mat 01 Life cycle impacts; LEED v.4)
- non-domestic projects: 60 years (BREEAM 2014 New Construction – Mat 01 Life cycle impacts; LEED v.4)
- infrastructure: 120 years (according to case studies in PAS 2080).

The proposed RSPs are based on a holistic understanding of the building's performance and enable comparability between the whole life carbon results to:

- be broadly representative of typical required service lives of the different building types;
- allow for a sufficient period of time for the property to undergo wear and tear and specifically the replacement cycles of major building components and systems;
- stretch across a time period in the future that is reasonably predictable.

When the RSP is longer than the required service life specified in the design brief, reasonable project-specific scenarios should be developed to allow for the period to the end of RSP shown above.

When the RSP is shorter than the required service life, the project should be assessed for the duration of the RSP, on a cradle-to-grave basis – modules [A–C] (see 3.5.4) – allowing for a sensible end of life scenario (see 3.5.4), even though the project is expected to have further service life beyond the RSP. Any benefits (or burdens) beyond the required service life of the project should be included in module [D] – see section 3.5.5 – and adjusted as appropriate – see EN 15978 – 7.3 Figure 5.

In addition to the mandatory RSPs specified above, whole life carbon emissions can also be reported against the design service life as determined in the project brief or any other relevant time period of interest to the body commissioning the assessment.

3.2.4 Life cycle stages – overview

Whole life thinking involves considering all life cycle stages of a project, from raw material extraction, product manufacturing, transport and installation on site through to the operation, maintenance and eventual material disposal. This section refers to EN 15978. It also considers the future potential for recovery, reuse and/or recycling. EN 15978 introduces a modular approach to a built asset's life cycle, breaking it down into different stages as shown in Figure 2.

[FIGURE 2 IS NOT PROVIDED AT CONSULTATION PENDING COPYRIGHT PERMISSION]

Figure 2: Modular information for the assessment as per EN 15978 including typical system boundaries

The life cycle stage modules enable transparency and flexibility in the assessment. They also provide a standardised structure for comprehensive and coherent reporting, with clusters that can be looked at individually as well as in conjunction with one another.

A complete whole life carbon assessment should account for all emissions arising over the entire life of a built asset. It should also account for any future reusability and/or recyclability of its different constituent elements – modules [A] to [D]: cradle to grave including impacts beyond the system boundary – as applicable to each project.

The boundaries of the whole life carbon assessment and the life cycle stage modules covered must be explicitly stated in the report.

Clear boundaries are critical for transparency and subsequent consistency and credibility of carbon results. Assessments covering the cradle to grave scope [A] – [C] are encouraged. Nevertheless, where more restricted scopes are instructed to fit the needs of specific projects, these must be identified and the life cycle stages included in the assessment clearly declared.

Module [D] must be communicated separately and not aggregated with the cradle-to-grave [A] to [C] carbon figures.

This is primarily due to its inherent future uncertainty. More details on the requirements and structure for reporting the carbon results can be found in section 3.6 *Reporting requirements*.

For new builds, all life cycle stages as described above are applicable. For existing buildings that are to undergo refurbishment works, all life cycle stages are applicable for any new elements installed to the building. For existing items being retained, only emissions associated with use [B], [C] and beyond [D] should be considered over the life cycle. The emissions from the product and construction stages [A] sit with the existing building and therefore lie outside of the scope of the project under study.

3.2.5 Floor area measurement

This section specifies how the floor areas of the built assets being assessed need to be determined.

Floor areas from the following sources must be used and clearly stated in the whole life carbon assessment in the following order of preference and subject to availability at the different project stages: 1. BIM model, 2. Bill of quantities (BoQ) or cost plan, 3. C**onsultants' drawings.**

Floor area measurements used in whole life carbon assessments should be in accordance with the *RICS property measurement*, 1st edition (2015) professional statement which incorporates the International Property Measurement Standards (IPMS).

3.2.6 Quantities measurement

This section refers to EN 15978; 9.1–9.3 and specifies how the quantities of the materials and/or products that make up the building components to be included in the whole life carbon assessment need to be determined.

Material quantities from the following sources must be used and clearly stated in the whole life carbon assessment, in the following order of preference and subject to availability at the different project stages: 1. Materials delivery records, 2. BIM model, 3. Bill of quantities (BoQ or cost plan, 4. **Estimations from consultants' drawings.**

In the case of existing buildings, actual quantities should be obtained from 'As built' drawings and contractor records, where possible. If this is not possible, site surveys might be required.

The assessment should account for gross material quantities allowing for any losses during transportation and on-site construction processes as appropriate in modules [A4–A5] – see section 3.5 *Life cycle stages*.

RICS property measurement and the *BCIS elemental standard form of cost analysis* should be followed. In case of uncertainty regarding the quantities in the cost plan or BoQ, the cost consultant should be contacted by the assessor to provide relevant clarifications and/or reasonable assumptions in line with the cost model. Any assumptions made should be explicitly stated in the whole life carbon assessment report.

3.2.7 Units of measurement

The whole life carbon assessment results must be reported using the following units: kgCO2 equivalent (kgCO2e), or any clearly stated metric multiples thereof as appropriate, e.g. tCO2e.

The total carbon results also need to be normalised as follows for the different project types:

- Buildings; planning use classes A1–A5, B1, C1–C4, D1–D2: $kgCO_2e/m^2$ GIA
- Buildings; planning use classes B2–B8: $kgCO_2e/m^3$ of internal building volume
- Infrastructure; bridges, roads, railway lines, power lines, water and fuel pipelines: $kgCO_2e/km$
- Infrastructure; waste and water treatment: $kgCO_2e/m^3$ of water or waste treated
- Infrastructure; power stations incl. dams, oil rigs, wind turbines: $kgCO_2e/kWh$ produced
- Infrastructure; transport hubs: $kgCO_2e$/passenger and $kgCO_2e/m^2$ GIA
- Infrastructure; telecommunication: $kgCO_2e/Mbps$

Where normalisation against units other than those specified is considered suitable for project-specific reporting purposes, the assessor can report against the preferred units of measurement in addition to the mandatory ones above.

3.3 Carbon data sources

3.3.1 Allowable carbon data

This section refers to EN 15978; 8.4 and 10.3 and determines the carbon data sources that are allowable for use in whole life carbon assessments.

The following are acceptable sources of carbon data for materials and products, in order of preference: EPDs and datasets in accordance with EN 15804; EPDs and datasets in accordance with ISO 14025; EPDs and datasets in accordance with ISO 21930; EPDs and datasets in accordance with PAS 2050; EPDs and datasets in accordance with ISO 14067; EPDs and datasets in accordance with ISO 14040 and 14044.

The assessor must explicitly state the data sources for the whole life carbon assessment.

The most recent geographically and technologically appropriate data should be selected depending on project location and subject to anticipated supply chains.

Carbon data for modules [A1–A3], [B1], [C1], [C3], [C4] and [D] should be retrieved from the allowable carbon data sources specified and used in line with the project-specific scenarios developed at building level. Carbon figures for the remaining life stages [A4], [A5], [B2–B7], [C2] should be calculated on a project-specific basis, considering the project location, likely procurement routes, anticipated operation and maintenance schedules and end of life scenarios. Where EPD data is used for these modules, the carbon values should be adjusted accordingly to fit the project-specific scenarios.

Where detailed specification for products and/or materials is available, the corresponding carbon data should be used. However, at early design stages the technical specification is likely to be indicative and the cost plan or BoQ not yet providing detailed information on building components and product types. In such instances, generic data representative of standard, market average specifications should be used in the assessment – see section 3.5.1. This data should be refined at the later project stages with product specific information as these become available.

EN 15804 – section 6.3.7 suggests that specific data should be no older than 5 years and generic data no older than 10 years.

Table 4 below presents the recommended use of different types of data as adjusted for PAS 2080 from EN 15978:

[TABLE 4 IS NOT PROVIDED AT CONSULTAITON PENDING COPYRIGHT PERMISSION]

Table 4: Recommended use of different data types as per PAS 2080

3.3.2 Allowable carbon conversion factors

The most recent GHG conversion factors for company reporting as issued by the UK government (BEIS (2016) 2016 Government GHG Conversion Factors for Company Reporting: Methodology Paper for Emission Factors), or equivalent sources for different countries, should be used for calculating the carbon equivalent (CO_2e) impact of transport, fuel consumption, refrigerants and water supply. The conversion factors should account for both direct and indirect GHG emissions – Scopes 1, 2 and 3, including WTT (Well To Tank) and T&D (Transmission and Distribution) impacts as applicable.

3.4 Factors influencing the assessment

3.4.1 Carbon sequestration

Biogenic carbon

Trees absorb CO_2 emissions from the atmosphere during their growth through photosynthesis. This carbon remains sequestered within the timber until the end of its life. It should though only be considered as a carbon credit in the scope of whole life carbon assessment when the timber is sustainably sourced – FSC or PEFC certified – to ensure that any trees felled are being substituted with a minimum of the same number of trees planted and hence not contributing to deforestation.

Regarding the end of life of timber products, when wood is discarded and left to rot, for instance when being landfilled, CO_2 as well as methane (CH_4), that has a GWP multiple to CO_2, are released. It is therefore crucial from a whole life carbon perspective to take the end of life impacts of timber into account in the calculations. Therefore:

Carbon sequestration must only be taken into account when all of the following criteria are met: 1. The whole life carbon assessment that includes the impacts of the end of life stage [C]. 2. The timber originates from sustainable sources. 3. The timer elements under study are either long servicing (>20 years) or highly reusable.

The last criterion is intended to ensure that sufficient time is allowed for trees to grow towards their peak carbon absorption age, before being harvested and turned into timber products.

The biogenic carbon stored (sequestered) in timber elements must be calculated based on the formula provided in EN 16449:

$$P_{CO_2} = \frac{44}{12} \times cf \times \frac{\rho_\omega \times V_\omega}{1 + \frac{\omega}{100}}$$

P_{CO2} : sequestered carbon dioxide – biogenic carbon oxidised at EoL
cf: carbon fraction of woody biomass (dry)
ρ_ω: timber density at the given moisture content
V_ω: timber volume at the given moisture content
ω: moisture content of timber product

The default values to be used in the carbon sequestration calculations in the absence of more specific data for the timber element under study are as follows, according to EN 16449:
cf = 50%; ω = 12 (%)

Where timber is being reclaimed and reused, it is assumed that the sequestered carbon is retained and carried forward with the timber elements being recovered and used in a subsequent project – see EN 16485 6.3.4.2. The sequestered carbon should therefore only be counted in the project in which it sits.

Carbon sequestration figures should be reported separately, but can be included in the total product stage figures [A1–A3] provided the conditions specified above are met.

Given satisfactory evidence, the benefit of carbon sequestration can be claimed for other plant-based materials (e.g. bamboo, etc.) as long as these are sustainably sourced and the treatment at the end of their life is included in the whole life carbon assessment.

Carbonation of CaO and $Ca(OH)_2$

Building materials such as concrete and mortar, containing cementitious materials and/or lime have the potential to absorb CO_2 when their surfaces are exposed to the air as the calcium oxide (CaO) and calcium hydroxide ($Ca(OH)_2$) they contain undergo carbonation, i.e. absorb CO_2, when exposed to the air.

For items containing exposed lime, the carbonation process is occurring fast during the hardening of the mortar and should therefore be accounted for in the construction process stage [A5] – see 3.5.2.2. Instructions on how to calculate the carbonation impacts are given in Annex C – 2 of BRE Global Product Category Rules for Type III environmental product declaration of construction products to EN 15804: 2012 + A1: 2013 PN514.

Cementitious materials also undergo carbonation when exposed. However, carbonation of reinforced concrete is not desirable as it can lead to corrosion of the embedded steel. Hence, reinforced concrete elements are treated as appropriate to prevent carbonation. Therefore, the impact of carbonation should only be taken into account for non-reinforced, non-coated exposed concrete components like low strength concrete mixes, concrete blocks, screeds and mortars. The carbonation process occurs over the life of these elements and should therefore be accounted for in the use stage [B1] – see 3.5.3.1. Instructions on how to calculate the carbonation impacts are given in Annex C – 3.1 of BRE Global Product Category Rules for Type III environmental product declaration of construction products to EN 15804: 2012 + A1: 2013 PN514.

When concrete is crushed into aggregate, carbonation continues taking place as long as the aggregate is left exposed either before being landfilled or reused as secondary aggregate. This is if the concrete has not been fully carbonated over the project life. If sufficient information is available, the carbon sequestered can be calculated based on the guidance provided in Annex C – 4 of BRE Global Product Category Rules for Type III environmental product declaration of construction products to EN 15804: 2012 + A1: 2013 PN514.

3.4.2 Grid decarbonisation

Current international environmental treaties call for significant GHG emissions mitigation to limit the impact of climate change. Electricity generation activities are a major carbon emitter and will subsequently need to decarbonise over time to be consistent with international statutory requirements.

In order to provide a realistic estimate of the carbon emissions throughout the life cycle of a project, a moderate approach towards the projection of the future expected fuel mix for electricity generation is suggested. Appropriate adjustments should be made to the carbon conversion factors for electricity to capture the grid decarbonisation impact.

The slow progression option from the latest Future Energy Scenarios developed by National Grid must be used to calculate the grid decarbonisation adjustment coefficients to be applied to the respective carbon conversion factors for UK electricity.

Equivalent scenarios produced from similar designated bodies should be used for different countries and assessors should clearly identify and explain the decarbonisation scenarios used in line with the guidance above.

The electricity carbon intensity should be calculated as follows:

Electricity carbon intensity $_{\text{Year X}}$ = carbon conversion factor for electricity (a) × grid decarbonisation adjustment coefficient (%) $_{\text{Year X}}$ (b)

(a) Allowable carbon conversion factor for electricity as per 3.3.2
(b) Coefficient calculated using the projected trend line in the slow progression scenario, assuming 100% for the year of the project's practical completion.

The carbon intensity values used in the scenarios should not be used nominally – the carbon intensity for electricity should be calculated in accordance with this equation based on the original allowable carbon conversion factor.

Grid decarbonisation is only relevant to emissions that will arise in the future, i.e. during the use and disposal stages [B] and [C], and it can impact the carbon figures considerably. For simplification purposes in the context of this guidance, grid decarbonisation is only applicable to operational emissions from electricity in [B6] and to exported energy substituting electricity in [D], as these are the areas where decarbonisation is expected to have the most significant impact.

3.5 Life cycle stages

This section refers to EN 15978; 7.4. EN 15978 is structured in a series of modules – see 3.2.4 – that cover all stages of the life cycle of a project. The sections below provide further detail and practical guidance on each of the modules to enable consistency of interpretation when conducting a whole life carbon assessment.

All aspects relating to each of the EN 15978 modules as listed here are discussed in the sections below:

- [A1–A3] Product stage
- [A4 and A5] Construction process stage: transport to site and construction installation process
- [B1] Use
- [B2] Maintenance
- [B3 and B4] Repair and replacement
- [B5] Refurbishment
- [B6] Operational energy use
- [B7] Operational water use
- [C1] Deconstruction and demolition process
- [C2] Transport
- [C3] Waste processing for reuse, recovery or recycling
- [C4] Disposal
- [D] Benefits and loads beyond the system boundary.

3.5.1 [A1–A3] Product stage

This section refers to EN 15978; 7.4.2 and 8.4, and EN 15804; 6.3.4.2. The product stage deals with the carbon emissions attributable to the cradle to gate processes; raw material supply, transport and manufacturing. This section provides additional detail to assist calculation of the carbon emissions for these stages. The processes covered by [A1–A3] frequently occur in several steps, where components are manufactured and then transported to a further fabrication plant for assembly into a system. All of these interim steps need to be taken into account.

The carbon emissions attributable to the product stage [A1–A3] of the items included in the whole life carbon assessment must be calculated by assigning suitable embodied carbon factors to the given elemental material quantities.

Therefore: [A1–A3] = Material quantity (a) × Material embodied carbon factor (b)

Acceptable carbon data sources are specified in section 3.3.1.

The assessor needs to ensure that (a) and (b) are measured against the same metric, e.g. per kg, and adjusted accordingly using, e.g. densities where necessary. Density data should be sourced from the relevant EPD used or from technical documentation provided by the product supplier. If specific density information is unavailable, average data representative of the type of item should be used with their source clearly stated. Project team members, such as the structural engineer, cost consultant, etc., should be consulted for clarification on material assumptions if necessary.

Subjective material selections made early in the design process due to lack of detailed information on technical specification can heavily influence the product stage carbon emissions [A1–A3]. This can lead to significant discrepancies between results for similar projects.

To ensure baseline consistency, the following specifications must be used in the absence of detailed information – see Table 5.

	Material	Details	Specification
1.	**Concrete**	Piling	C32/40 20% cement replacement [1]
		Substructure	C32/40 20% cement replacement [1]
		Superstructure	C32/40 20% cement replacement [1]
		Generic concrete	C16/20 0% cement replacement [1]
2.	**Steel**	Reinforcement bars	97% Recycled Content [2]
		Structural steel sections	20% Recycled Content [3]
		Studwork/Support frames	Galvanised steel, 15% Recycled Content [4]
3.	**Blockwork**	Precast concrete blocks	Lightweight blocks for building envelope
			Dense blocks for other uses
4.	**Timber**	Manufactured structural timber CLT, Glulam, etc.	100% FSC/PEFC [5]
		Formwork	Plywood
		Studwork/Framing/Flooring	Softwood
5.	**Aluminium**	Cladding panels	Aluminium sheet, 35% Recycled Content [6], anodised if exposed
		Glazing frames	Aluminium extrusions, 35% Recycled Content [6], anodised if exposed
6.	**Plasterboard**	Partitioning/Ceilings	Min. 60% Recycled Content [7]
7.	**Insulation**	To floors, roofs & external walls	PIR

Table 5: Default specifications for main building materials

The values in the table above are based on average industry standard practice.

The assessor should clearly indicate the items for which the default generic assumptions of Table 5 have been used due to lack of detailed information. These assumptions should be updated according to project-specific information as it becomes available.

Notes on Table 5:

[1] Low end industry averages developed from consultation with design and supply chain specialists, in alignment with relevant concrete specification standards: BS EN 206:2013 and BS 8500-1:2016.
[2] UK CARES EPD for Carbon Steel Reinforcing Bar – Sector Average by BRE, 2016.
[3] UK manufactured structural steel sections are currently manufactured mainly via the BOS (Basic Oxygen Steelmaking) route. This process utilises approximately 20% of recycled steel scrap (C. Broadbent – Steel's

recyclability: demonstrating the benefits of recycling steel to achieve a circular economy, 2015. Also TATA steel information).

[4] WRAP Choosing construction products – Guide to the recycled content of mainstream construction products, 2008.

[5] As suggested by contractors, it constitutes standard practice for manufactured timber used in construction to be sustainably sourced under 100% FSC or PEFC certification.

The Government's Timber Procurement Policy (TPP 2013) and the GLA Group Responsible Procurement Policy (2016) further underpin timber sustainable sourcing as a requirement. Sustainable timber sourcing is also mandatory for obtaining BREEAM certification.

Please note that FSC Mixed certification is not acceptable as 100% FSC.

[6] Global Aluminium Recycling Committee (GARC) (2009). Global Aluminium Recycling: A Cornerstone of Sustainable Development suggests an average of 32% recycled content in aluminium products – p.30. Certificates from European aluminium product manufacturers suggest an average of 35% recycled content.

[7] Following review of EPDs for the most widely used plasterboard types. Also, average of standard and good spec as suggested by WRAP Choosing construction products – Guide to the recycled content of mainstream construction products, 2008.

3.5.2 [A4 and A5] Construction process stage

This section refers to EN 15978; 7.4.3 and 8.5, and EN 15804; 6.3.4.3. Modules [A4] and [A5] respectively capture the emissions associated with the transportation of the materials and components from the factory gate to the project site and their assembly into a building.

3.5.2.1 [A4] Transport emissions

This section refers to EN 15978; 7.4.3.2 and 8.5, EN 15804; 6.2.3.

Transport emissions must include all stages of the journey of the products following their departure from the final manufacturing plant to the project site, taking into account any interim stops at storage depots and/or distribution centres.

Transport emissions should be calculated as follows:

[A4] = Material or system mass (a) × transport distance (b) × carbon conversion factor (c)

Material or system mass (a):

Should be obtained from acceptable sources as specified in 3.2.6 and account for any material losses during transport wherever possible.

Transport distance (b):

Should be calculated based on the distance between the manufacturing location and the project site, and is subject to the anticipated supply chain route of each item. When specific sourcing information is unavailable, the transport scenarios in Table 6 should be used in whole life carbon assessments for UK based projects. Similar default scenarios should be developed for different countries. The assessor, in consultation with the design team, should reasonably allocate the anticipated products and components into each of the categories: locally, nationally, European and globally manufactured, to inform the transport scenario.

Transport scenario	km by road*	km by sea**
Locally manufactured e.g. concrete, aggregate, earth	50 [1]	-
Nationally manufactured e.g. plasterboard, blockwork, insulation	300 [1]	-
European manufactured e.g. CLT, façade modules, carpet	1,500 [2]	-
Globally manufactured e.g. specialist stone cladding	200 [3]	10,000 [3]

Table 6: Default transport scenarios for UK projects

* Means of transport assumed as average rigid HGV with average laden – average laden as per BEIS carbon conversion factors
** Means of transport assumed as average container ship

Notes on Table 6

[1] EeB Guidance Document, Part B: Buildings – Operational guidance for life cycle assessment studies of the Energy-Efficient Buildings Initiative, p.199.
[2] Generic distance for items assumed to be sourced from continental Europe, e.g. Austria.
[3] Generic distance for items assumed to be sourced from Eastern Asia.

The above distances are applicable to projects located in the UK and include a generic allowance for interim storage depots before reaching the construction site. These should be adjusted accordingly based on project location if in a different country.

Carbon conversion factor (c): Based on the selected mode of transport, suitable carbon conversion factors should be used – see 3.3.1.

The above assumptions should be updated as project-specific evidence from the main contractor and sub-contractors becomes available.

The transport of persons and commuting of employees is excluded from the calculations as the emissions associated with these activities are not attributable to the project but to the individual employees.

3.5.2.2 [A5] Construction – installation process emissions

This section refers to EN 15978; 7.4.3.3 and 8.5, EN 15804; 6.2.3.

The carbon emissions arising from any on- or off-site construction-related activities must be considered in [A5]. This includes any energy consumption for site accommodation, plant use and the impacts associated with any waste generated through the construction process, its treatment and disposal.

The following figure can be used as an average for building construction site emissions, in the absence of more specific information: 1400kgCO_2e/£100k of project value (BRE Meeting Construction 2025

Targets – SMARTWaste KPI p.3, footnote 9). Cost figure based on the date of the publication, March 2015; to be adjusted to current value in accordance with CPI. Average data from contractors' site emissions monitoring suggest similar levels of construction emissions. This rate should be refined by substitution with site monitoring data provided by the project contractor as these become available.

Appropriate allowances for site waste should be made. The carbon impacts from the product stage and transport of the site waste and any emissions associated with its disposal should be included in the calculations. Installation and deconstruction impacts can be assumed as zero as the material wasted is not being installed.

In the absence of more specific information, default assumptions on site waste rates for the different materials should be determined based on the standard wastage rates provided by the WRAP Net Waste Tool Reference. These rates should be applied to the corresponding material quantities provided to allow for the wastage during construction. These rates should by refined by substitution with site monitoring data provided by the project contractor as these become available.

The carbon emissions associated with any waste generated during the construction process should be accounted for in accordance with the principles outlined for the product and transport stage [A1–A3] and [A4] – see 3.5.1 and 3.5.2 – and EoL stages [C2–C4] – see 3.5.4.

Depending on the EoL scenarios developed for site waste, the following carbon impacts are applicable to the respective waste quantities.

Site waste EoL scenarios		
Disposal to landfill	Reuse on-site	Reuse or recycling off-site
[A1–A3] + [A4] + [C2] + [C4]	[A1–A3] + [A4] + [C3]	[A1–A3] + [A4] + [C2] + [C3]

Table 7: Site waste EoL scenarios

3.5.3 [B1–B7] Use stage

This section refers to EN 15978; 7.4.4.1 and 8.6.1, EN 15804; 6.3.4.4.1.

The use stage must capture the carbon emissions associated with the operation of the built asset over its entire life cycle, from practical completion to the end of its useful life.

This includes any emissions relating to operational energy and water use as well as any embodied carbon impacts associated with maintenance, repair, replacement and refurbishment of building components.

Reasonable scenarios should be developed for the maintenance, repair, replacement, refurbishment and operation of the building based on project-specific information and consultation with the project team.

3.5.3.1 [B1] In use emissions

This section refers to EN 15978; 7.4.4.2 and 8.6.2, and EN 15804; 6.3.4.4.2.

The in use module [B1] captures the emissions arising during the life of a building from its components, e.g. release of GHG from HFC blown insulation.

Any carbon emissions emitted from building components during the life of the building must be reported in [B1].

Carbon emissions released from building elements and the impact of potential carbon absorption should be taken into account. Particular attention should be paid to any emissions arising from refrigerants, insulation blowing agents, paints, etc. over the life cycle of the project. Data on refrigerant leakage thresholds should be provided by the MEP consultant in accordance with relevant regulations. Data from DEFRA, EPDs, C2C (Cradle to Cradle) certification reporting, manufacturers' declarations and other relevant specialist documentation can be used.

Details on how to account for the impacts of the carbonation process in items containing exposed concrete and/or lime are given in section 3.4.1. The carbon absorption by green roofs and facades is considered negligible for green areas of less than 1,000 m^2 (Getter et al 2009, Whittinghill et al 2014), unless otherwise stated. Carbon absorption potential by green roofs and facades should be supported by relevant evidence e.g. landscape consultants' report.

3.5.3.2 [B2] Maintenance emissions

This section refers to EN 15978; 7.4.4.3 and 8.6.3, and EN 15804; 6.3.4.4.2.

Built assets with sophisticated cladding and MEP installations require regular maintenance to ensure continued efficiency, good appearance and validity of warranties. All of these repetitive activities involve the use of energy and/or products. These should be accounted for in module [B2].

Module [B2] must account for the carbon emissions arising from any activities relating to maintenance processes, including cleaning, and any products used. Additionally, it should include any emissions from the energy and water use associated with these activities.

Maintenance-related carbon emissions [B2] should be reported for the following building element categories – see 3.2.2: 2.3) Roof; 3) Internal finishes; 4) Fittings, furnishings and equipment (FF&E); 5) Services/MEP; 6) Facade. Additional items should be included as appropriate if specific information on their maintenance is provided.

Reasonable maintenance scenarios should be developed based on facilities management and maintenance strategy reports, façade access and maintenance strategy, Life Cycle Cost reports, O&M manuals and professional guidance, e.g. CIBSE Guide M, RICS NRM 3, etc.

Relevant carbon data from EPDs should be adjusted according to the project-specific maintenance scenario.

3.5.3.3 [B3] Repair emissions

This section refers to EN 15978; 7.4.4.4 and 8.6.3.

This module [B3] is intended to provide a reasonable allowance for repairing unpredictable damage over and above the maintenance regime.

Module [B3] must take into account the carbon emissions arising from all activities that relate to repair processes and any products used.

Data from facilities management/maintenance strategy reports, façade access and maintenance strategy, Life Cycle Cost reports, O&M manuals, professional guidance, e.g. CIBSE Guide M, should be used to develop scenarios for repair.

In case none of the above sources is available, repair emissions should be assumed as equivalent to 25% of maintenance emissions [B2] for the relevant items as specified in 3.5.3.2.

3.5.3.4 [B4] Replacement emissions

This section refers to EN 15978; 7.4.4.5 and 8.6.3.

Over the service life of a building there will be carbon impacts arising from the replacement of items, such as building services equipment, windows and cladding, roof surfaces, interior finishes, etc. These will occur at different cycles depending on the original specification and corresponding life expectancy.

Module [B4] must take into account any carbon emissions associated with the replacement of building components, including any emissions from the replacement process. All emissions arising from the production, transportation to site and installation of the replacement items must be included. This extends to cover any losses during these processes, as well as the carbon associated with their removal and end of life treatment.

The carbon emissions from the replacement of items from the following building element categories – see 3.2.2 – should be reported: 2.3) Roof; 3) Internal finishes; 4) Fittings, furnishings & equipment; 5) Services/MEP; 6) Facade. Additional items should be included if specific information on their replacement is provided.

It should be assumed that items are being replaced on a like for like basis and full replacement (100%) of the items is assumed once the specified lifespan is reached.

Appropriate life cycle scenarios that will set out the expected replacement cycles for the different components should be developed and clearly explained in the whole life carbon assessment report. The scenarios should be based on data from facilities management and maintenance strategy reports, façade access and maintenance strategy, Life Cycle Cost reports, O&M manuals, guidance, (e.g. CIBSE Guide M and BCIS Life Expectancy of Building Components), international standards, (e.g. ISO 15868-5: 2008 Buildings and Constructed Assets – Service Life Planning, and manufacturers' documentation).

The lifespans provided in Table 8 should be used for the components listed, in the absence of more specific data. These figures should be replaced with the actual life expectancies of the specific items to be used in the project as information becomes available.

Building component		Expected lifespan
Roof	Roof coverings	30 years
Internal finishes	Internal partitioning and dry lining	30 years
	Wall finishes: Render/Paint	30/10 years
	Floor finishes Raised Access Floor (RAF)/ Finish layers	30/10 years
	Ceiling finishes Substrate/Paint	20/10 years
FF&E	Loose furniture and fittings	10 years
Services/MEP	Heat source e.g. boilers, calorifiers	20 years
	Space heating and air treatment	20 years
	Ductwork	20 years
	Electrical installations	30 years
	Lighting fittings	15 years
	Communications installations and controls	15 years
	Water and disposal installations	25 years
	Sanitaryware	20 years
	Lift and conveyor installations	20 years
Facade	Opaque modular cladding e.g. rain screens, timber panels	30 years
	Glazed cladding/Curtain walling	35 years
	Windows and external doors	30 years

Table 8: Default component lifespans

Table 8 contains conservative generic assumptions for the lifespan of items based on information from BCIS Life expectancy of building components (2006); CIBSE Guide M; Scheuer, Keoleian, and Reppe (2003). Life cycle energy and environmental performance of a new university building: modelling challenges and design implications. Energy and Buildings, 35, pp.1049–1064.

5.3.3.5 [B5] Refurbishment emissions

This section refers to EN 15978; 7.4.4.6 and 8.6.4, and EN 15804; 6.3.4.4.2.

Refurbishment, as distinct from replacement, is defined as a planned alteration or improvement to the physical characteristics of the building in order for it to cater for the desired future function that is identified and quantified at the outset. This would typically involve a predetermined change of use at a point during the service life of the project, as well as a sizeable amount of works to several parts of the building.

Module [B5] must take into account any carbon emissions associated with any building components used in a refurbishment, including any emissions from refurbishment activities. All emissions arising from the production, transport to site and installation of the components used must be included. This includes any losses during these processes, as well as the carbon associated with their removal and end of life treatment.

The calculation of refurbishment emissions [B5] should account for any material additions and variations as per new build – see 3.5.1, 3.5.2 – instead of like for like as in replacement – see 3.5.3.4.

3.5.3.6 [B6] Operational energy use

This section refers to EN 15978; 7.4.4.7 and 8.6.5.

This module covers any emissions arising from the energy use of the operation of technical systems in the building over the life of the project.

The operational carbon emissions arising from the energy use of building-integrated systems as projected and/or measured throughout the life cycle of the project must be reported under module [B6].

Operational emissions should include all energy use regulated as per Part L of the Building Regulations, including heating, domestic hot water supply, air conditioning, ventilation, lighting and auxiliary systems.

The life cycle emissions associated with the operation of further building-integrated systems (lifts, safety, security and communication installations) should also be included as part of the total operational emissions [B6] but reported separately where possible.

Carbon emissions from non-building-related systems (e.g. ICT equipment, cooking appliances, specialist equipment, etc.) – unregulated energy use – can represent a significant part of the total operational emissions. Therefore these should be included in the assessment where possible to provide a more complete picture of the life cycle impacts of the project. Such carbon emissions from unregulated energy use should be reported separately within [B6].

Any impact from waste produced by operational energy use should also be considered including any treatment and transportation these might require.

Where building operation requires fuel to be transported to the site, e.g. gas bottles, oil supply, etc., the transport emissions associated with the fuel delivered should be included in the calculation of operational emissions, as transportation emissions represent upstream transmission and distribution impacts for such fuels.

Data provided by MEP, sustainability and ICT consultants should be used in the operational emissions calculations, e.g. BRUKL submissions, energy modelling results from SBEM and/or dynamic thermal simulation, energy calculations according to CIBSE TM54, etc.

Operational carbon figures according to current practice (Part L of Building Regulations) are typically expressed as CO_2. According to the government's Standard Assessment Procedure (SAP), CO_2 in this instance is representing CO_2e (SAP for Energy Rating of Dwellings, 2012, p.164).

Where on-site renewables are installed (PVs, solar thermal systems, etc.), the whole life carbon assessment report should state how the energy outputs are expected to be used for the specific project. If information on the allocation of the on-site generated energy is unavailable, the assumption that energy produced on-site satisfies building needs first should be adopted. That is, building-related (regulated energy plus lifts, security and communications installations) take priority over non-building-related systems (unregulated energy) being exported to the grid (EN 15978, p.25). Unregulated energy demand can be assumed as equal to regulated for the purposes of this calculation, in the absence of project-specific estimates (BREEAM UK New Construction 2014, Ene 01 Reduction of energy use and carbon emissions – Compliance Note 3.5). The generated energy used to meet operational needs of the building can offset the equivalent amounts of imported energy and their subsequent carbon emissions.

Any benefit accruing from energy produced onsite and exported to the grid should be captured within module [D] – see 3.5.5, as suggested in EN 15978 7.4.4.7, and not discount the total energy demand.

The effect of the anticipated future grid decarbonisation must be taken into account when estimating the operational carbon impact over the life of the project – see 3.4.2.

A comprehensive assessment of the entire life of a project should inform decision making as accurately as possible. Therefore, considering the impact of climate change when calculating future operational emissions, such as the heating and cooling demand over the service life of the building, is important. It is suggested that the figures used are modelled or adjusted utilising future weather data. Such information should be acquired from the University of Exeter publication *On the creation of future probabilistic design weather years from UKCP09* (2011). Other sources of robust national or local data should be used depending on geographic location.

3.5.4.7 [B7] Operational water use

This section refers to (EN 15978; 7.4.4.8 and 8.6.6) and covers the carbon impacts associated with water use during the operation of the building.

All carbon emissions related to water supply and wastewater treatment, over the life cycle of the building (excluding water use during maintenance, repair, replacement and refurbishment that are reported elsewhere), must be reported under module [B7].

Any emissions associated with energy expended from water-related systems, e.g. provision of domestic hot water, etc. should be captured under module [B6].

Estimates on anticipated water consumption in the UK should be made based on the values provided in Table 22 of the *BSRIA Rules of Thumb – Guidelines for the building services,* 5th edition for the respective building type, in the absence of project specific information at early design stages. The estimated water consumption should be replaced by figures provided by the public health and/or MEP consultant and landscape architect as they become available.

Carbon conversion factors for water use and treatment as published by the local water supplier should be used. If unavailable, the relevant generic carbon conversion factors from an allowable source should be used – see 3.3.2.

3.5.4 [C] End of Life (EoL) stage

This section refers to EN 15978; 7.4.5.1 and 8.7.1, and EN 15804; 6.3.4.5.

The end of life (EoL) stage commences when the built asset has reached the end of its life and will no longer be used. For the purposes of the whole life carbon assessment this is assumed to occur at the end of the reference study period of the building as defined in 3.2.3.

Any emissions arising from decommissioning, stripping out, disassembly, deconstruction and demolition operations as well as from transport, processing and disposal of materials at the end of life of the project must be accounted for in module [C].

The EoL stage is considered complete within the scope of whole life carbon assessment when the site is cleared and levelled to the ground plane and is ready for further use.

The assessor should develop suitable project-specific EoL scenario(s) at a building level as well as individual components level where relevant, based on future intentions provided by the project team, precedent and current EoL practices. The EoL scenario(s) should be clearly stated and explained within the whole life carbon assessment report.

In the absence of specific information, scenarios on the proportion of landfilling, reuse and/or recycling each item at the end of life should be developed according to current standard practice. Further relevant guidance is provided below.

Based on *UK statistics on Waste* (2016) from DEFRA, the suggested default scenario for the EoL for construction and demolition-related items should assume 10% of waste mass to landfill and 90% being diverted, i.e. recovered and repurposed: reused or recycled. With respect to timber waste, 25% should be assumed to be landfilled and 75% incinerated with energy recovery (based on averaged data from Figure 6 of DEFRA (2012) *Wood waste: a short review of recent research)*. The DEFRA statistics are included here as one such source of respected national data. Ratios based on the robust national data should be estimated and applied to projects located in different countries.

Most metals used in construction such as steel, aluminium and copper, are highly recyclable without significant degradation in quality. Therefore, high recovery rates have been established across the industry due to their reuse and recycling potential as well as the high residual economic value of the scrap. The following proportions can be assumed for the EoL treatment of such metals.

Metal	Recovery rate Repurposing: reuse or recycling	Disposal Landfill
Steel	96% [1]	4%
Aluminium	85% [2]	15%
Copper	65% [3]	35%

Table 9: Default metal recovery rates in the UK

Notes on Table 9

[1] Sansom, M. and Avery N. (2014) Briefing: Reuse and recycling rates of UK steel demolition arisings. *ICE Proceedings: Engineering Sustainability.* 167; issue ES3
[2] Global Aluminium Recycling Committee (GARC) (2009) – Global Aluminium Recycling: A Cornerstone of Sustainable Development, p.16.
[3] Table 1, p. 6569 – Glöser, S., Soulier, M. and Tercero Espinoza L. A. (2013) Dynamic Analysis of Global Copper Flows. Global Stocks, Postconsumer Material Flows, Recycling Indicators, and Uncertainty Evaluation. *Environmental Science and Technology.* 21: 1658–1665.

The given assumptions are intended to represent the low end of common practice in the UK. Equivalent data should be used when the project being assessed is located elsewhere.

The recommended default EoL scenarios should be updated according to project specific data relevant to the end of life stages as information becomes available over the progression of the project.

Data for [C] from EPDs and other carbon data sources – see 3.3.1 – should be used in line with the project-specific EoL scenarios developed.

3.5.4.1 [C1] Deconstruction and demolition emissions

This section refers to EN 15978; 7.4.5.2 and 8.7.2.

Deconstruction should cover all site-based activities required to dismantle, deconstruct and/or demolish the built asset being assessed.

The carbon emissions arising from any on- or off-site deconstruction and demolition activities, including any energy consumption for site accommodation and plant use, must be considered in [C1].

An average rate of 3.4 $kgCO_2e/m^2$ GIA (rate from monitored demolition case studies in central London) based on aggregated data should be used in the absence of more specific information.

3.5.4.2 [C2] Transport emissions

This section refers to EN 15978; 7.4.5.3 and 8.7.3.

Any carbon emissions associated with the transportation of deconstruction and demolition arisings to the appropriate disposal site, including any interim stations, must be captured within module [C2].

For items being discarded to landfill, the transport emissions should be calculated based on the following formula:

[C2] = Mass of waste to be transported (a) × Transport carbon factor (b) × Distance to landfill (c)

The default distance to be used for disposal, landfilling or waste processing plant in the absence of specific information should be taken as the average between the distances of the two closest landfills to the project site. The mode of transport should be assumed is average HGV with 50% load to account for the vehicles coming to site empty and leaving with a 100% load.

For items being repurposed, i.e. reused or recycled, the following default transport scenarios should be adopted, in case of lack of more specific information:

EoL scenario	Transport scenario
Reuse/repurposing on site	No transport emissions; [C2] = 0
Reuse/repurposing elsewhere	Assumed same as [A4]
Recycling	Assumed same as [A4]

Table 10: Default transport assumptions for different EoL scenarios

3.5.4.3 [C3] Waste processing for reuse, recovery or recycling emissions

This section refers to EN 15978; 7.4.5.4 and 8.7.4.

When materials and/or components are intended to be recovered and reused or recycled after the end of the life of the built asset, any carbon emissions associated with their treatment and processing prior to reaching the end-of-waste state must be included in module [C3].

The calculation of [C3] should follow the EoL scenarios developed by the assessor for each item. Data for [C3] from relevant EPDs should be used, adjusted appropriately to suit the selected EoL scenario. In the absence of specific information regarding the waste processing for items to be repurposed, the default emissions for disposal to landfill – see 3.5.4.4 – should be applied.

3.5.3.4 [C4] Disposal emissions

This section refers to EN 15978; 7.4.5.5 and 8.7.5.

Module [C4] captures the emissions resulting from any processing required prior to disposal and from the degradation and/or incineration of landfilled materials. This is for items not being recovered for reuse and/or recycling.

For elements not expected to be recovered and repurposed, either to be discarded in landfill or incinerated, an allowance for the emissions arising from their disposal must be included in [C4].

The calculation of [C4] should follow the EoL scenarios developed by the assessor for each item. [C4] data from relevant EPDs should be used, adjusted appropriately to suit the selected EoL scenario.

Where data for disposal is unavailable or is stated as 0, a generic assumption should be used for the [C4] emissions of inorganic items. The default figure suggested is 0.013 $kgCO_2e$/kg waste [1]. This figure has been developed as an average with reference to BEIS 2016 Government GHG Conversion Factors for Company Reporting (0.01 $kgCO_2e$/kg waste as an average of all construction waste types reported excluding wood), and Ökobaudat (0.016 $kgCO_2e$/kg waste).

For timber and other types of bio-based, organic waste where specific data from EPDs or other allowable sources is unavailable, the following rates should be used for the corresponding scenarios:

- Landfilling; no landfill gas recovery: 2.15 $kgCO_2e/kg$ of timber product (Symons, Moncaster and Symons (2013)).
- Incineration: same as sequestered carbon – see 3.3.1 (EN 16485:2014; 6.3.4.2).

Potential energy recovery from organic waste incineration and landfill gas should be captured within module [D] – see 3.5.5.

3.5.5 Module [D] Benefits and loads beyond the system boundary

This section refers to EN 15978; 7.4.6 and 8.8, and EN 15804; 6.3.4.6 and 6.4.3..)

Module [D] covers any benefits or burdens arising from the recovery and subsequent reuse and/or recycling of products beyond the project life cycle. It is intended to provide a broader picture of the environmental impacts of a project by accounting for the future repurposing potential of components. Module [D] captures the avoided emissions (or potential loads) from utilising recovered, i.e. reused and/or recycled items, to substitute primary materials. Module [D] can be used as a metric for quantifying circularity and assessing future resource efficiency.

Module [D] includes the potential environmental benefits or burdens of materials and components beyond the life of the project. Module [D] must be reported separately and not aggregated with cradle to grave modules [A–C].

Module [D] is communicated separately due to the uncertainty inherent in the future treatment of items beyond the EoL stage.

Project-specific scenarios for the future intended handling of items beyond the end of life of the project, at building and/or component level, should be developed and substantiated as appropriate based on supporting information provided by the project team and the anticipated supply chain. Different scenarios can be developed for the same project concerning the future recovery and repurposing of items beyond the end of life. Each scenario will therefore result in a different value for [D]. Each scenario should be clearly presented and explained within the whole life carbon assessment report with an indication of its likelihood.

Depending on the extent of reuse and/or recycling anticipated appropriate boundaries for the potential benefits or burdens should be determined. Reuse/recycling activity can range from the full reuse of the item as is (e.g. retained structural frame) to individual component reuse (e.g. steel sections, cladding modules, etc.), or material recycling (e.g. glass cullet from discarded windows, concrete crushed into aggregate, plasterboard recycled into new panels).

When full reuse of components in their exact assembled state, i.e. onsite retention is anticipated in the future, the emissions from both product and construction stages [A1–A5] could be offset alongside any avoided deconstruction, transport and disposal [C1, C2 and C4] impacts. In case of individual element reuse, when this is expected to occur on site then the offset of product stage [A1–A3] and transport [A4] carbon impacts can be claimed. For all other instances where reuse and/or recycling are anticipated, the scope of the impacts to be taken into account in [D] shall be limited to the product stage [A1–A3].

Module [D] data should be derived from appropriate sources – see 3.3.1 –in accordance with project-specific scenarios developed. The scenarios used to estimate the [D] figures in the selected sources should be checked against the project-specific ones developed by the assessor. If different, the [D] values should be adjusted to fit the project specific scenario. For example, if an EPD for precast concrete panels is assuming recycling (downcycling) of the disposed items via crushing into aggregate while the project-specific scenario is anticipating reuse of the discarded panels elsewhere rather than crushing, [D] figures should be adapted to reflect the scenario for the project under study, based on the principles described.

In the absence of any specific data relating to the future potential of items, the assessor can quantify such benefits or burdens where applicable as follows.

Module [D] is intended to capture the impacts of reusing and recycling materials discarded from the project under study or recovering energy from them the primary materials these recovered items could substitute. Therefore, the emissions associated with the making (and also transportation to site and construction in the case of retained structures) of the primary item being substituted by a reused or recycled one should be subtracted from the corresponding emissions of the secondary (reused or recycled) item.

The products to be substituted by a recycled item should be assumed as representative of current standard practice and market averages, e.g. Assuming glass wool insulation materials feature a 30% recycled content on average, then when an item is recycled whose resulting secondary product will substitute glass wool insulation, then: [A1–A3] of the substituted primary item = [A1–A3] of standard glass wool, i.e. with 30% recycled content, rather than glass wool from virgin material.

With respect to recycling, two main routes are identified: a) closed loop recycling, where he discarded (secondary) product is deemed to be recycled into an item of functional equivalence to the original without change in its properties and b) open loop recycling, where the discarded product is recycled into a different one undergoing changes in its nature, usually being downgraded to a product of lower quality and/or value.

Any losses in material quantity or quality along the recycling/remanufacturing process should be taken into account when determining the avoided environmental impact of the item substituted. If specific data on the proportion between the reclaimed and the final product is unavailable, a one-to-one equivalence can be assumed, i.e. 1kg of bricks reclaimed at the EoL of a project will substitute 1kg of new bricks.

Energy recovery from materials beyond the end-of-waste state e.g. timber incineration, when the energy recovery rate is higher than 60% should be accounted for within module [D]. The type of energy displaced should be determined based on reasonable assumptions and therefore enable the estimation of the carbon emissions avoided by the energy recovered. Where exported energy is assumed to substitute electricity, the avoided carbon impacts should be decarbonised in line with the guidance provided in 3.4.2.

The impact of module [D] should be accounted for every item for which a repurposing (reuse, recovery or recycling) scenario has been developed. Therefore, for components that are being replaced one or multiple times over the life cycle of the building module [D] should be considered for each of the times they are being replaced.

3.6 Reporting requirements

The following section specifies the attributes (assumptions, results, etc.) that need to be reported and provides a recommended structure for clarity in doing so.

A whole life carbon assessment report should contain the following:

1. Details of the commissioning body, assessor and verifier if applicable.
2. Date of assessment completion.
3. A purpose statement declaring the drivers and aims of the assessment.
4. A clear statement of the scope and boundaries regarding building components as well as project life cycle stages accounted for in the assessment. If restricted scopes are used, justification in line with the aims of the study should be provided.
5. A clear indication of the point in time within the project process the assessment was conducted; e.g. early design stage (RIBA Stage 3), on practical completion, etc.
6. Explicit declaration of all sources of carbon data, material quantities and all relevant technical information and references throughout the assessment.
7. The percentage (%) of material quantities covered for each building element category – see 3.2.2.
8. The percentage (%) of data entries originating from different sources, if more than one carbon data sources are used in the assessment.
9. A description of the built asset assessed including its main physical and technical characteristics, e.g. number of storeys, floor area, as well as information on its use.
10. Declaration of the reference study period used in the assessment.
11. Clear statement and explanation of all assumptions made and scenarios developed to facilitate the carbon calculations such as transport distances and End of Life scenarios, including the percentage of quantities covered per building element category.
12. Itemised carbon results, separately per: 1. Building element category – see 3.1.2; and 2. Life cycle stage module – see 3.1.4.
13. Total carbon results for the cradle-to-grave scope [A] to [C] per building element category; both absolute and normalised totals should be reported.
14. Total carbon results for each life stage module excluding figures for building element category 0. Facilitating works; both absolute (in $kgCO_2e$ or appropriate metric multiples thereof) and normalised (in kgCO2e/unit of measurement e.g. m^2) totals should be reported.
15. Aggregated carbon results for the cradle-to-grave scope [A] to [C] for all building element categories excluding Facilitating works; both absolute (in $kgCO_2e$ or appropriate metric multiples thereof) and normalised (in kgCO2e/unit of measurement e.g. m^2) totals should be reported.
16. Modules [A1 – A3] (Product stage) can be reported jointly as a single figure.
17. Carbon sequestration figures should be identified separately, but can be included within the total cradle-to-grave figures [A] to [C].
18. To be reported separately: 1. Emissions associated with 0. Facilitating works; 2. Operational emissions for non-building-related; 3. Module [D] figures.

Figure 3 provides an organised presentation of the carbon results, according to the requirements set out. The cells shaded in grey indicate the minimum results required for a whole life carbon assessment. The assessor should use this template for reporting results.

[INSERT LINK TO PDF]

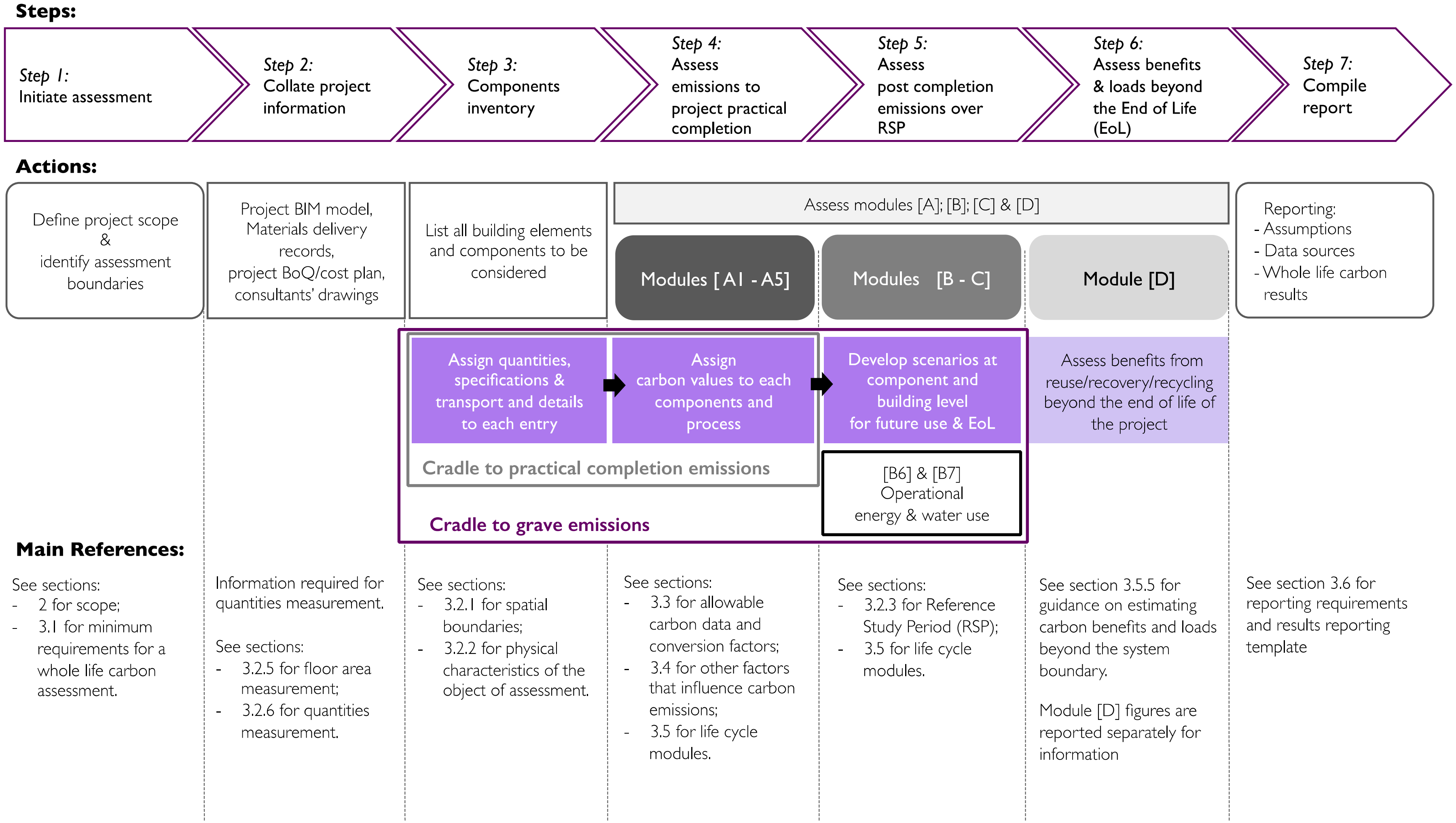
Figure 3: Results reporting template © Sturgis Carbon Profiling

Appendix 1: Whole life carbon assessment flowchart

WHOLE LIFE CARBON ASSESSMENT

Recommended sequence of activities to complete an assessment

This diagram is to be read in conjunction with the RICS Professional Statement: *Whole Life carbon Measurement: Implementation in the built environment.*



Appendix 2: Glossary

BIM: Building Information Modelling; it is the process of digitally representing and managing the properties of objects.
BoQ: Bill of Quantities: list of materials used in a project.
BREEAM: Building Research Establishment (BRE) Environmental Assessment: well Method: UK-based internationally applied scheme for the evaluation, rating and certification of the sustainability of buildings by the BRE.
BRUKL: reporting according to Building Regulations UK Part L.
C2C: Cradle to cradle: product certification scheme based on sustainability and circular economy principles.
circularity: process considering he potential for recovery, reuse and recycling of items following circular economy principles.
CLT: Cross Laminated Timber: type of engineering timber for structural use.
CO_2e: Carbon dioxide equivalent: metric expressing the impact of all greenhouse gases on a carbon dioxide basis.
COP 21: 2015 United Nations climate Change Conference.
CPI: Consumer Price Index.
DER: Dwelling Emission Rate: actual carbon emissions of a building in accordance with SAP calculations.
EoL: End of Life.
EPD: Environmental Performance Declaration.
FF&E: Fittings, Furnishings and Equipment.
FSC: Forest Stewardship Council: forest certification scheme for sustainable timber sourcing.
GHG emissions: Any gases that contribute to the greenhouse effect that causes global warming. The primary greenhouse gases in the Earth's atmosphere are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_2), ozone (O_3), chlorofluorocarbons (CFCs) and water vapour (H_2O).
GIA: Gross Internal Area of buildings according to RICS property measurement standards.
grid decarbonisation: gradual reduction of the energy and carbon intensity of electricity production.
GWP: Global Warming Potential.
HFC: Hydrofluorocarbons.
HGV: Heavy Goods vehicle.
HVAC: Heating, Ventilation and Air Conditioning.
ICT: Information and Communications Technologies.
IPMS: International Property Measurement Standards.
LCA: Life Cycle Assessment.
LEED: Leadership in Energy and Environmental Design: US-based internationally applied scheme for the evaluation, rating and certification of the sustainability of buildings by the USGBC.
MEP: Mechanical, Electrical and Plumbing equipment.
O&M: Operation and Maintenance .
PEFC: Programme for the Endorsement of Forest Certification: forest certification scheme for the sustainable timber sourcing.

PV: Photovoltaics cells: technology producing electricity from renewable solar energy.
RSP: Reference Study Period – see section 3.2.3.
SAP: Standard Assessment Procedure: calculation method for the energy performance of residential buildings for compliance with the UK Building regulations.
SBEM: Simplified Building Energy Model
Scope 1, 2 and 3:

- Scope 1: direct GHG emissions arising from energy use (combustion) on site.
- Scope 2: indirect GHG emissions arising from the use of purchased electricity, heat or steam.
- Scope 3: other indirect (embodied) GHG emissions, according to the GHG Protocol.

TER: Target Emission Rate: targeted emissions a building needs to achieve in accordance with SAP calculations.

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